Tutorial

MAX, MAX-LS and MAX-3D Layout System

Micro Magic, Inc.

Version 5.5

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Part 1 Introduction

Welcome to MAX, the full-custom layout editor from Micro Magic, Inc. MAX is more than just a simple layout editor. It is a complete layout environment.

MAX Features

- Optimized for large databases
- Very Fast Redisplay for Whole Chip Viewing and Editing
- Interactive viewing and editing of hierarchical layout
- Continuous DRC feedback during layout
- Hierarchical and incremental DRC
- Built in netlisting
- Interactive connectivity tracing
- Interactive wiring tool with flylines to show connections not yet completed
- Layout generator for gates (using MAX-LS)
- Generators for large regular structures such as SRAMS, ROMs, PLA's, and DRAM's (with the optional MegaCell Compiler)
- Smart palette for easy control and feedback on layers
- Full customization and extension via Tcl/Tk scripting language and API
- Technology independence via technology description files
- Reads/writes GDSII
- True transparency through layers
- Representational 3D rotation view
- True 3D Thru-Silicon Via Wafer Level editing
- Calibre® interface can display Calibre® DRC errors on layout view (Optional feature)
- Runs on Linux and Solaris-10 operating systems.

This tutorial will introduce you to many of these features. Consult the Micro Magic, Inc. *MAX User Manual* and on-line documentation for further information.

Tutorial Objectives

In this tutorial for MAX Layout Editor, you will learn how to:

- Understand MAX Layout screen
- Navigate around the layout
- Push into and Pop out of sections of layout
- Check net connectivity
- View DRC errors with MAX or check for Calibre® DRC errors
- Create layout with MAX_LS
- Create and edit custom layout

- Load GDSII layout files
- Create MAX technology files

Installing MAX

If MAX is already installed at your site, skip this section.

If you are reading this tutorial, you should have already downloaded the MMI software. This tutorial assumes that you have already received a license file for MAX. The following information is also found in the **README** file that comes with the software.

INSTALLING MAX

Step 1

- Create an installation directory and **cd** to it.

```
cd <install_dir>
```

Step 2

- Put the release in the install directory. The release file **mmi_090831.tgz** listed below is an example. Use the file which you have downloaded.

```
cp  <where_ever_you_put_the_release>/mmi_090831.tgz .
gtar xzvf mmi_090831.tgz
```

- If you do not have access to **gtar** (or **tar** on Linux) but do have **gunzip**, then type:

```
gunzip mmi_090831.tgz
tar xvf mmi_090831.tar
```

Note that moving the release around with "**cp -r**" is not a good idea, since **cp** can screw up symbolic links and permissions. Just **untar** it where you want it to live.
If you absolutely need to copy it, use "**cp -a**".

Step 3

- Make a symbolic link from **<install_dir>/mmi** to the **<release_dir>**.

```
ln -s <release_dir> mmi
```

From the example above the **<release_dir>** is **mmi_090831**. You would type:

```
ln -s mmi_090831 mmi
```

This allows you to refer to the release simply as **mmi**.

When you wish to upgrade to a new release, all you need to do is **untar** the new release into your **install_dir** and then change the "**mmi**" relative link to point to the new release.

Step 4

- Create your initial **mmi_local** directory as follows:

```
cp -a mmi/mmi_local.sample mmi_local
```

All site specific data is kept in **<install_dir>/mmi_local**. That way you can upgrade to new releases without losing or having to move around local data.

Step 5

- Put the license file where MAX can find it.
  One place MAX automatically looks for the license file is the **mmi_local** directory. The file needs to be called **mmi_license.lic**

```
cd mmi_local
cp <license file> mmi_license.lic
```

Step 6

- Start the license server for for floating license: (If you have a nodelocked license, skip this section.)

```
Nohup mmiserver -f /full_path/mmi_license.lic -l mmi_server_log &
```

To have the license server automatically start up when the machine is rebooted, add the following line to `/etc/rc.d/rc.local`:

```
mmiserver -f /full_path/mmi_license.lic -l mmi_server_log &
```

Step 7

- Add path and environment variable info to your **.cshrc** or **.login** file. This assumes you're using **csh** or **tcsh**. Add the following lines to the file:

```
setenv MMI_TOOLS <install_dir>/mmi
set path=(${MMI_TOOLS}/bin.i486-linux $path) #For Linux
set path=(${MMI_TOOLS}/bin.sparc-solaris5.10 $path) #For Sun Solaris
```

Step 8

- Source your **.cshrc** file.

You are now ready to run MAX and start the tutorial.

Starting up MAX

Before we get started make sure someone has already installed MAX at your site.

INSTALL TUTORIAL

To run the tutorials, you need to make a personal copy of the MAX tutorial example files using **mmi_tutorial**.

Step 1

- **To install the MAX tutorial**, type the following at the UNIX prompt:

```
mmi_tutorial
```

Make sure that the appropriate tool (MAX) is selected and then click on **Install Tutorial**.

The default installation directory is "**mmi_private/tutorial**" in your home directory. You can also select a different directory for installation. Don't worry if the directory doesn't exist, the **mmi_tutorial** script will make it if it can. You can also use this to reinstall a clean copy of the tutorial.

Step 2

- **To start the tutorial**, you must first "***cd***" (change directory) to the directory that you installed the tutorial into. If you used the default directory, type:

```
cd ~/mmi_private/tutorial/max
```

Otherwise, replace the above directory with the directory you selected. This directory contains files that you will need to run the tutorial.

Step 3

- **Then to start MAX**, simply type:

```
max -tech mmi25
```

A window should come up that looks something like Figure 1-a.

- MAX lets you customize all of the layer colors including the background color.

  If you are used to working with a black background, you can add "**-bb**" to the end of any MAX technology name. A separate palette is created for a black background with the layer colors adjusted for visibility (shown in Figure 1-b).

  So for this tutorial, to use a black background you would type:

```
max -tech mmi25-bb
```

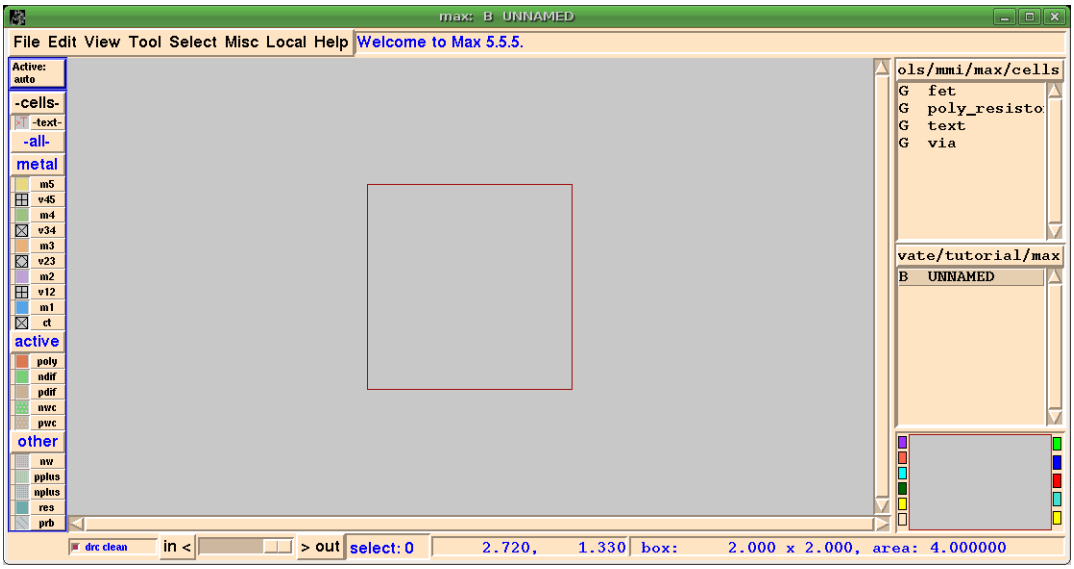
  NOTE: The bulk of this tutorial will be illustrated using MMI default colors for clarity and ease of reading.

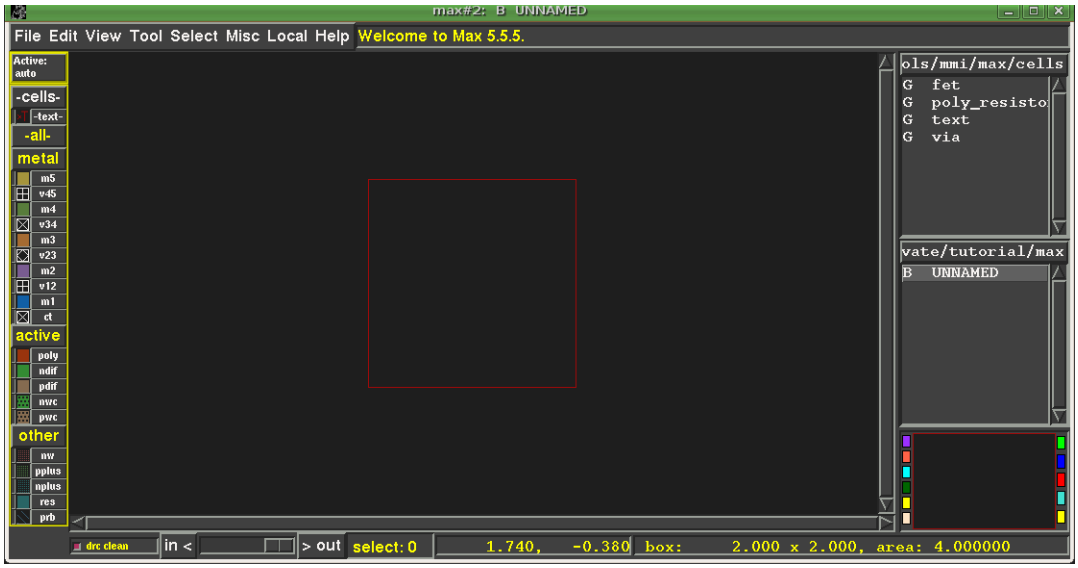
If you have just installed MAX, the the default technology is **mmi25**, so you would only need to type: **max**

If you want MAX to come up with a different technology by default, you can set the environment variable **MAX_DEFAULT_TECH**.

The rest of this section of the tutorial will go over each element of the MAX window.

Figure 1: MAX Window a) MMI Default Colors; b) Generic Black-Background Colors





MAX Screen Layout

On the very top of the window the title bar should say "**max: B UNNAMED**".

"**UNNAMED**" means that you have *not specified the file* (cell) you wish to edit. The "**B**" tells you that the cell resides only in the memory buffer.

Next, across the top you should see the menu bar which contains the following menu items: **File**, **Edit**, **View**, **Tool**, **Select, Misc**, **Local**, and **Help**. These are pull down menus much like any other application.

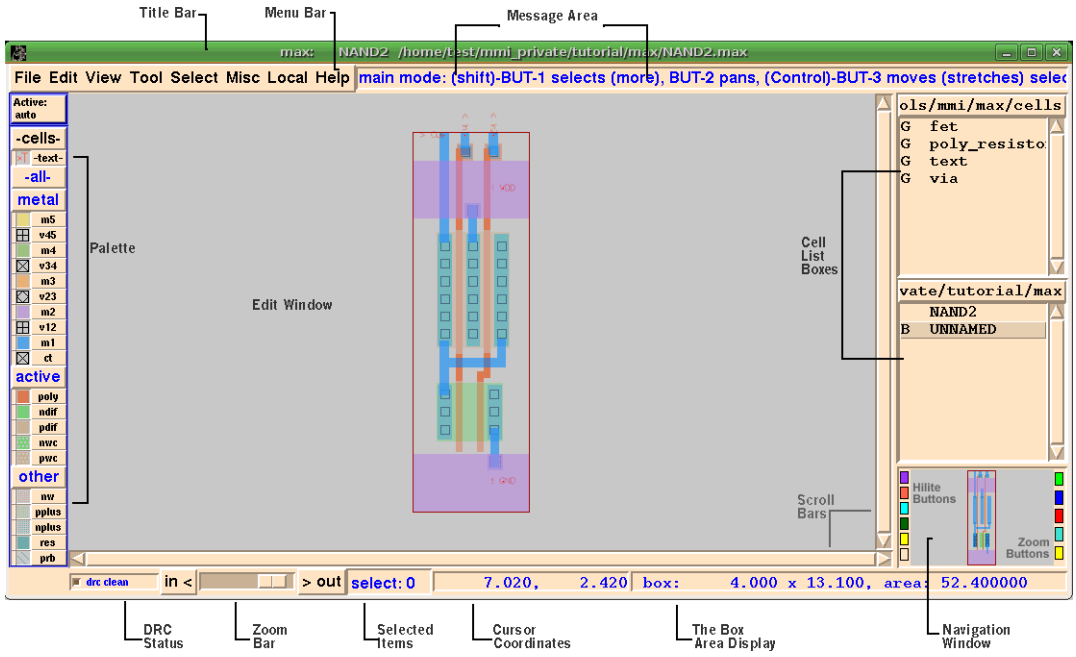
Directly to the right of the **Help** menu is the **MAX Message Area**. Depending on the location of the cursor, it currently says something like "**`main mode, (shift)-BUT-1 selects (more), BUT-2 pans, (Control)-BUT-3 moves (stretches) selection`**". The **MAX Message Area** is a sort of mini-help feature. It tells you what each mouse button does, and when you have pulled down one of the menus from the menu bar, the message area will give you a short explanation of what the highlighted menu item does.

In each of the menus, hotkeys are listed to the right for those commands that have hotkeys. You can always find out what the current hotkeys are by selecting "**Current Hot Keys**" from the **Help** menu or using the **SPACE** hotkey. Later in the tutorial we will cover how to change hotkeys.

The remainder of this section of the tutorial goes over each area of the MAX window. Refer to the *MAX User Manual* for a more detailed description of the MAX window.

Figure 2 points out the different attributes of the MAX window.

Figure 2: Items in MAX Window



Cell List Boxes

Down the right side of the window are small **List Boxes**.

Each List Box displays the cells in a given directory. That directory can be the user's "working directory" or a library.

Additional List Boxes can be added (or boxes deleted) by:

- Clicking the left mouse button (**Button-1**) over the List Box header (the horizontal bar saying: **`demo/tutorial/max`** in Figure 2), then,

- Clicking the left mouse button (**Button-1**) on either **Make new list box,** or **Close this list box**.

The directory the list box points to can also be changed by clicking on the desired directory. The directory list includes the directories of all cells that are currently loaded into MAX.

By default, no cells are loaded into MAX if not specified on the command line.

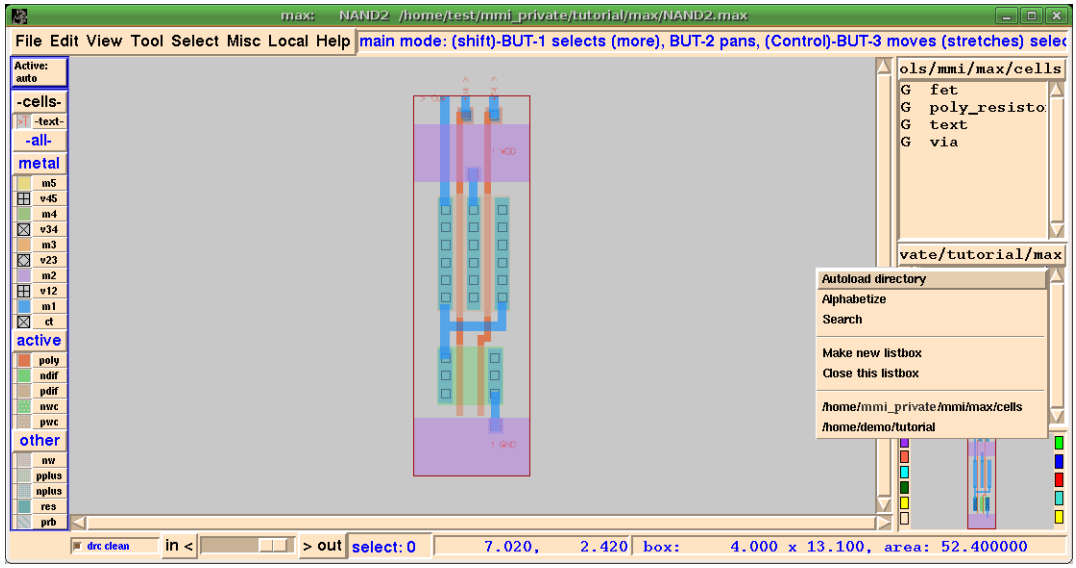
AutoLoad Cells Into List Box

To load all of the cells in a paticular directory, you autoload all of the cells. Let's try this:

Step 1

- Hold down the **LEFT mouse button** over the bottom list box directory and select **Autoload directory** as shown in Figure 3.

Figure 3: Autoload Directory from Cell List Box



You should now see the cells **INV, NAND2**, **drc_test**, **test_cell**, and **UNNAMED** in the cell list box.

Your **`max.rc`** file can specify library directories to be autoloaded at startup time using the **`max_auto_load`** command.

The **`max.rc`** file contains several other useful pieces of information. (See the ***Micro Magic, Inc. MAX User Manual*** for more details.)

The commands and variables available to use in your **max.rc** file can be found by selecting **Text Commands/Variables** from the **Help** menu or using the **?** hotkey. If you click on one of the commands, a definition and syntax for that command is listed. If you select a variable, a description and the current value is listed. The syntax for setting variables is:

```
set <variable> <value>
```

You can also adjust the width of the list boxes.

Step 2

- Move the mouse pointer over the vertical bar just to the left of the list box. The mouse will change to a small horizontal line with arrows on both ends.

Step 3

- When the arrows appear, adjust the list box width by holding down and dragging with **Button-1** to the left or right.

Navigation Window

Below the list boxes is the **Navigation Window**. For large designs, you can use the **Navigation Window** to control the view you see in the main **MAX window**.

The **Navigation Window** shows a copy of the layout; the **brown outline** represents the boundary of the MAX Window. A **red outline** represents the "Box". The "box" is used for editing, and is used to define regions used by other commands in MAX.

Holding down the left mouse button (**Button-1**) and dragging out a region in the **Navigation Window** will cause the main window to zoom to that region.

The small colored (green, blue, red, cyan, yellow) rectangular buttons on the right of the **Navigation Window** allow you to do several things.

- The topmost button (green by default) steps through the view stack. **Button-1** zooms backwards in the view stack, **Button-3** zooms forward in view stack.
- The other buttons allow you to save (remember) and return to views — a different view for each. Position the mouse cursor over the buttons, and read their function descriptions in the **Message Area**.
  - For example, if you are at a view you know you want to return to, simply click the right mouse button (**Button-3**) on the blue button to lock in and remember that location and zoom factor.
  - If you later wish to return to that view you simply click the left mouse button (**Button-1**) on that blue button to recall that view.

- The top button always zooms back and forth in the view stack. If you desire, you can change the number of buttons and their colors. Both the number of view-save buttons, and their colors, can be changed in your **`max.rc`** file by setting the **`ZOOM_BUTTONS`** variable.

Change Zoom Buttons

Let's try changing the color of zoom buttons.

Step 1

- Exit MAX (hotkey: **Ctrl-d**).
- Go to the command window (the shell window where you started MAX).

Step 2

- Create a **`max.rc`** file in your current directory (default is `~/mmi_private/tutorial/max`).

  Add the following line:

```
set ZOOM_BUTTONS {blue yellow purple orange green}
```

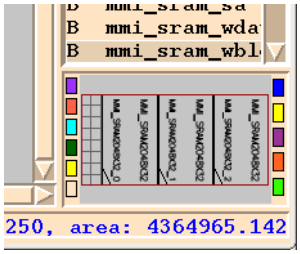
Step 3

- Restart MAX. From the shell window, type:

```
max
```

Your Navigation Window should now look like Figure 4.

Figure 4: Navigation Window Zoom Buttons - New Colors



Hilite Buttons

The buttons along the left side of the Navigation Window are used to **highlight** items you have selected. Whenever you have selected objects, for example a net, you can highlight them in the layout with the specified colors.

Load Example Layout

To cover the other portions of the MAX window, we will load in an example GDSII file.

Step 1

- Exit out of MAX by going to the **File** menu and selecting **Exit** or use the hotkey **Ctrl-d**.

The rest of the tutorial will be using the default zoom button colors, so if you want MAX to match, you can delete the `max.rc` file which you created earlier.

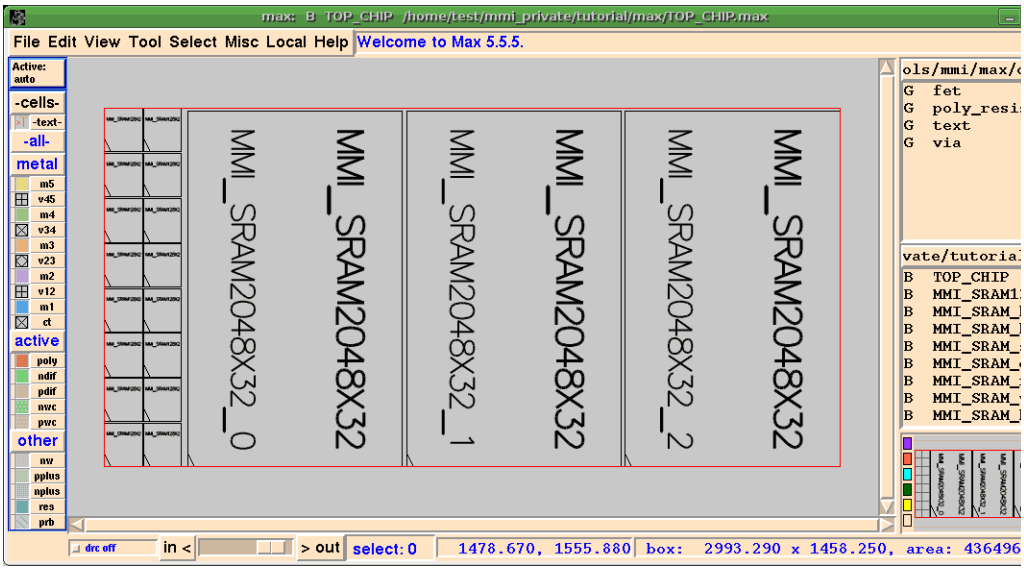
Step 2

- In your shell window (make sure you're still in the correct directory), type the command:

```
max -tech mmi25 TOP_CHIP.gds
```

You should see the example layout shown in Figure 5. This block was created in MAX using the **mmi25** technology and then exported to a GDSII file.

Figure 5: Example Layout Loaded into MAX (default colors)



VIEW INTERNALS

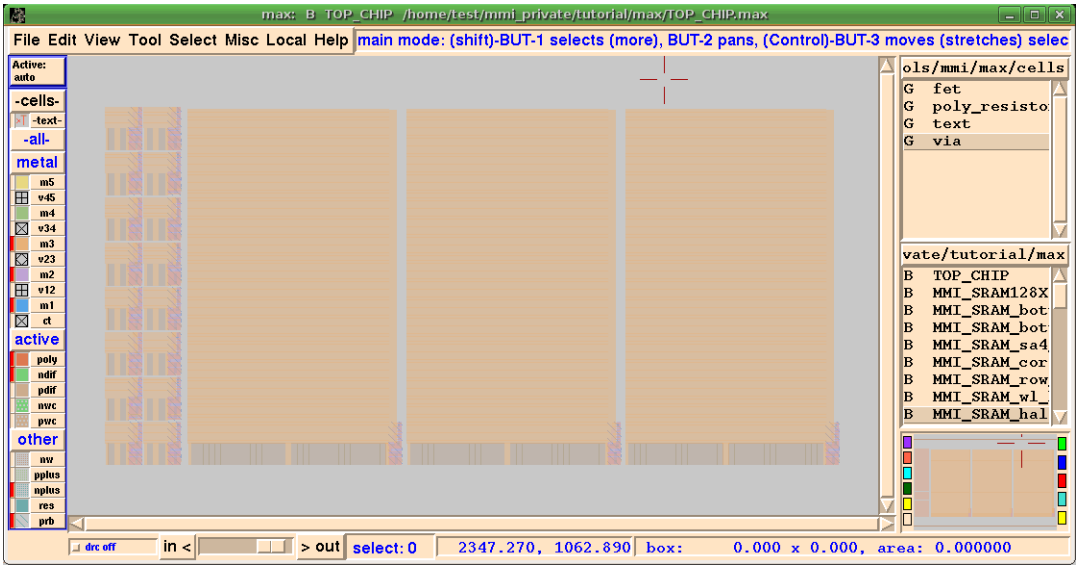
This GDSII file is made up of a number of SRAMs. The top level cell has over **1 million** transistors. By default, MAX shows the top level of the hierarchy.

Step 3

- View all levels of hierarchy by typing the hotkey "**i**" or selecting "**Internals, View All**" from the **View** menu.

Your MAX window should now look like Figure 6. All layers and all levels of hierarchy are visible.
Figure 6-b shows this same layout loaded using generic black-background colors.

Figure 6: Layout of TOP_CHIP.gds with "View Internals, All": a) Default colors; b) Black Background colors



We've already covered the **Cell List Box**. Notice now though that there are many cells listed.

USING THE LIST BOX

- Load the cells into the MAX window by clicking the **right (Button-3)** mouse button on the desired cell name. This is noted in the **MAX Message Area** at the top of the window.

Step 1

- Try loading cells by clicking on cells with the **right (Button-3)** mouse button in the cell list. If you accidently use the **left (Button-1)** mouse button, **Ctrl-C** will cancel.
- To get back to the top level, click on **TOP_CHIP** at the beginning of the list with the **right (Button-3)** mouse button.

If you click with the **left (Button-1)** mouse button on a cell, MAX adds an instance of that cell to your current cell. We'll try this later in the tutorial. Don't worry if you make a mistake. You can always undo a command with the hotkey **u**.

DRC Control and Status

In the lower left corner is the ***DRC Status Box***. It tells you the current status of the continuous interactive DRC which runs in MAX. The **DRC Status Box** also has a small radio button where you can click to turn the interactive DRC on or off. If there are DRC errors, the **DRC Status Box** will report the number of DRC errors.

Step 1

- Because we read in a GDSII file, MAX defaults to **drc off**. Click on the radio button and it may report some DRC errors.

Number of Items Selected

To the right of the DRC Control and Status area is a box that shows the number of items selected. The default is to display "**>100**" if more than 100 items are selected. By default any item (gcells, instances, rectangles, etc.) selected is displayed. This can be changed in your **max.rc** file.

To find commands and variables, you can select **Text Commands/Variables** from the **Help** menu or use the **?** hotkey. In the search field, if you type in "**select**", you'll find that the variables mentioned above are: **SELECT_DISPLAY** and **SELECT_MAX_DISPLAY**.

Scroll and Zoom bars

Scroll Bars are laid across the bottom and right side of the **Layout Window** (and on the right side of the List boxes). These work like the scroll bars in most other applications.

Below the bottom scroll bar is the ***Zoom Bar***. Pulling the slider button to the left zooms in, and to the right zooms out.

SCROLL WHEEL ZOOM

In addition, the mouse scroll wheel can be used to zoom in and out. Scroll wheel zooming is centered around the cursor position.

Step 1

- Try zooming around using the scroll wheel on your mouse. Place the cursor in the upper left corner of the cell and move the scroll wheel forward to zoom in. Zoom out by moving the scroll wheel down. To get back to the **full view** of the cell, type the **v** hotkey.

- If you hold down the **Shift** key while while using the **scroll wheel**, MAX pans left and right. If you hold down the **Ctrl** key while using the **scroll wheel**, MAX pans up and down.

Using the Navigation Window

SAVING ZOOM VIEWS

The ***Navigation Window*** can be used to zoom to particular areas, save views, and save highlights.

Step 1

- In the Navigation Window, drag out a box by holding down the **left (Button-1)** mouse button. Notice that the main MAX window zooms to this area.

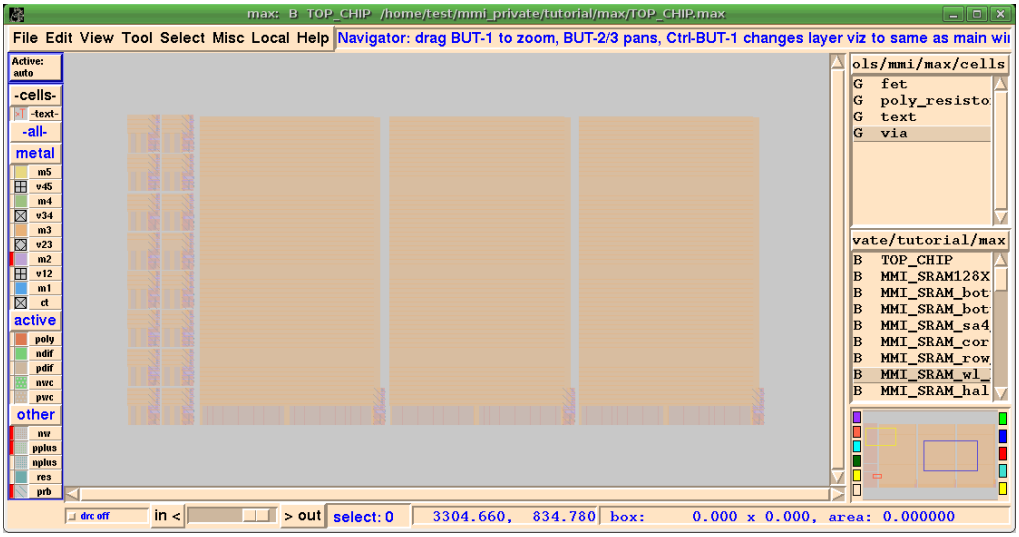
Step 2

- Save this zoom by moving over to the colored buttons on the right edge and selecting the second button (blue by default, yellow if you changed it earlier) with the **right (Button-3)** mouse button. Notice that view area in the Navigation Window is now surrounded with a (blue or yellow) box.

Step 3

- Zoom around to some other areas and save their zoom views using the buttons on the right edge of the Navigation Window. You should see something similiar to Figure 7. Notice that the zoom areas you saved are shown in the Navigation Window. You can return to these zoom views by clicking with the **left (Button-1)** mouse button.

Figure 7: Zoom Views Saved in Navigation Window



Step 4

- Push into one of the smaller cells by clicking on it with the **right (Button-3)** mouse button in the cell list.

Step 5

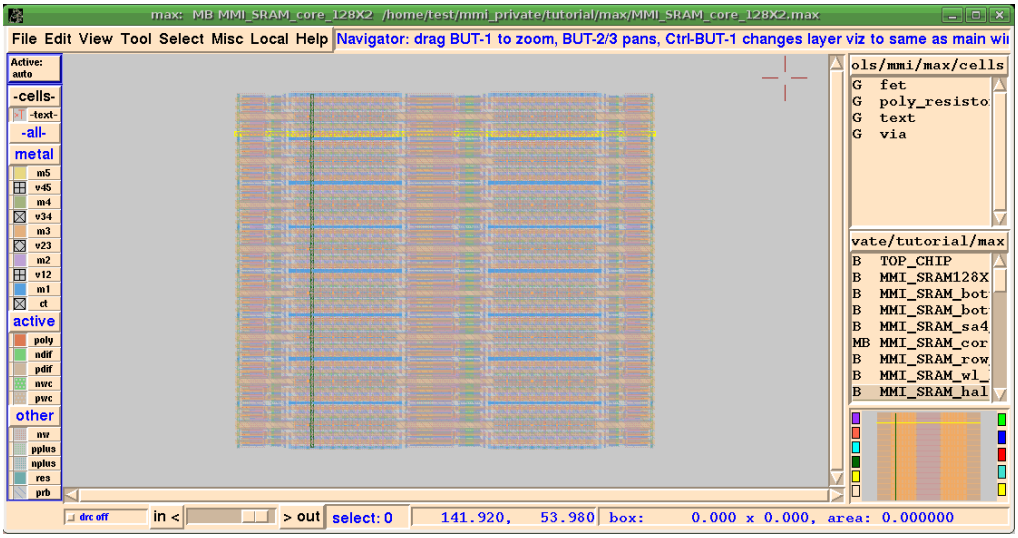
- Select a net by moving the mouse over part of the net and typing the **s** hotkey for **Select Net**. (We'll cover this in more detail later in the tutorial.) If you select a large net (i.e. **vdd** or **gnd**) a popup will appear that will allow you to stop the selection.

Step 6

- Save this selection by clicking on the top colored button at the left edge of the navigation window with the **left (Button-1)** mouse button. Notice that the net is now highlighted in yellow (default color) both in the Navigation Window and the main MAX Window. Repeat this for some other nets.

  You should now see something similiar to Figure 8.

Figure 8: Highlighted Nets Saved in Navigation Window



Notice that if you go back to the top level of the layout by clicking with the **right (Button-3)** mouse button on **`TOP_CHIP`** in the Cell List box, the zoom view areas are still saved. The zoom view area and highlights are saved for each cell.

- To **clear a saved zoom view or highlight**, click on the colored buttons in the Navigation Window using the **middle mouse button (Button-2)**.

> **Tip** Remember, if you ever forget which mouse button to use just move the mouse over the area you're interested in (Cell List, zoom buttons on right of navigation window, etc.) and read the description in the **`Message Area`** at the top of the MAX window.

Mouse Coordinates and Box Size Location

In the lower right hand corner the ***Box Size*** (in microns) is displayed. (The Box is used extensively in the MAX Layout Editor.) This is useful for when you select an object and want to know how big it is. It is also used for the measure command.

If you click with the **left mouse button** on the ***Box Size*** area, a pop-up will appear where you can specify a box or change what information is displayed in the ***Box Size*** area. It defaults to displaying the *size and area* of the box. You can also have MAX display the *corners* or the *origin and size*.

Just to the left of the Box Size is the ***Mouse Coordinates display***. Mouse coordinates are oriented with respect to the top level cell. As you move the mouse notice that this info changes.

The Palette

Along the left side of the window is the ***Smart Palette***. The Smart Palette provides many features:

- It controls which layers are visible.
- It gives feedback on what is currently under the cursor, and what is currently selected.
- It allows you to control which layers can be selected.
- And finally, it allows you change the color or stipple patterns of any of the layers.

The Smart Palette features are described in detail in the *MAX User Manual*.

Working with the Layout View

Now that you have some familiarity with the MAX window and its' particulars, let's experiment with moving around and viewing the **TOP_CHIP** layout in detail.

ZOOMING IN

We're going to zoom in on the layout, and change the layer visibility.

Step 1

- Make sure that **TOP_CHIP** is the edit cell. Remember, you click on it with the **right (Button-3)** mouse button in the cell list.

Step 2

- To clear any highlights you might have, go to the **View** menu and select **Clear**.

Step 3

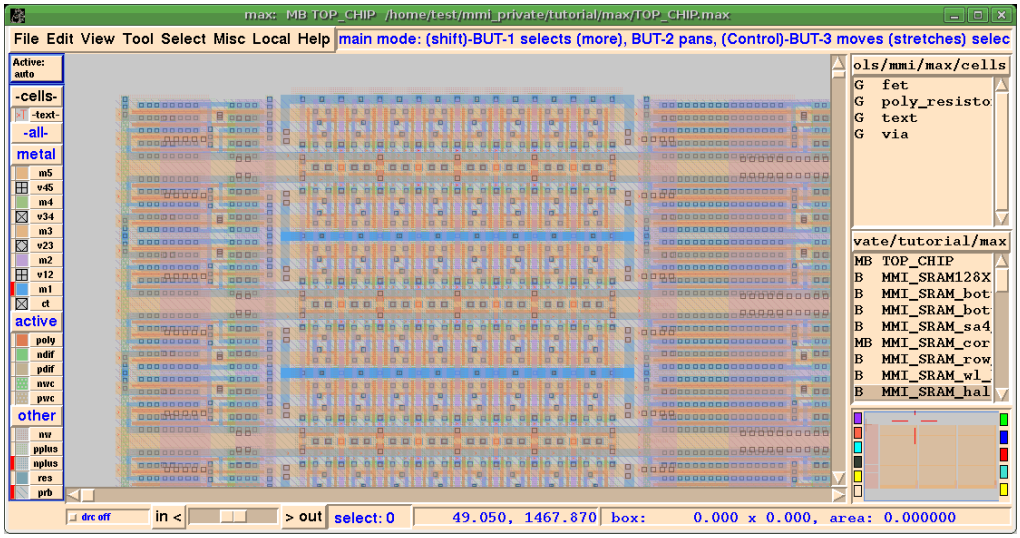
- Zoom in on the upper left corner of **TOP_CHIP**. You can zoom in by placing the cursor in the upper left corner of the cell and moving the scroll wheel up on your mouse.

Step 4

- A faster way is to use the **z** hotkey or select **Zoom to Area** on the **View** menu. After you type the **z** hotkey, drag out a box around the upper left portion of **TOP_CHIP**.
- You can also zoom in by placing the cursor in the top left of the layout, and typing the hotkey **j**, or selecting **Zoom In on Cursor** from the **View** menu.
- Or, you can use the Navigation Window to zoom to this area.

Zoom in until you see something similiar to Figure 9.

Figure 9: Zoomed In View with All Layers Visible



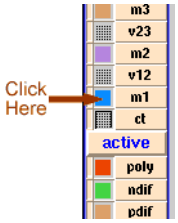
Changing Layer Visibility

Currently, all layers are on and visible. Let's change that.

Step 1

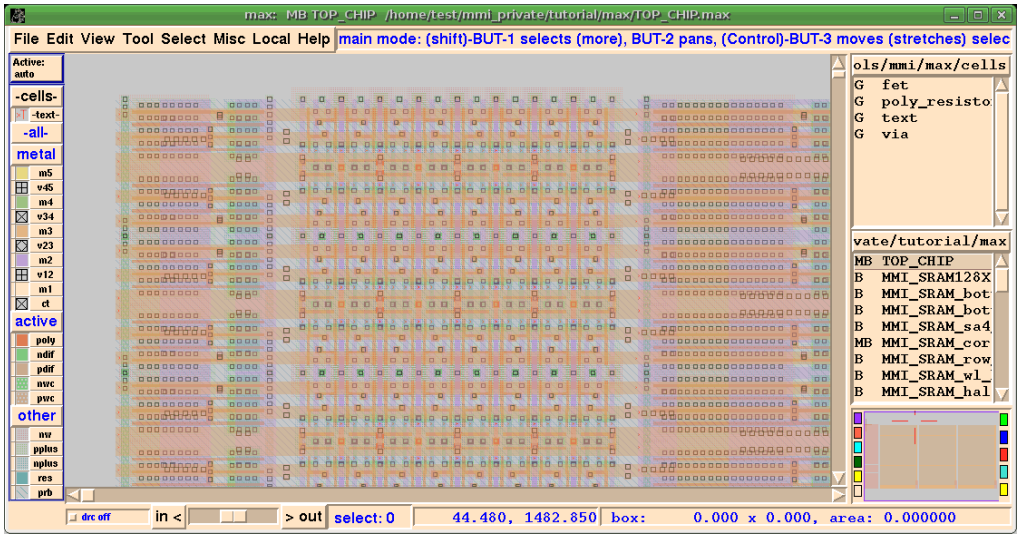
- Turn off ***visibility*** of **`m1`** by clicking with the **LEFT (Button-1)** mouse button on the blue square to the left of "**`m1`**", as shown here.

Figure 10: Turn Off Visibility of "m1"



You should now see something similiar to Figure 11. The **`metal 1`** layer is no longer visible (the bright blue has disappeared).

Figure 11: Metal 1 Layer Visibility Turned OFF - No Blue Showing



- If you click with the **LEFT (Button-1)** mouse button on the box with the word "**`-metal-`**", the ***visibility*** of all metal layers will be turned on.
- If you click on the label again, the ***visibility*** for all metal layers will be turned off. We will discuss how the palette can be used to control ***selectability*** later in this tutorial.
- Click on the "empty" **`m1`** palette square to turn visibility for **`m1`** back on.

Changing Layer Color

Now, let's try changing the color of the layer **`m1`**. First make sure all layers are ***visible***.

Step 1

- To access the palette:

  — Click with the **MIDDLE mouse button** (**Button-2**) on the blue square to the left of **`m1`** on the palette,

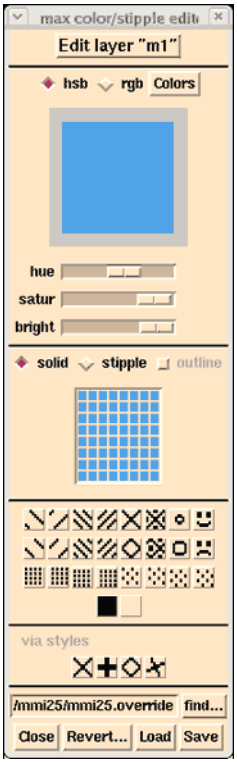
  OR:

  — Go to the **File** menu, select **User Preferences** and then **Color Editor...**

  You should now see the pop-up in Figure 12.

- At the top of the pop-up, hold down the **LEFT** (**Button-1**) mouse button and select "**`m1`**."

Figure 12: Editing Layer "m1"



Step 2

- To change the color of a layer, you can use the hue, saturation and brightness scroll bars or select a color from a list by holding down the **LEFT** (**Button-1**) mouse button on **Colors**.

  Change the color of **metal 1** and notice that it changes interactively in the layout.

Step 3

- To get back to the original color, click on the **Revert...** button and then click on **Done**.

Step 4

- To exit the color editor, click on **Close**.

Refer to the *MAX User Manual* for more details on editing layer colors and styles.

Layers

Just above the palette are buttons labeled **Active:**, **-cells-**, **-text-** and **-all-**.

Active lets you select the *active* layer for wiring or drawing polygons.

Cells controls whether or not sub-cells and gcells can be selected.

Text controls the visibility and selectability of text.

All allows you to toggle the visibility or selectability of all layers at the same time.

Getting Help and the Help Menu

Before we go any further, here is how to get help if you ever need it.

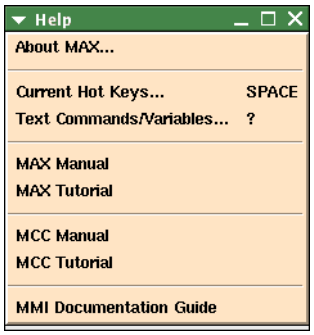
- There are several levels of help available on-line to MAX users. You already know about the quick **Help** feature listed in the **MAX Message Area**.

- In addition, you can access the complete on-line manual, this tutorial, a list of MAX commands and variables and the complete list of active hotkeys.

Step 1

- Click and hold down the **left mouse button** (**Button-1**) on the **Help** menu. This should pop up a sub menu as shown in Figure 13.

Figure 13: MAX Help Menu



Help Menu

About MAX tells you the version of MAX you are running, the technology you are using, etc.

> Unless you have the technology specified in a **`max.rc`** file, or you used the **`-tech`** option when starting MAX, it defaults to the ***mmi25*** technology.

Current Hot Keys gives you a list of all available hot keys. You can also hit the Space bar to bring up this list.

Text Commands/Variables brings up documentation for the MAX text commands and variables. Text commands are useful for writing scripts, generators, and other helpful programs. Text commands and the Tcl/Tk interface are the MAX API. They allow the user to add their own features to the **Local** and **Tool** menus.

MAX Manual brings up the MAX manual in your browser. The default browser is ***Firefox***. This can be changed in your **`max.rc`** file.

MAX Tutorial brings up this tutorial.

MMI Documentation Guide brings up all of the documentation for all of the Micro Magic, Inc. software. This document has links to items like the Micro Magic, Inc. *SUE User Manual*, the Micro Magic, Inc *MAX User Manual*, other Micro Magic, Inc. software programs, and even to this tutorial.

Before proceeding you should bring up the Micro Magic, Inc *MAX User Manual* and see what's there. The User Manual is the reference manual to MAX and contains lots of information that is not found in this tutorial.

You might also want to look at the menu items just to familiarize yourself with what's there.

Tear Off Menus

Sometimes it is convenient to make a menu its own window.

For example:

Step 1

- Going back to the **Help** menu: when you hold down the **left mouse button** (**Button-1**) over the **Help** menu notice that there is a dotted line just before the **About MAX** menu item (not shown in the above figure).

Step 2

- If you release the button while over the dotted line the menu will “tear off”. The menu then becomes a full-fledged window, like any other window on your desktop. The exact behavior will depend upon which OS and window environment you are running.

If you are running another window manager, your windows might behave a little differently. Consult your window system documentation for more details.

The chosen menu will stay pulled-down until you select either a menu item, or another menu.

Part 2
Viewing and Selecting Layout

This part of the tutorial covers viewing, selecting, and editing an existing layout. The next part will cover creating new layout.

Simple Viewing

In the previous section of this tutorial, we covered some basic commands for moving around the layout and changing layer colors and fill patterns. This section will cover how you move around the layout, view the hierarchy, view connectivity, edit wires, and measure things.

- You should still have the GDSII file **`TOP_CHIP.gds`** loaded in the MAX window. If not, go back to the previous section and load the GDSII file.

OK, let's get started.

Zooming

Once loaded, there are several methods for zooming into/out of the layout. Zoom commands are found in the **View** menu, and also have hotkeys.

ZOOM IN

- Use the zoom hotkey to zoom to an exact region.

Step 1

- Type **z**. This puts you in *zoom mode*. Note that the cursor has changed. Next hold down the left mouse button (**Button-1**) and "drag" out a box surrounding the region to which you wish to zoom. When you release the mouse, MAX will zoom to this region.

- If you mess up don't panic. Remember, **u** will *undo any edits you have made*, and **v** will always *zoom to fit*.

ZOOM OUT

Step 2

- Zoom out by typing **Shift-z**, or use **Zoom Out** in the **View** menu, or use the **scroll wheel** on your mouse (if you have one). You can also use the ***Zoom Bar*** at the bottom just below the scroll bars.

ZOOM TO FIT

Step 3

- Type **v**. The layout will be automatically returned to a centered position to fit within the size of the layout window.

Zoom In/Out by 2X

- One often-used technique for zooming is to use the **j** hotkey to *zoom in* by a factor of two centered on the mouse. The hotkey **Shift-z** can be used to *zoom out* by a factor of two.

Zoom with Scroll Wheel

- If you are using a scroll wheel mouse, you can zoom in/out by pushing forward or backward on the scroll wheel while in the MAX window. Zooming will be centered around the point of the cursor.

Zoom Using Navigation Window

- Using the **left** (**Button-1**) mouse button within the Navigation Window itself, drag out a box enclosing the desired zoom area. The advantage of using the Navigation Window is that it always displays the entire edit cell, so you can zoom to a particular area of the layout without having to first zoom out.

  The **right** (**Button-3**) mouse button in the Navigation Window lets you pan around the design.

Pan with Scroll Wheel

- If you hold down the **Shift** key while using the mouse scroll wheel, MAX will pan to the left as you scroll "away" and to the right as you scroll "towards" yourself.

  If you hold down the **Ctrl** key while using the scroll wheel, MAX will pan up and down.

Selecting Layout

After your layout is loaded, MAX offers several different selection options. Using these options, for an object (cell) or rectangle you can:

- select individual rectangles of the layout
- select cells or layers within the layout
- select nets and trace connectivity

When MAX is in main mode (the default), dragging out a region while holding down the **left mouse button** (**Button-1**) will select whatever is contained within that box when you release the button, highlighted in white.

LOADING A SMALLER CELL

First we will load and view a smaller cell to make things simpler.

Step 1

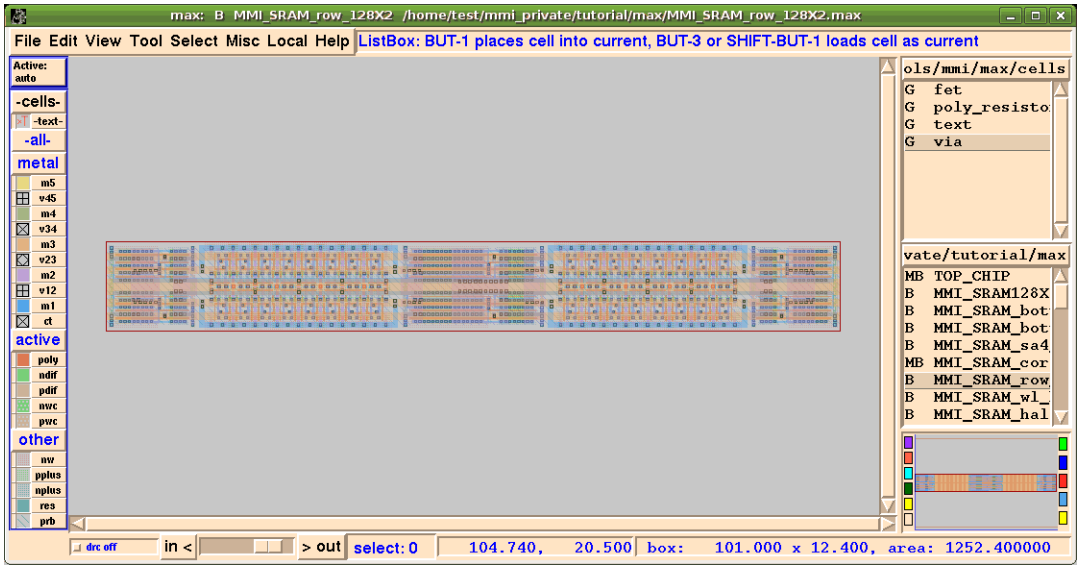
- Go over to the cell list on the right side of the MAX window and click with the **RIGHT mouse button** (**Button-3**) on **`MMI_SRAM_row_128x2`**.

Remember, if you click with the **LEFT mouse button** (**Button-1**), MAX will ***instantiate*** **`MMI_SRAM_row_128x2`** in your current chip.

Don't worry, you can always use the **undo** (hotkey: **u**) command. If the cell has not been placed yet, **Ctrl-C** will get you out of the command.

- You should now see something similar to Figure 14

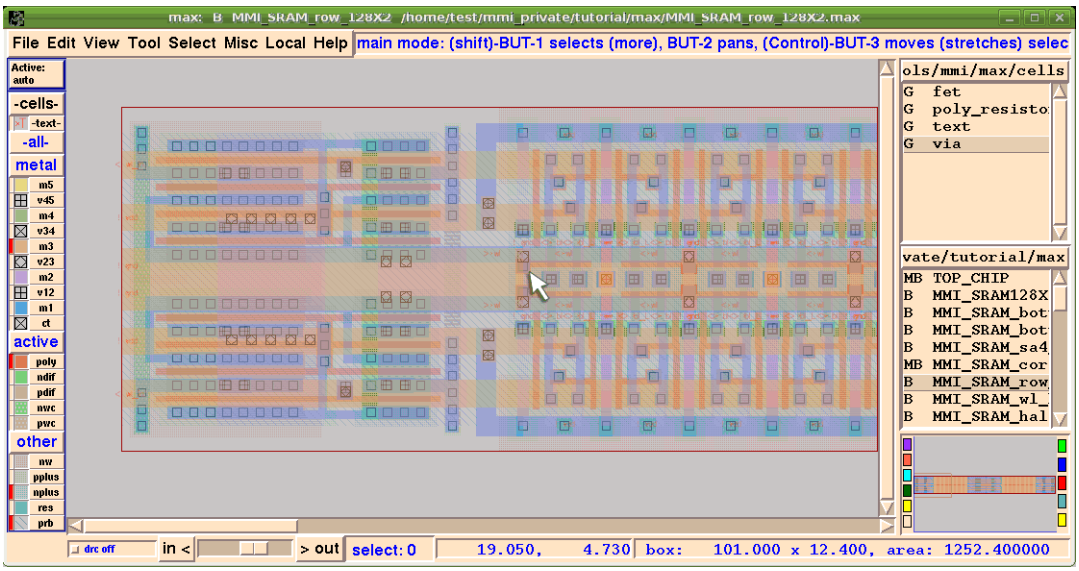
Figure 14: Cell MMI_SRAM_row_128x2 Loaded



Step 2

- Zoom in on the left half of this cell. Type the "**z**" hotkey and drag out a box using the **LEFT mouse button** (**Button-1**). You should now see something similar to Figure 15.

Figure 15: Zoom In on MMI_SRAM_row_128x2



Select Using Hotkey

Now we will select cells through the hierarchy of the layout.

Step 3

- Move your mouse to the center of the MAX window as shown in Figure 15 (above). Type the hotkey "**f**" which selects a cell.

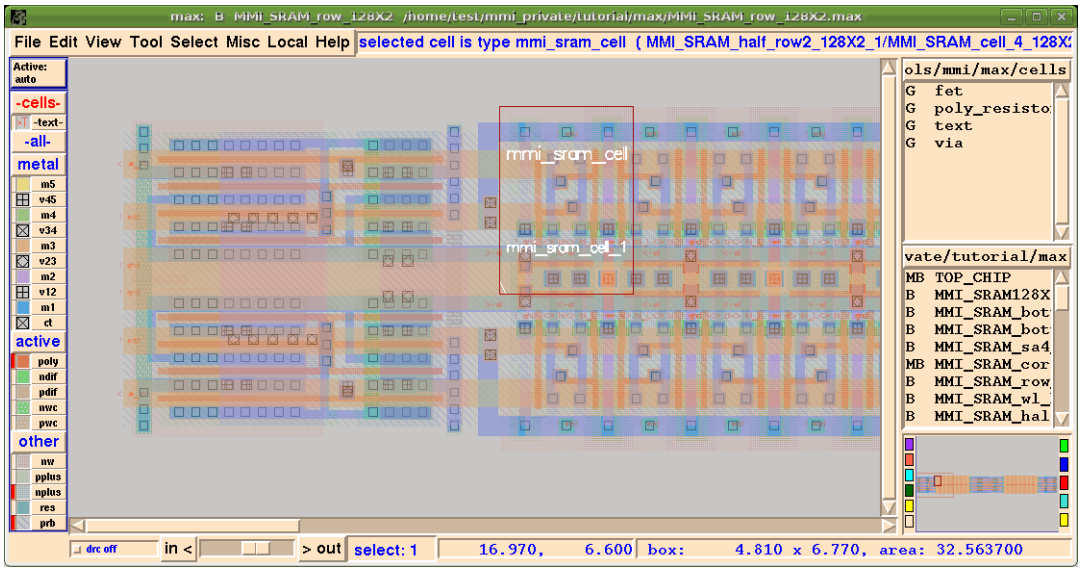
You should now have the cell **`mmi_sram_cell`** selected.

- If you look in the message area at the top of the MAX window, you should see a message like "**`selected cell is type mmi_sram_cell (MMI_SRAM...)`**".

  This tells you which cell has been selected and shows the hierarchical path to the cell inside the parentheses.

You should see something similiar to Figure 16. It doesn't matter if you have a different **`mmi_sram_cell`** selected than is shown in the figure.

Figure 16: "mmi_sram_cell" Selected in MMI_SRAM_row_128x2



Step 4

- Without moving the mouse, type the hotkey **f** once more. You should now have the cell **`MMI_SRAM_cell_4_128x2`** selected.

- If you have moved the mouse, you will see **`mmi_sram_cell`** selected again. That's OK, just type the **f** hotkey a second time without moving the mouse.

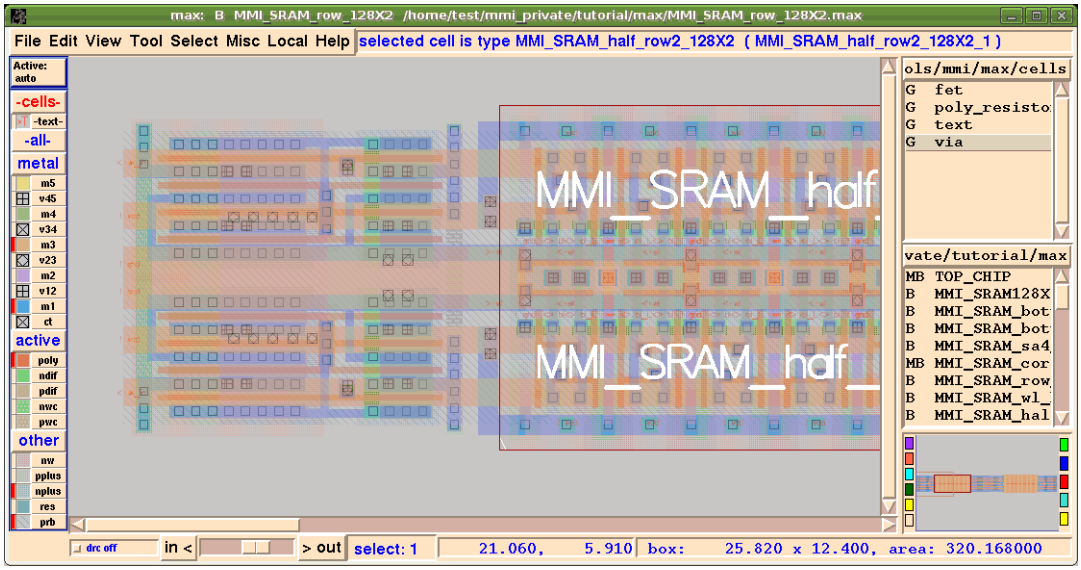
- Depending on where you placed the mouse initially, you could see the **`mmi_sram_cell`** adjacent to the first one selected. Simply type the **f** hotkey for a 3rd time and **`MMI_SRAM_cell_4_128x2`** will be selected.

- Notice the Navigation Window shows you where this particular cell (brown outline) is located in relation to the current cell and the zoomed area of the cell (light brown rectangle).

Step 5

- Type the **f** (select cell) hotkey another time without moving the mouse to select **`MMI_SRAM_half_row2_128x2`** . You should see something similiar to Figure 17.

Figure 17: MMI_SRAM_half_row2_128x2 Selected



The first time you use the **Select Cell** command (hotkey: **f**) it finds the cell at the bottom of the hierarchy. The next time it moves up to the next level of hierarchy. If two cells overlap at the same level of the hierarchy and you place the mouse over the region that overlaps, **Select Cell** will highlight the first cell, then the second cell, and then move up the hierarchy. You may have seen this happen when selecting the cells.

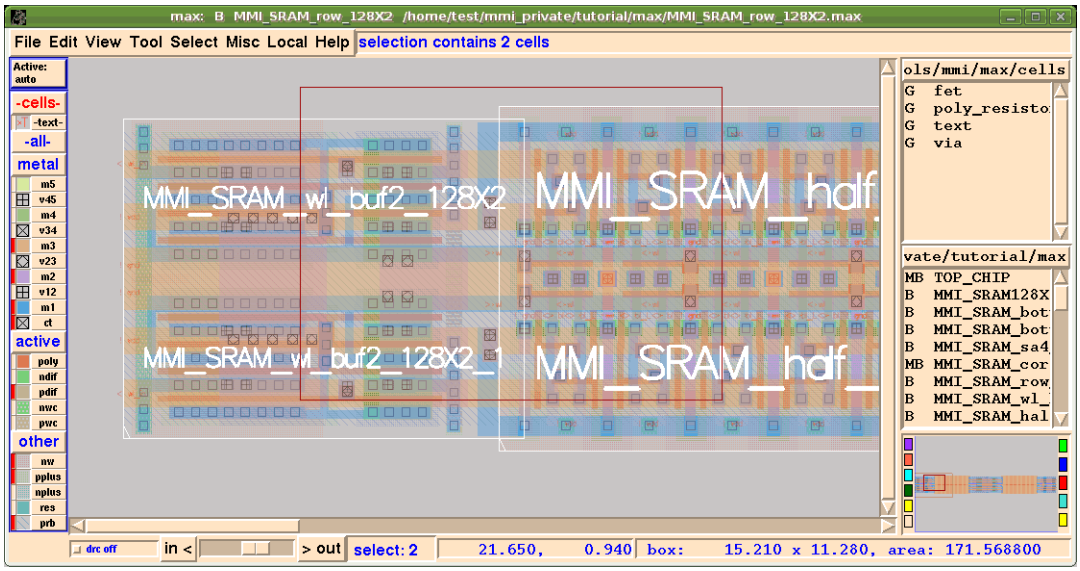
Select Using the Box

You can also select cells by dragging out a box with the **LEFT (Button-1)** mouse button that includes some part of the cell.

Step 6

- Try selecting a cell by dragging a box with **Button-1** around part of the layout. You should see something similiar to Figure 18.

Figure 18: Selecting by Dragging Out a Box



Notice that the message area at the top of the MAX window says "**`selection contains 2 cells`**" and the Select Box at the bottom of the MAX window says "**`select: 2`**". If only one cell has been selected, then the name of this cell is listed in the message area. Dragging out a box only selects cells at the current level of hierarchy.

Another way to select a cell is to click over it with the **LEFT (Button-1)** mouse button. This method only selects the cell that is at the current level of hierarchy. If you want to select cells throughout the hierarchy, you need to use the **Select Cell** (hotkey: **f**) command.

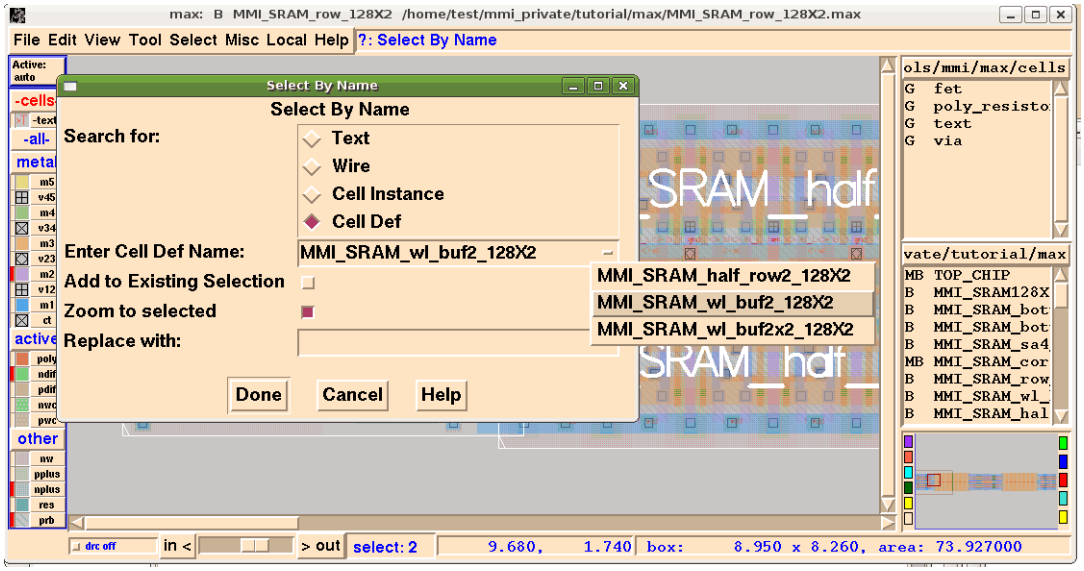
SELECT BY NAME

Additionally, you can select cells by name.

Step 7

- In the **Select** menu, go to "**Select by Name...**" or use the **n** hotkey. You should see a pop-up similiar to Figure 19.

Figure 19: Select By Name Pop-up



Most pop-ups in MAX have a **Help** button. Clicking on **Help** opens another pop-up that describes the items in the pop-up.

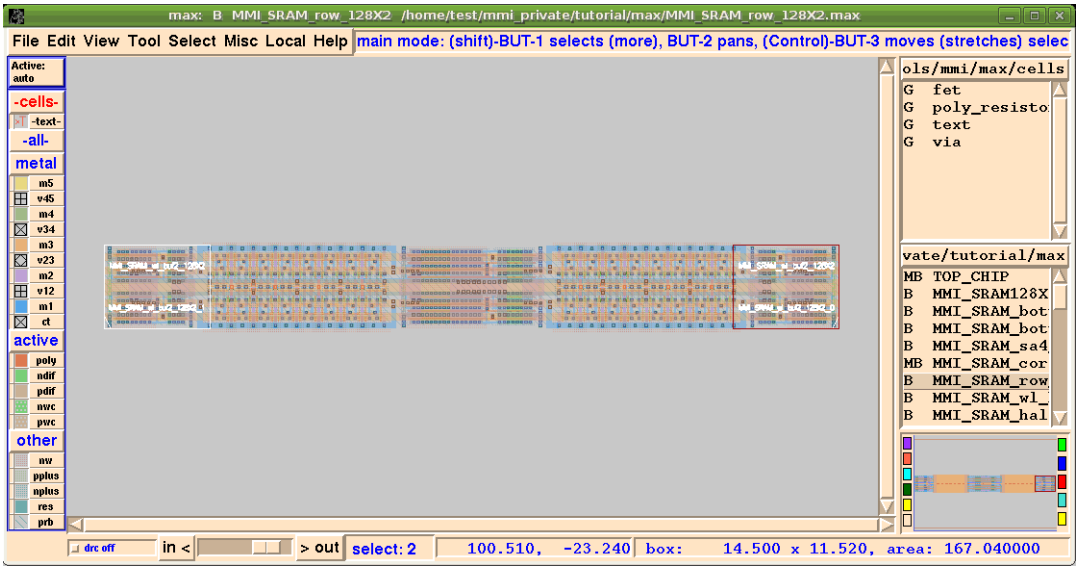
Step 8

- Click on the "**Cell Def**" toggle button. We're going to be selecting cells by the name of the cell definition (ex: **`mmi_sram_cell`**) and not by the instance name.

Step 9

- Hold down the **LEFT (Button-1)** mouse button on the pull down list to the right of "**Enter Cell Def Name:**" Select **`MMI_SRAM_wl_buf2_128x2`**.
- Click on the "**Zoom to selected**" toggle button. Now click on **Done** and you should see something similiar to Figure 20

Figure 20: MMI_SRAM_wl_buf2_128x2 Selected by Name and Zoomed Out



There are two cells selected. MAX zoomed out so that both cells are visible.

Selecting Polygons and Controlling What is Selected

In this section we will now look at how to select rectangles or polygons. We will also look at how you know what layers have been ***selected*** and how to control what layers are ***selectable***. If you are trying to select a rectangle on **`m1`** and there are other layers on top of it, you can turn off the selectability of the other layers. That way you can select just the **`m1`** rectangle.

SELECTING POLYGONS

First we need to push into a cell that contains layout, and not just instances of cells. We will push into the bottom level cell **`mmi_sram_cell`**.

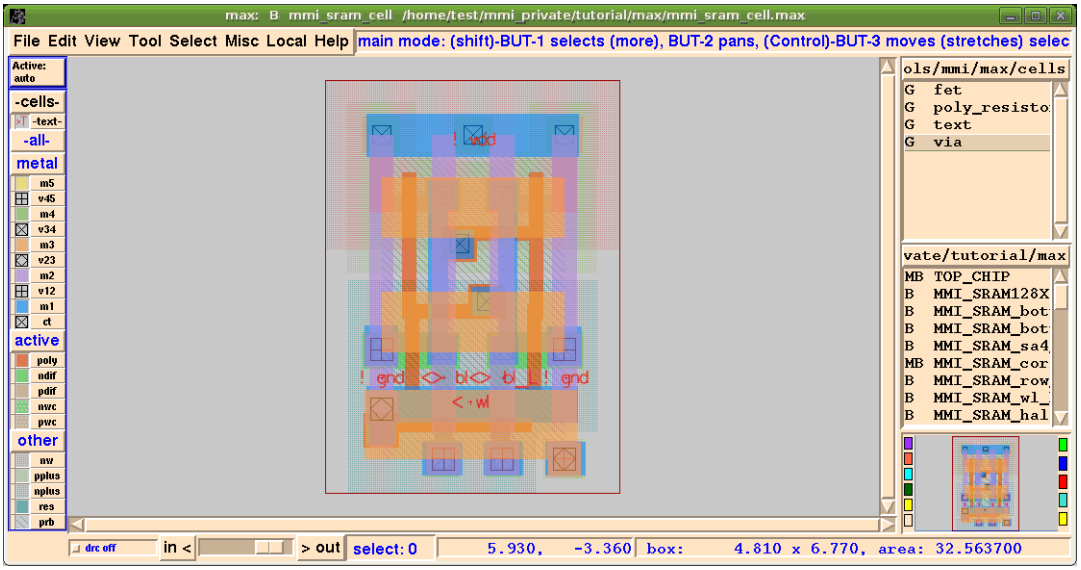
Step 1

- Go back to the left side of the layout and use the **Select Cell** command (hotkey: **f**) to select the same **`mmi_sram_cell`** as we did earlier.

Step 2

- Push into the cell by using the **Push into Cell** command (hotkey: **e**) in the **View** menu. You should now see something similiar to Figure 21.

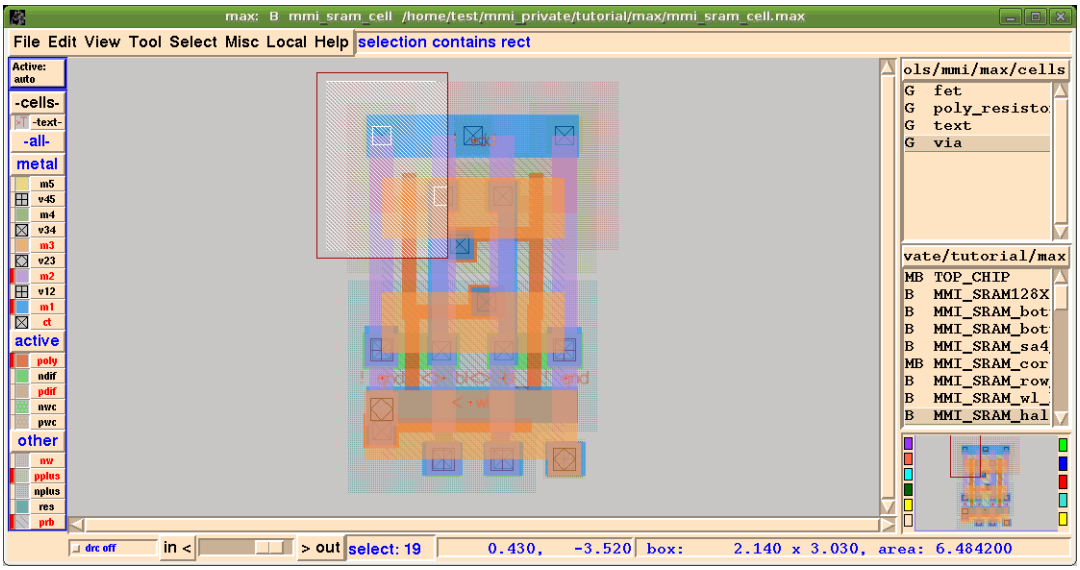
Figure 21: Push Into View of MMI_SRAM_cell



Step 3

- Drag out a box with the **LEFT (Button-1) mouse button** that encloses the upper left corner of the cell. You should see something similiar to Figure 22.

Figure 22: Selecting Rectangles by Dragging Out a Box



The number of rectangles selected will most likely differ from the number shown in Figure 22 (above). The message area should say "**`selection contains rect.`**" Notice that the **Select Box** at the bottom middle of the MAX window (to the right of the Zoom sliders) lists how many things are selected. In the figure above, 19 rectangles have been selected.

If your box included the **vdd** text, then the message area will say "**selection contains rect, text.**"

Step 4

- Look at the palette along the left side of the MAX window. Notice that some of the layer names are now red. This means that rectangles on that layer have been ***selected***.

  On the far left of the palette, notice the red indicator rectangles next to some of the layers. These show when the cursor is currently hovering over that layer.

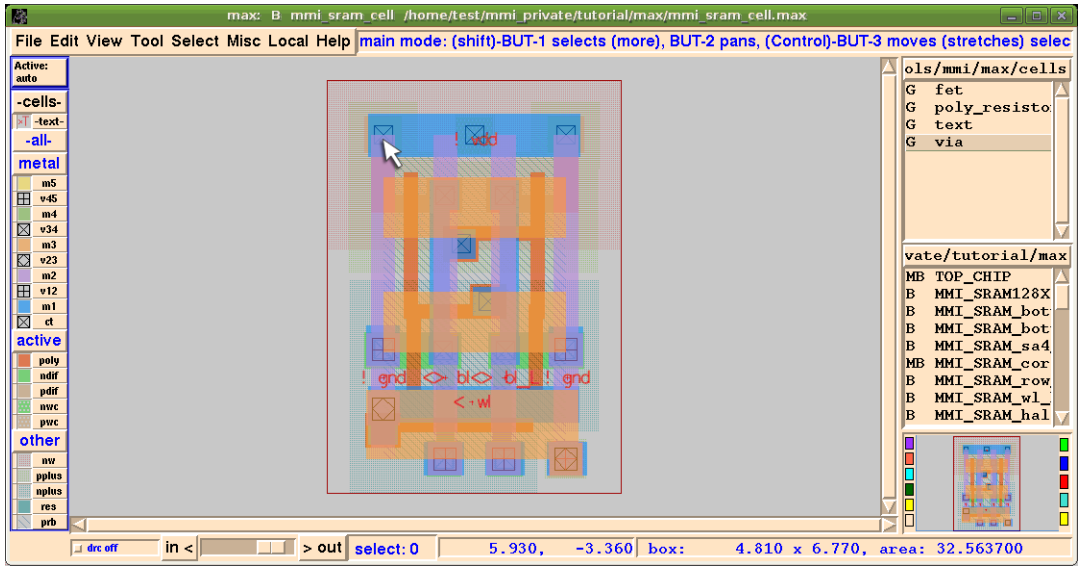
- You can also select objects by clicking once over them with **Button-1**.

Selecting Objects

Step 5

- Move the mouse so that it is over the upper left contact as shown in Figure 23

Figure 23: Mouse Cursor Positioned Over Upper Left Contact

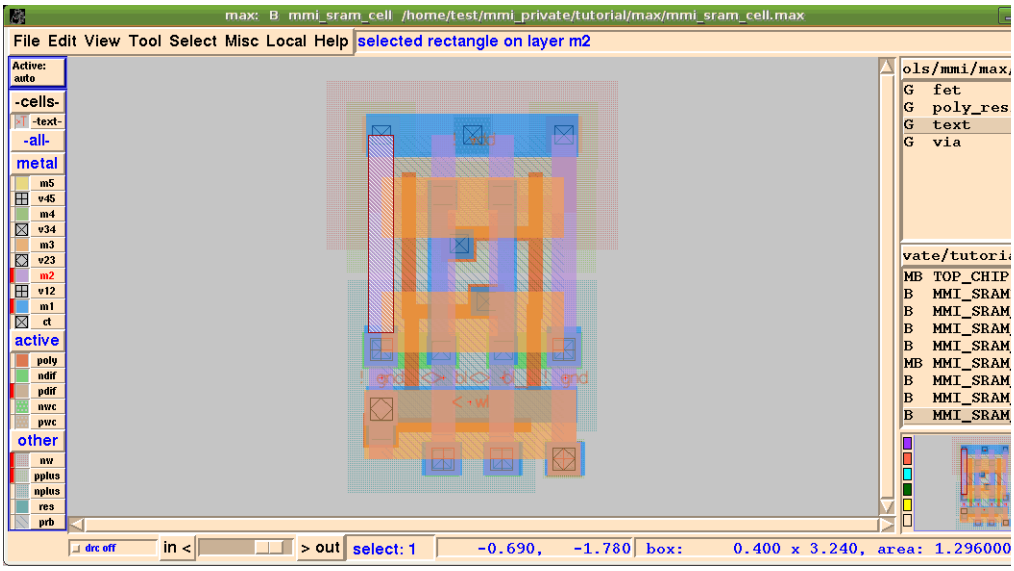


Clicking the **left (Button-1)** mouse button on a rectangle selects that particular rectangle.

Step 6

- Click once with **Button-1** at the location shown in the above figure to see something similiar to Figure 24.

Figure 24: "m2" Rectangle Selected



You should have selected an **m2** rectangle. The message area should say "**selected rectangle on layer m2**".

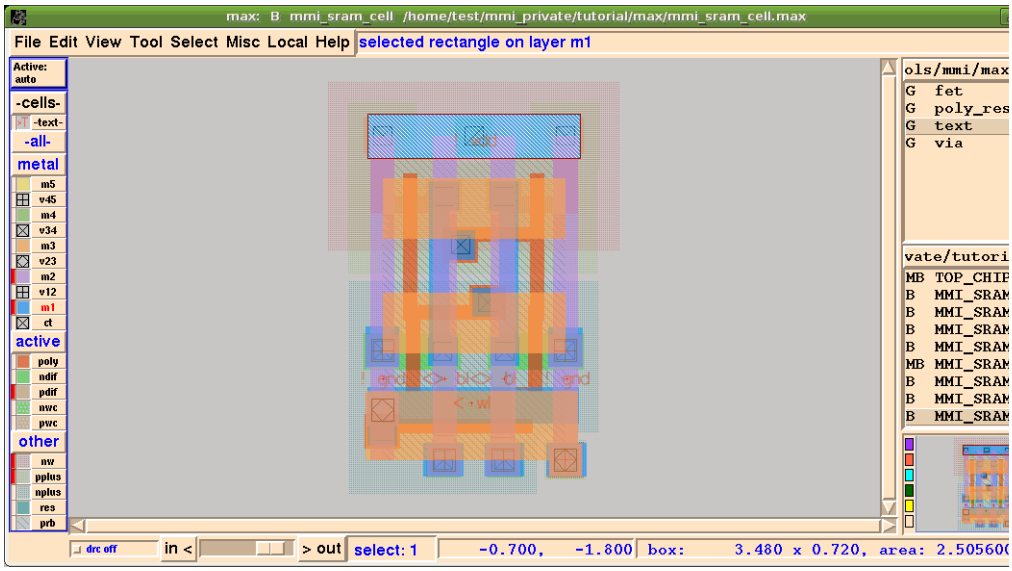
When there are multiple layers under the mouse cursor, clicking more than once without moving the mouse will select each layer in turn. You can keep clicking until the one you want is selected.

MAX starts with the layer that is the "highest" layer. For example, it would select **m3**, then **v23**, then **m2**, etc.

Step 7

- Without moving the mouse, click **Button-1 two more times**. You should now see something similiar to Figure 25.

Figure 25: "m1" Rectangle Selected



SELECTING USING CURSOR PROBE

Another way to select a rectangle on a particular layer is to use the **Cursor Probe** command (hotkey: **l** - lower case L). This opens a pop-up window showing everything underneath the cursor.

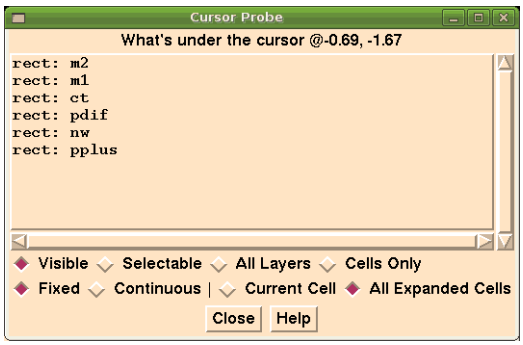
Step 1

- Clear everything that is selected using the **Clear Selection** command (hotkey: **c**) from the **Select** menu.

Step 2

- Move the mouse back to the same location shown in Figure 23 above. Type the **Cursor Probe** hotkey **l** (ell-lower case L) and a form should pop-up similiar to Figure 26.

Figure 26: Cursor Probe Results for Layers Under Selection



Step 3

- As you click on each of the layers in the list, that layer will be selected. Click on the layer a second time to turn off the selection. Refer to the *MAX User Manual* for more information on the **Cursor Probe**.

Selecting Nets

MAX can trace connectivity through vias and contacts to interactively show everything connected to a net. We'll first see this using the **mmi_sram_cell**.

Selecting a Net

Step 1

- Place the mouse in the same location shown in Figure 23 and type hotkey **s**, or choose **Select Net** from the **Select** menu. You should now see something similiar to Figure 27.

Figure 27: Select Net on 'mmi_sram_cell'

MAX will automatically select the entire net that is connected to the **m2** rectangle that was under the mouse and will also display the net name, if known, in the ***MAX Message Area***. The net name(s) are taken from any Text (labels) attached to the net. For the above net, the net name is **gnd**.

Notice in the palette on the left that some of the layer names are in red. This indicates that the selected net contains all of these layers.

Step 2

- **Clear the selection** by typing the hotkey: **c**.

  Now we will use the **Cursor Probe** to select the net. Move your mouse once more to that same location and type **l** (ell-lower case L). In the pop-up, double-click the **left (Button-1)** mouse button on "**rect: m2**" and you should see the same net highlighted.

Step 3

- **Close** the **Cursor Probe** popup.

Controlling Layer Selectability

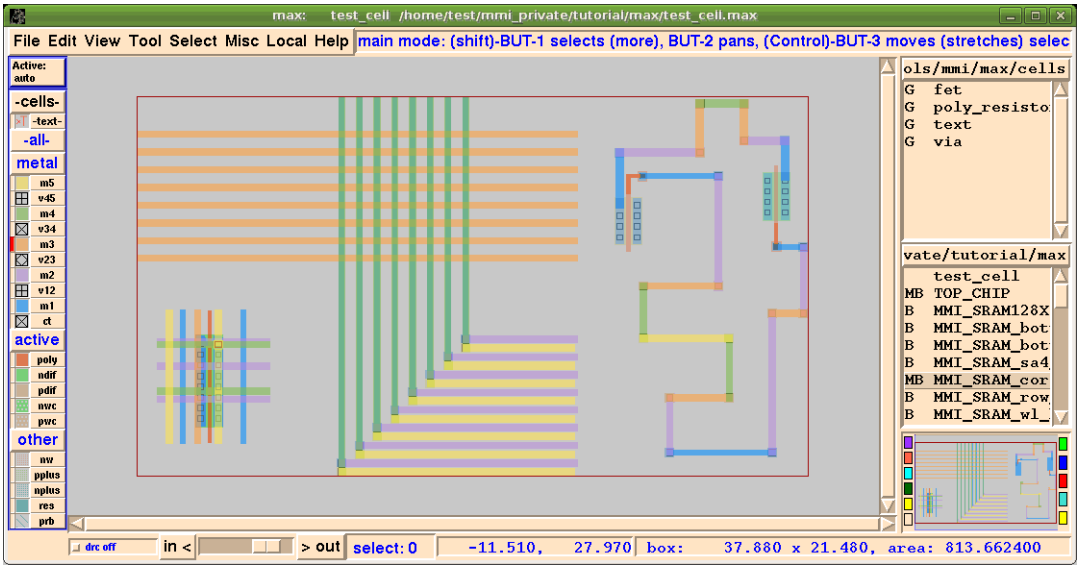
Now we will load simple test cell that will make it easier to see how selecting works.

Step 1

- Go to the **File** menu and select **Open**

- Once the pop-up form appears, click select "**`test_cell.max`**."
- Click **OK**. You should now see something similiar to Figure 28.

Figure 28: Loaded MAX file "test_cell"

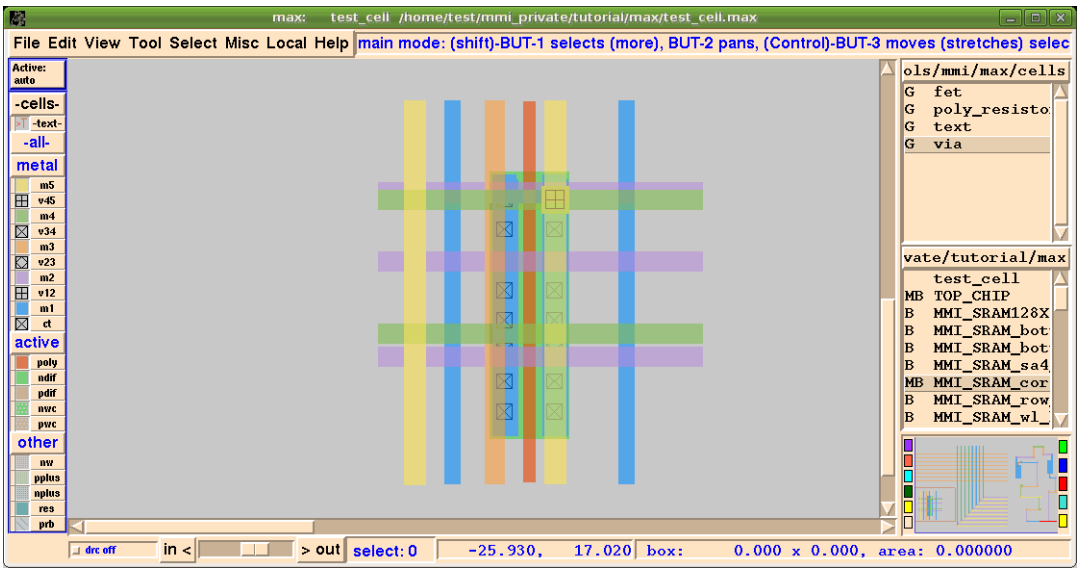


Step 2

- Zoom in on the lower left corner of the cell so that you see something similiar to Figure 29.

  Remember, to zoom in you can use the **z** hotkey and then drag a box around the desired area.

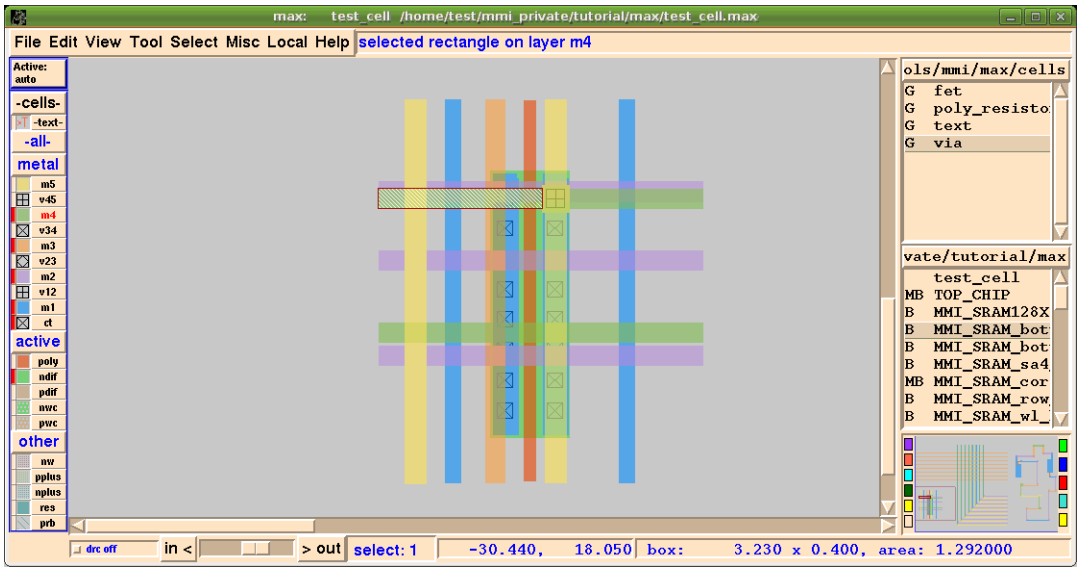
Figure 29: Zoomed in on “test_cell”



Step 3

- Place the mouse so that it is over both the left side diffusion and **m4** as shown in Figure 30. Click the **left (Button-1)** mouse button once and notice that an **m4** rectangle has been selected.

Figure 30: Selected ‘m4’ Rectangle in “test_cell.gds”



For this example, the nfet has been flattened and is no longer a gcell. (Gcells are discussed later in this tutorial.)

Turning Off Selectability

To select the **ndif** rectangle, you could continue clicking at the same location until the piece of **ndif** is selected. Another way is to **turn off the selectability** of some of the layers.

Step 4

- Move over to the palette along the left side of the MAX window. Click **Button-1** on the "**metal**" button to ***turn off visibility*** of the metal layers. It may still show you where the piece of **m4** is that you previously selected.

Step 5

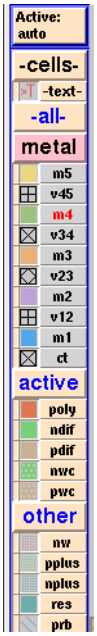
- Turn visibility of all the metal layers ***back on*** by clicking again with the **LEFT (Button-1)** mouse button over the "**metal**" toggle button.

Step 6

- Now click with the **RIGHT (Button-3)** mouse button on the "**metal**" toggle button. The palette should look like Figure 31.

- Notice that all of the metal layer names are greyed out. This means that you ***cannot select*** anything on that layer. If the piece of **m4** is still selected, the name "**m4**" will be in red on the palette.

Figure 31: Palette Showing Metal Layers Selectability Turned Off



-metal- toggle button: Click with **Button-3** to ***turn off selectability*** of all metal layers (buttons turn grey)

Red text showing **m4** layer ***selected***

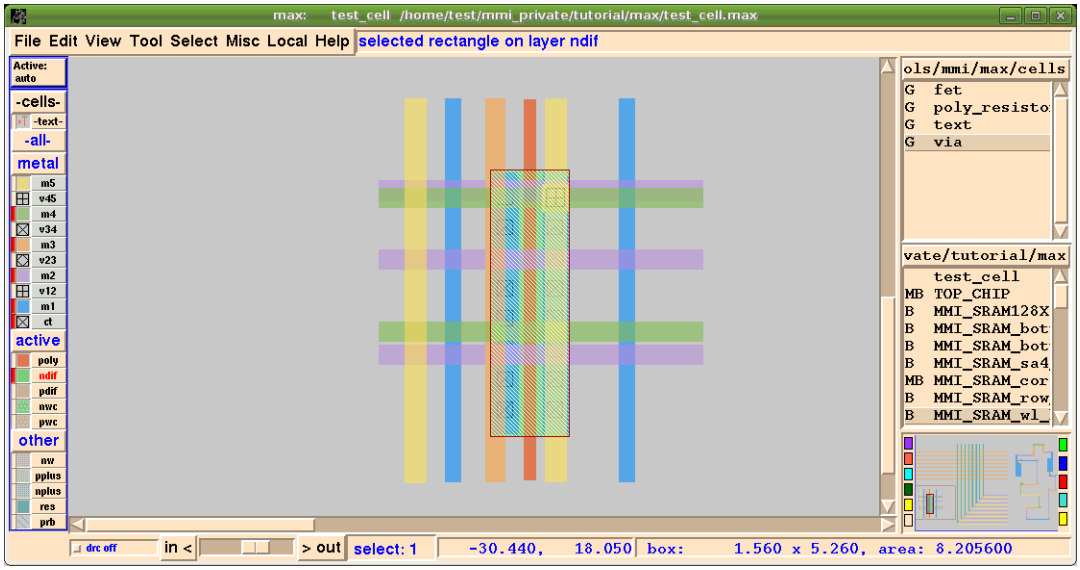
Grey buttons indicate **selectability** of all metal layers is ***off***

Step 7

- Now click with the **left (Button-1)** mouse button in the same location as shown in Figure 30.

A rectangle of **ndif** should now be selected, as shown in Figure 32. Because the ***selectability*** of all metal layers ***has been turned off***, MAX finds the next layer under all of the metal layers. That layer name is shown in red in the palette. Remember that the red rectangles on the far left of the palette show which layers are under the cursor.

Figure 32: Rectangle of "ndif" Selected



Step 8

- ***Turn back on the selectability*** of the metal layers by clicking again with the **RIGHT (Button-3)** mouse button on the "**`metal`**" toggle button (layers no longer greyed out).

Selecting Nets, Layer Selectability, Editing Wires

We have selected single and multiple rectangles. Now we will look at how to select nets to help you investigate connectivity.

Zooming in on Selection

Step 1

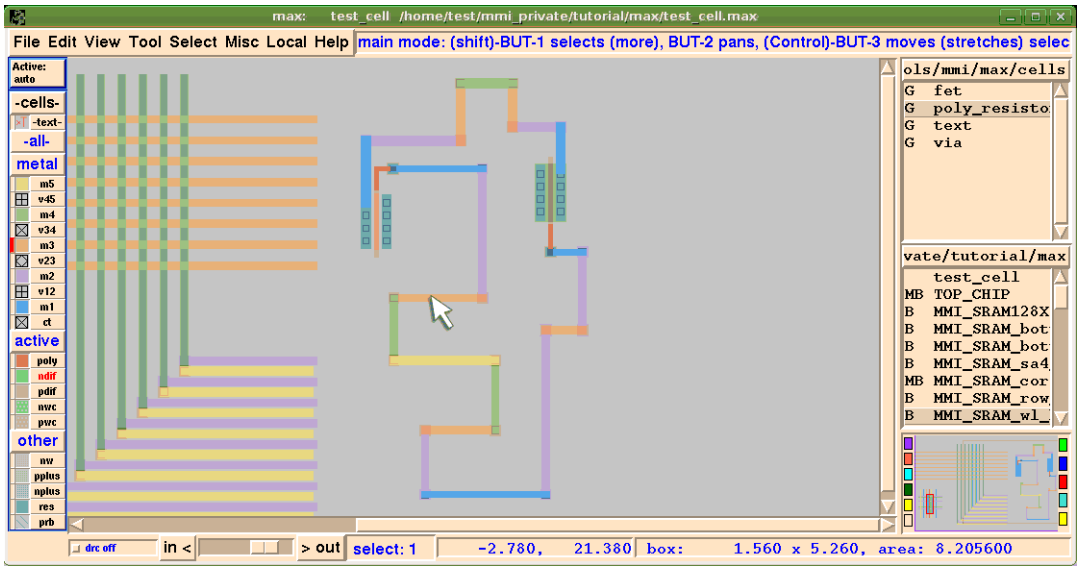
- Zoom back out to view the entire **`test_cell`**. Remember, you can use the **v** hotkey.

Step 2

- Zoom in on the right side of **`test_cell`**. You should now see something similiar to Figure 33.

Remember that you can also use the Navigation Window to zoom in to the same area.

Figure 33: Cursor positioned over ‘m3’ in “test_cell”

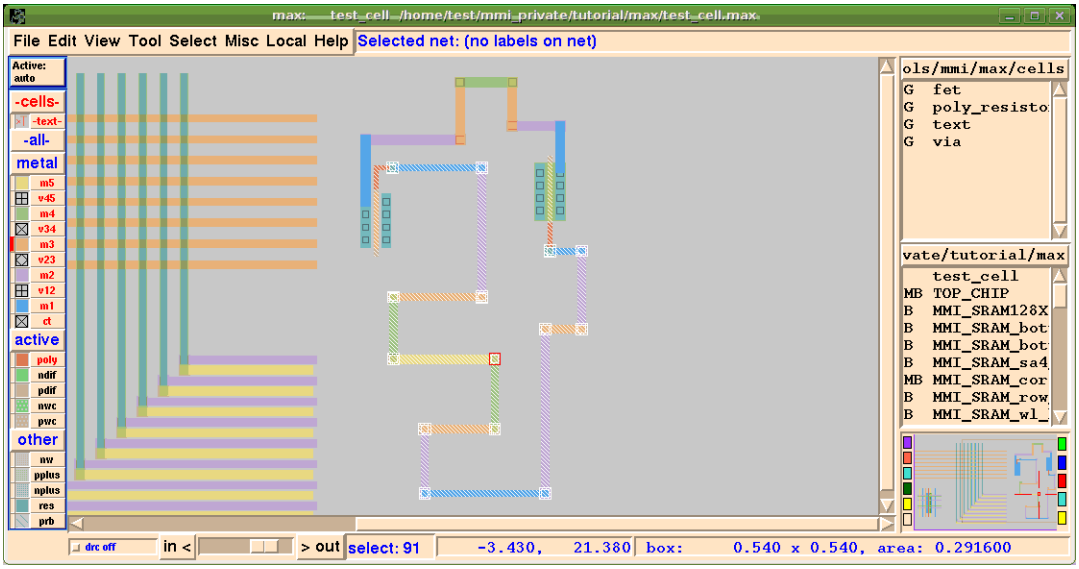


Step 3

- Place the mouse over the middle left **m3** rectangle as shown in Figure 30. Now type the **Select Net** hotkey: **s**.

  You should now see something similiar to Figure 34.

Figure 34: Select Net at Cursor Position over ‘m3’

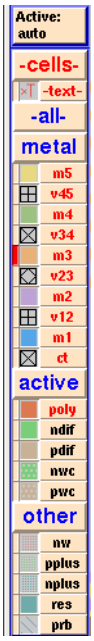


Notice that the entire net is selected from gate to gate. The information on how layers connect is specified in the ***MAX technology file***. The technology file is also where the layer names, colors, fill patterns, and DRC rules are specified. We'll cover a couple of ways to generate a technology file in a later section.

Step 4

- Look at the palette, as shown in Figure 35. Notice that there is a red rectangle to the left of **m3**. This tells you that the mouse is currently over a piece of **m3**. All of the metal names, as well as **poly**, **nfet**, and **pfet** are highlighted in red. This means that rectangles on those layers have been selected.

Figure 35: Highlighted Layer Names in Palette Indicating Selected Layers



Red LED and text showing mouse over **m3** layer ***and*** **m3** ***selected***

Names of Layers in red indicates there are rectangles on these layers selected, but mouse not over these layers.

A nice feature often used for debugging is that, when MAX selects a net, the name of all of the text labels on that net are displayed in the **MAX Message Area** (at the top, just to the right of the menus). For example, if you select a **VDD** net and the names **VDD** and **GND** both appear, you know you have a problem.

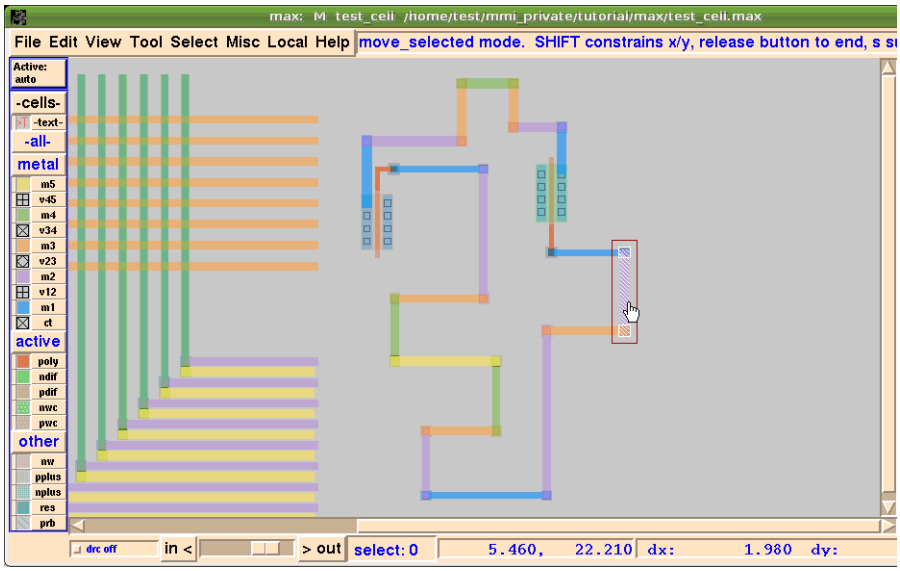
Editing Wires

One of the features of MAX is the ability to easily edit wires while ensuring that the appropriate vias are moved with the wire segment.

Step 5

- Type the **Ctrl-w** hotkey or select **Edit Wire** from the **Edit** menu. Hold down the **left mouse button**, **Button-1**, over the right middle segment of **m2** as shown in Figure 36. Drag the mouse to the right and notice that the associated vias move with the segment of **m2**.

Figure 36: Editing m2 Wire in "test_cell.max"



USING LAYER SELECTABILITY

We will now look at the ways you can use layer selectability to control which nets are selected.

Step 6

- Use the **Pan** hotkey "**->**"(**KP_RIGHT**) to pan the layout over until you see something similiar to Figure 37.

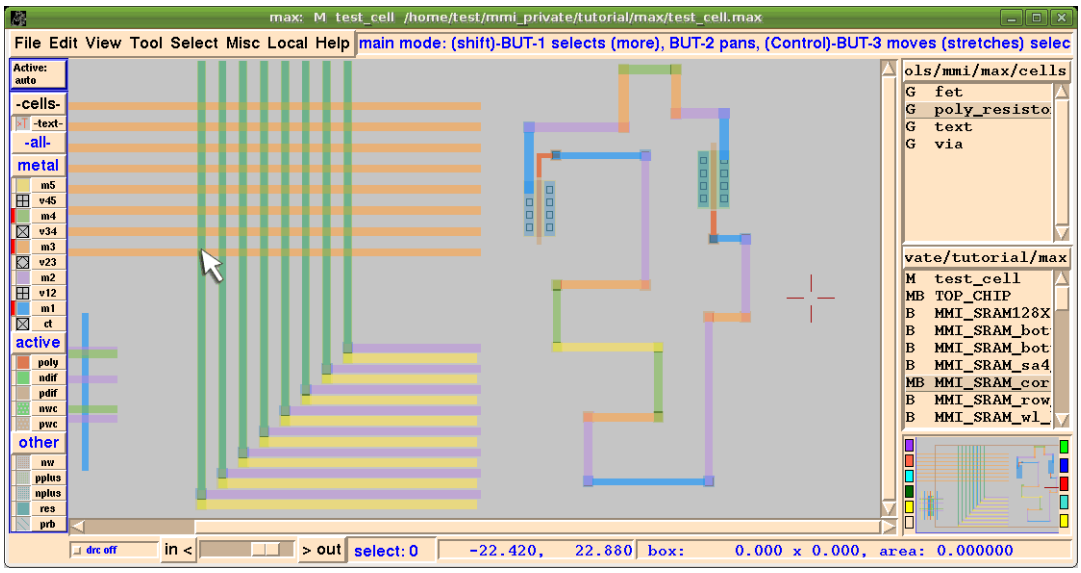
  KP_RIGHT is the **right arrow key** on the number keypad to the right of the main key pad. If your key pad is mapped differently, you can always use the **Pan** scroll bar at the bottom of the MAX window, or the **right (Button-3)** mouse button in the Navigation Window.

You can also pan left and right by holding down the **Shift** key while using the scroll wheel on your mouse. If you hold down the **Ctrl** key, MAX will pan up and down.

Step 7

- Move the mouse over an area where **m4**, **m3**, and **m1** overlap as shown in Figure 37.

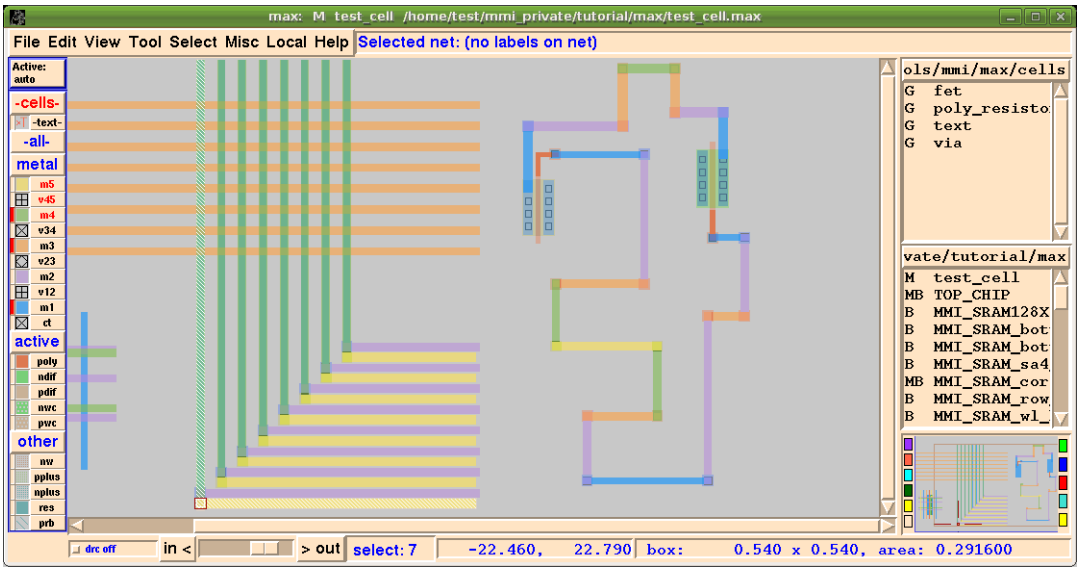
Figure 37: Cursor on Overlapping Layers ‘m4’, ‘m3’ and ‘m1’



Step 8

- Click on the **Select Net** hotkey: **s**. You should see something similiar to Figure 38.

Figure 38: Select Net at Cursor Position



- MAX selected the net that contained **m4**.
- If you type the **s** hotkey a second time at the same location, the net containing **m3** below will be selected.
- Typing the **s** hotkey a third time will select the net containing **m1**.

TURNING OFF SELECTABILITY

If you know that you want to select the net that contains **m1**, you can turn off the selectability of the other metal layers. This way you only have to **Select Net** one time.

Step 9

- On the palette, click on the layer names **m4** and **m3**. These layer names should now be greyed out in the palette.
- Move the mouse over the same location as shown in Figure 38 (above). Type the **s** hotkey and notice that the net containing **m1** was selected. Remember, you can always look to see which layer names in the palette are in red to find the layers that have been selected.

Bigger Designs and Hierarchy

Show/Hide Internals

In this section, we will look at ways to view the layout through the hierarchy.

HIDING INTERNALS

Step 1

- Load **TOP_CHIP** again into the MAX window by clicking on it at the beginning of the cell list with the RIGHT mouse button (**Button-3**).

Remember if you click with the **left mouse button** (**Button-1**), MAX will ***instantiate*** **TOP_CHIP** in your current cell. Donv't worry, you can always use the **undo** (hotkey: **u**) command.

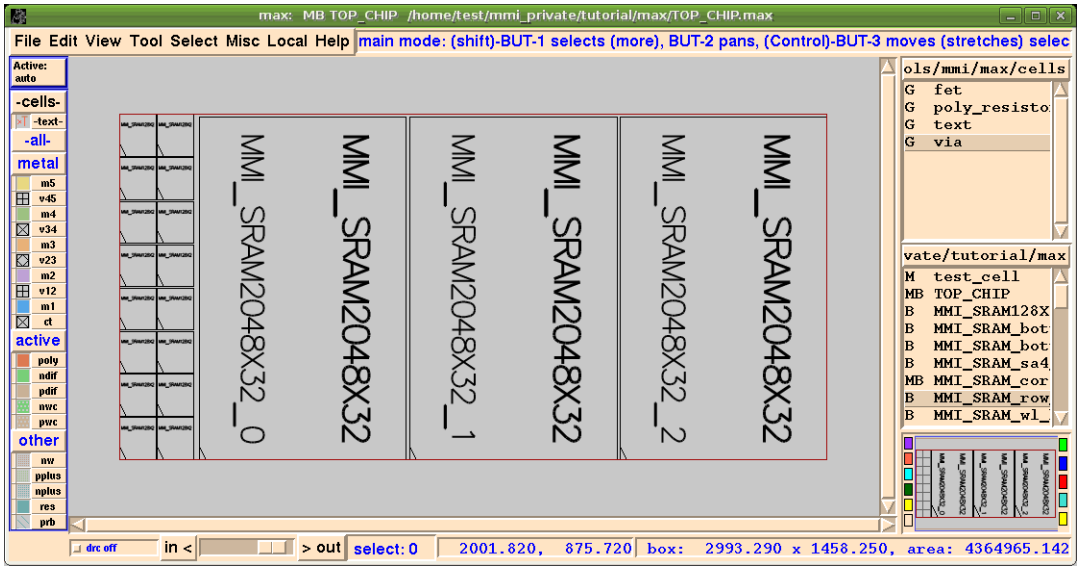
If you have not restarted MAX, then all layers and all levels of hierarchy are visible.

Step 2

- Type the **Internals, Hide All** hotkey: **h**. This will hide all of the internals of all of the cells so that you are viewing only the top level instantiations of cells.

  You should now see something similiar to Figure 39.

Figure 39: Hiding Internals of "TOP_CHIP.gds"



One way of looking at the hierarchy of the layout is to view internals of the entire cell or selected subcells. At the beginning of this tutorial we already viewed internals of the *entire cell* using the hotkey **i** (**Internals, View All** from the **View** menu).

VIEWING SELECTED CELL INTERNALS

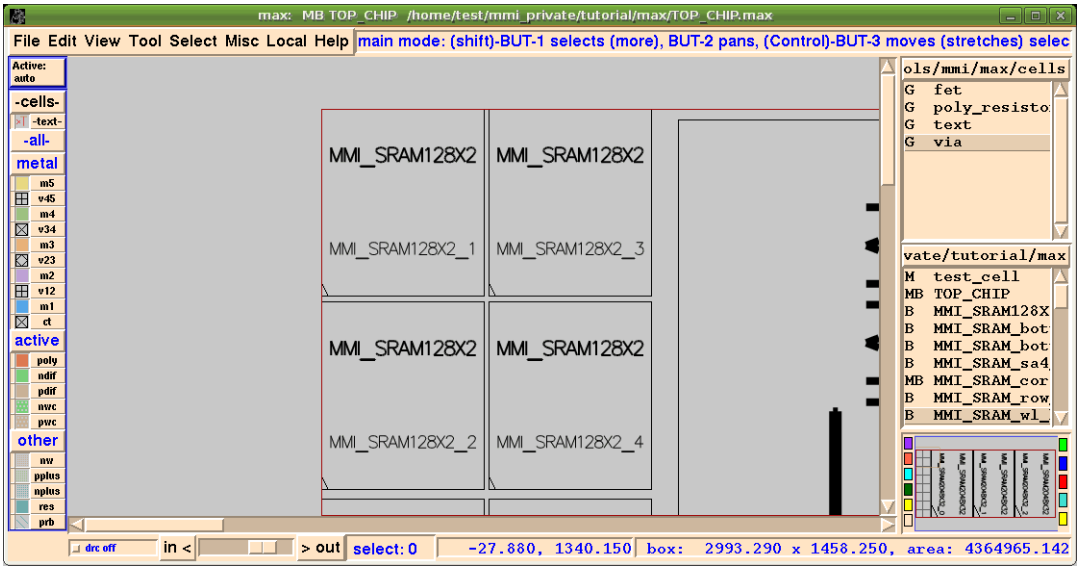
Now, we'll look at viewing the internals of ***selected cells***.

First we will look down at the next level of hierarchy of a cell.

Step 3

- Zoom in on the upper left corner of **`TOP_CHIP`** as shown in Figure 40.

Figure 40: Zoom In on Upper Left of "TOP_CHIP.gds"

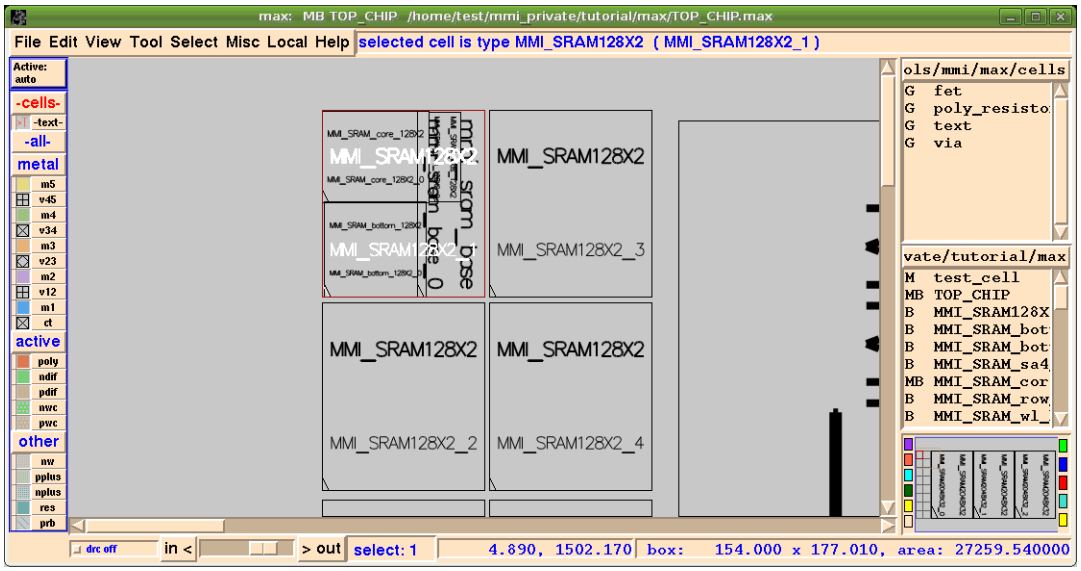


Step 4

- Select the upper left **`MMI_SRAM128x2`** cell by clicking on it with **Button-1**.
- Type **Shift-i**, or select **Internals, Show Cell** from the **View - > Internals, Misc.** menu.

  You should now see something similiar to Figure 41.
  (Typing **Shift-h** will **Hide Internals** for the cell.)

Figure 41: Viewing Internals of "MMI_SRAM128x2" Cell



You are now looking at the top level cells for the upper left **`MMI_SRAM128x2`** cell.

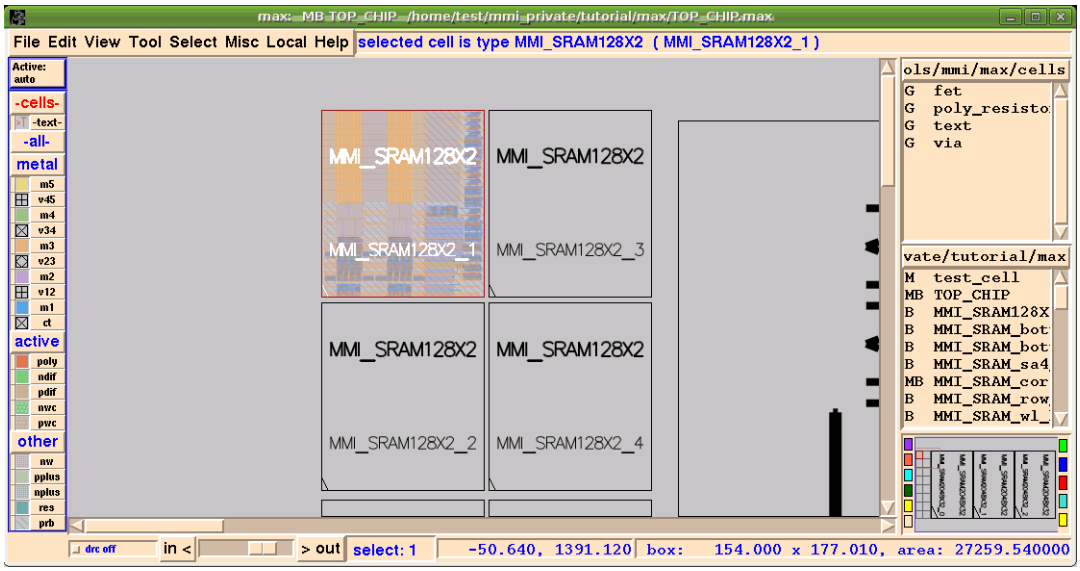
Step 5

- To view all internals for the **`MMI_SRAM128x2`** cell, select **Internals, View Area** from the **View - >Internals, Misc.** menu.

If you find that you are using a command often that doesn't currently have a hotkey, you can edit the hotkeys and add a hotkey for this command.

You should now see something similiar to Figure 42. All levels of hierarchy for the upper left **`MMI_SRAM128x2`** are visible.

Figure 42: Viewing All Area Internals of Cell "MMI_SRAM128x2"



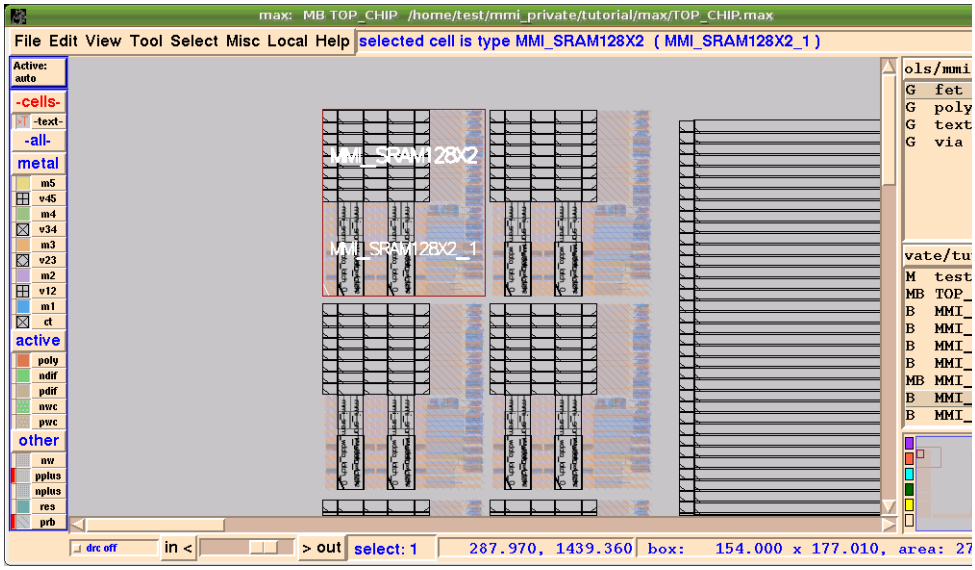
VIEW INTERNALS OF HIERARCHY

- If you want to continue viewing down another level of hierarchy, you can use the **Internals, View More** command.

Step 6

- First **hide** all of the internals by typing the **h** hotkey.
- Type the **Ctrl-i** hotkey 3 times. You should now see something similiar to Figure 43.

Figure 43: Internals, View More of Cell "MMI_SRAM128x2"

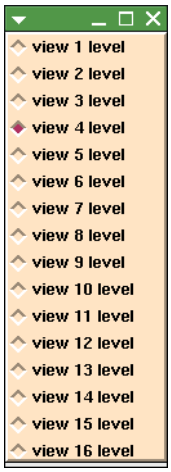


Step 7

- Another way to view levels of hierarchy is to select **Internals, View Levels** from the **View** menu.

  The easiest way to use this feature is to tear off the sub-menu. Do this by clicking with the **Button-1** on the dotted line at the top of the sub-menu. You should now see the pop-up shown in Figure 44.

Figure 44: Internals, View Levels of Cell "MMI_SRAM128x2"



Step 8

- Click on the different levels and notice the results.

Push & Pop

In addition to the **zoom** and **internals** features for really getting to know your layout, you can **Push into** or **Pop out of** cells. Pushing into goes deeper into the hierarchy one level at at time; popping out moves back up through the hierarchy.

Pushing Into / Popping Out of Cells

TO PUSH IN

Step 1

- You should still have `TOP_CHIP` loaded in MAX. **View all levels** of hierarchy by typing the **i** hotkey.

Step 2

- Select a cell using **f** or **Select Cell** from the **Select** menu.

Step 3

- Now type **e** or select **Push into Cell** from the **View** menu.

TO POP OUT

You will now be viewing just the cell you selected. To get back to the top level of hierarchy, you can pop up to that level.

Step 4

- Type **Ctrl-e** or select **Pop out of Cell** from the **View** menu to "pop" up a level
- You can keep using **e** or **Ctrl-e** to continue going further into or out of levels.

EDIT IN PLACE

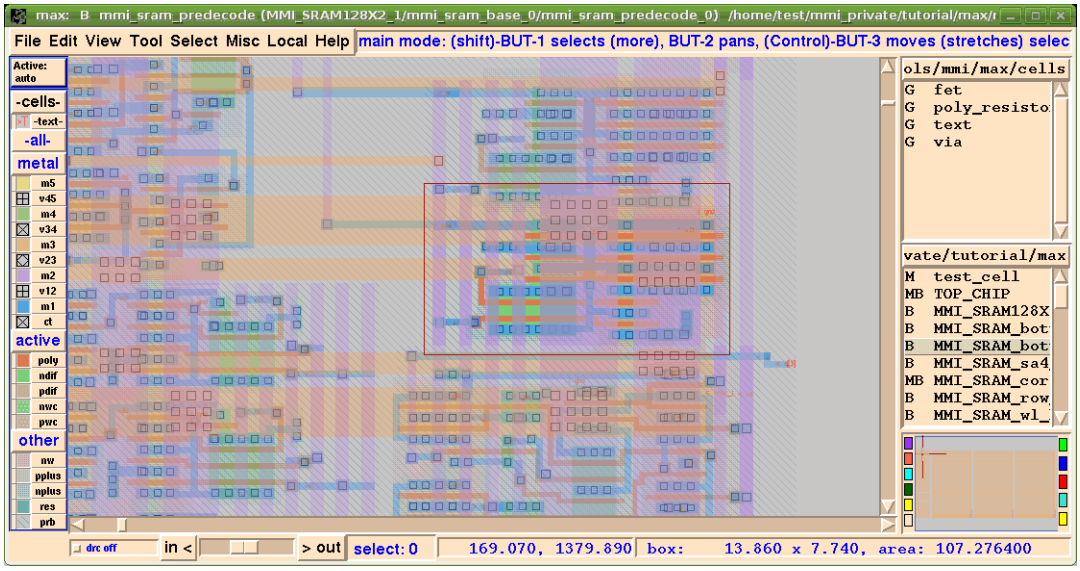
If you want to edit a cell and also see all of the layout around it, you can ***edit a cell in place***.

Step 5

- From the top level, again select a cell with the **f** hotkey. Now type **Shift-e** or select **Edit Cell or Object in Place** from the **View** menu.

The cell you are editing in place will show darker than the surrounding layout, as shown in Figure 45

Figure 45: Edit Cell in Place



.

Cell Hierarchy Browser

Yet another way to explore the hierarchy of your chip or block is to use the **Cell Hierarchy Browser**.

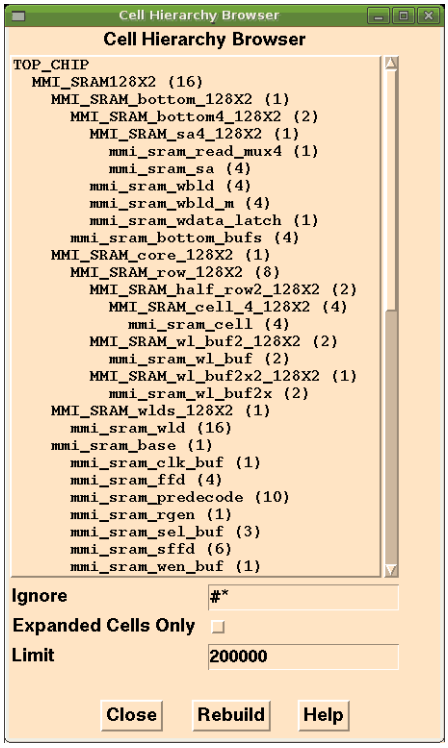
BROWSING CELL HIERARCHY

Make sure you are back at the top level of **TOP_CHIP**. You can always **RIGHT click (Button-1)** on **TOP_CHIP** in the Cell List to the right of the MAX window.

Step 1

- Select **Display Hierarchy...** from the **View** menu or type the **Shift-L** (ell) hotkey. You should now see a pop-up like Figure 46.

Figure 46: Cell Hierarchy Pop-up



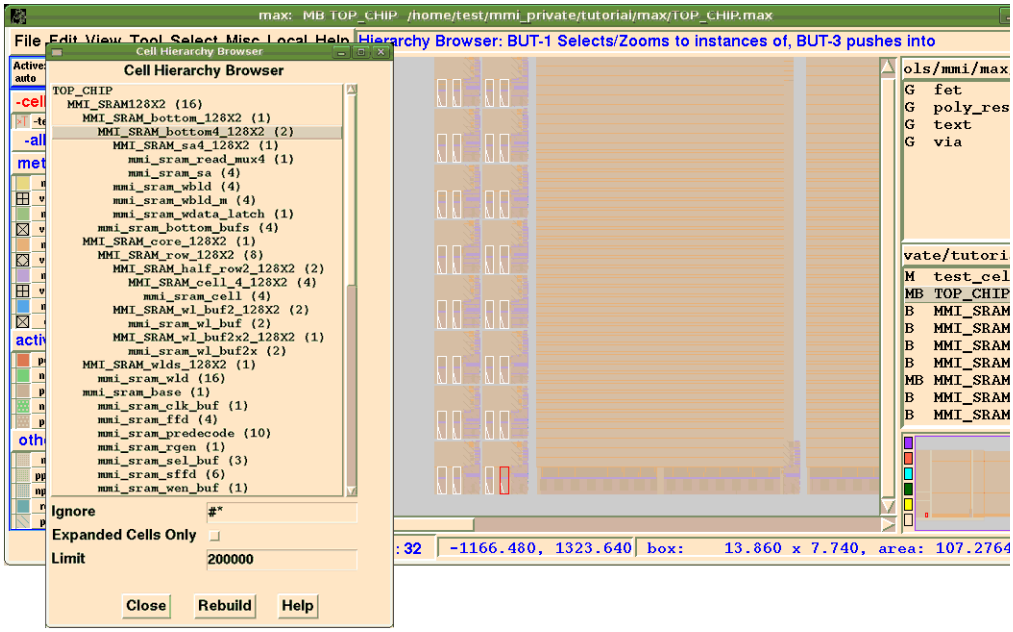
- If you click with the **LEFT mouse button** (**Button-1**) on any of the cells in the hierarchy browser, all instances of the cell at that level of hierarchy will be selected in the layout and you will be zoomed out to fit all of those instances.

Step 2

- Click with the **LEFT mouse button** (**Button-1**) on **`MMI_SRAM_bottom4_128x2`** toward the top of the **Cell Hierarchy Browser** list as shown in Figure 47.

  The "2" is brackets, to the right of **`MMI_SRAM_bottom4_128x2`**, indicates there are 2 of these cells at this level of hierarchy. Because there are 16 copies of the **`MMI_SRAM128x2`**, there will be 32 **`MMI_SRAM_bottom4_128x2`** cells selected, as shown in Figure 47.

Figure 47: Selecting "MMI_SRAM_bottom4_128x2" in Cell Hierarchy Browser Showing 32 Selected Cells in Layout

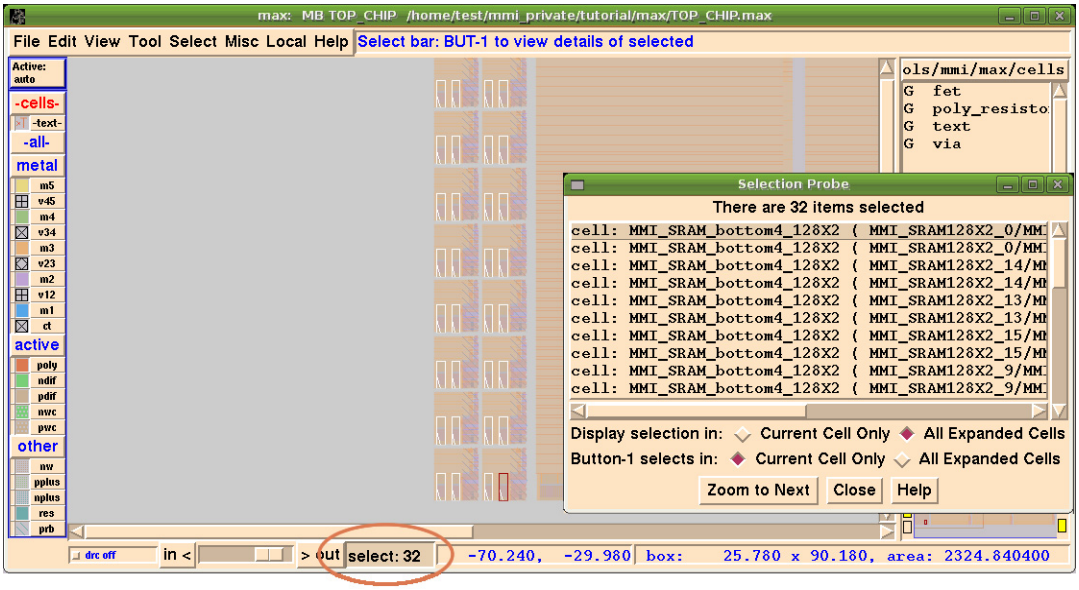


If you want to zoom to each of them, you can use the **Selection Probe**.

Step 3

- With the cells still highlighted, click on the ***Select Box*** at the bottom middle of the MAX window as shown in Figure 48. It should say "**`select: 32`**"

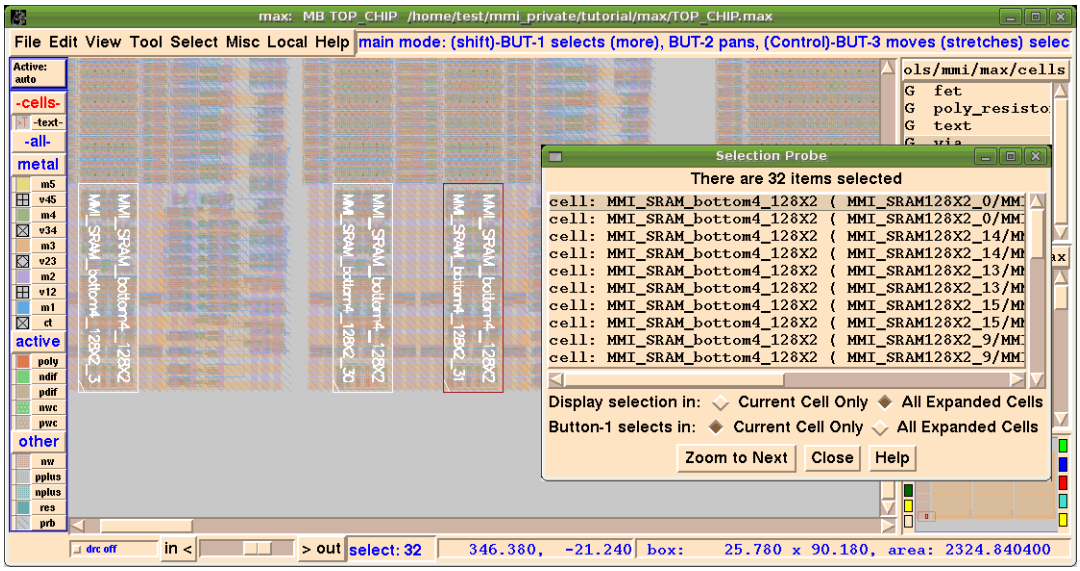
Figure 48: Click on Select Box to Open Selection Probe Pop-up



Step 4

- Click on one of the cells with **Button-1**, or click on the **Zoom to Next** button to step through each of the **`mmi_sram_clk_buf`** cells. You should see something similiar to Figure 49. When you are done, click on **Close**.

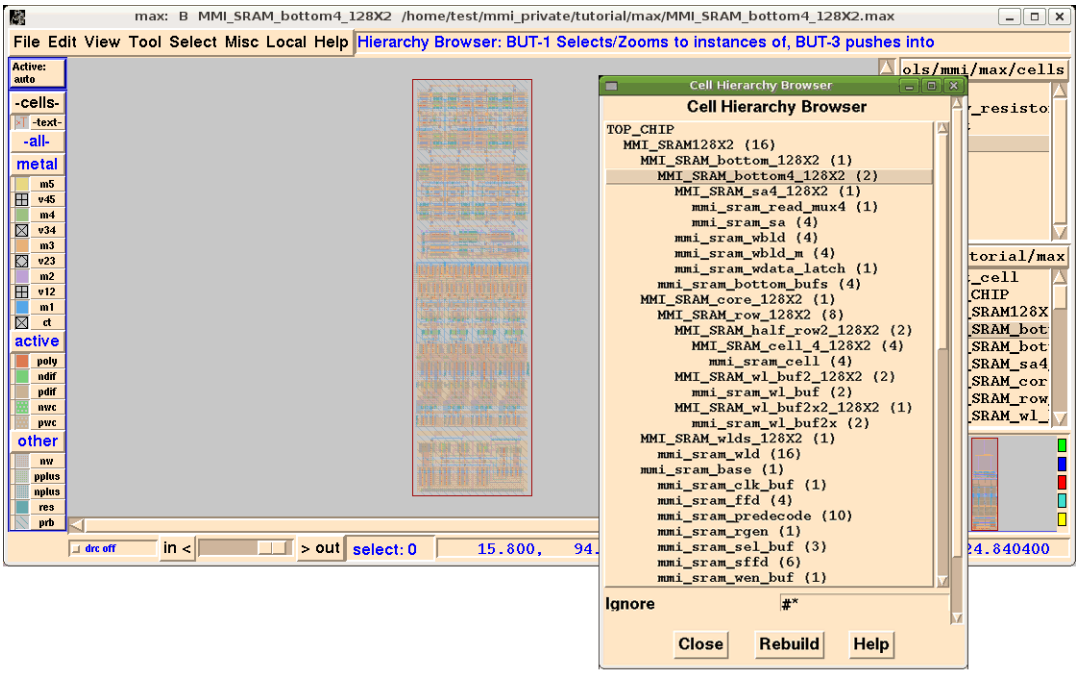
Figure 49: Zoom to Next Cell in Selection Probe



Step 5

- On the **Cell Hierarchy Browser**, click with the **RIGHT mouse button** (**Button-3**) on **`MMI_SRAM_bottom4_128x2`**.
- If you can't find the the **Cell Hierarchy Browser**, you can always select **Display Hierarchy** again from the **View** menu or type the hotkey **Ctrl-l** (ell). You should see something similiar to Figure 50.
- When you are done, click on the **Close** button.

Figure 50: "MMI_SRAM_bottom4_128x2" Cell Loaded into MAX from Cell Hierarchy Browser



Next, we'll see how MAX handles interactive real-time DRC, a useful and powerful feature.

Viewing DRC Errors in MAX and with the Calibre® Interface

MAX includes interactive DRC (design rule) checking. You can step through DRC errors and fix them on the fly. MAX also includes an interface to the Mentor Graphics' *Calibre*® DRC checker where MAX is used to step through and view each of the DRC errors. You can interactively correct the DRC errors as you go. MAX reads in the **`<cell_name>.drc_maskdb`** results from a Calibre® run.

MAX can also interface with Calibre® RVE. For information on how to use this interface, refer to the *MAX User Manual*.

VIEW MAX DRC ERRORS

We'll load in a small test cell which has some DRC errors and for which we've already run Calibre®.

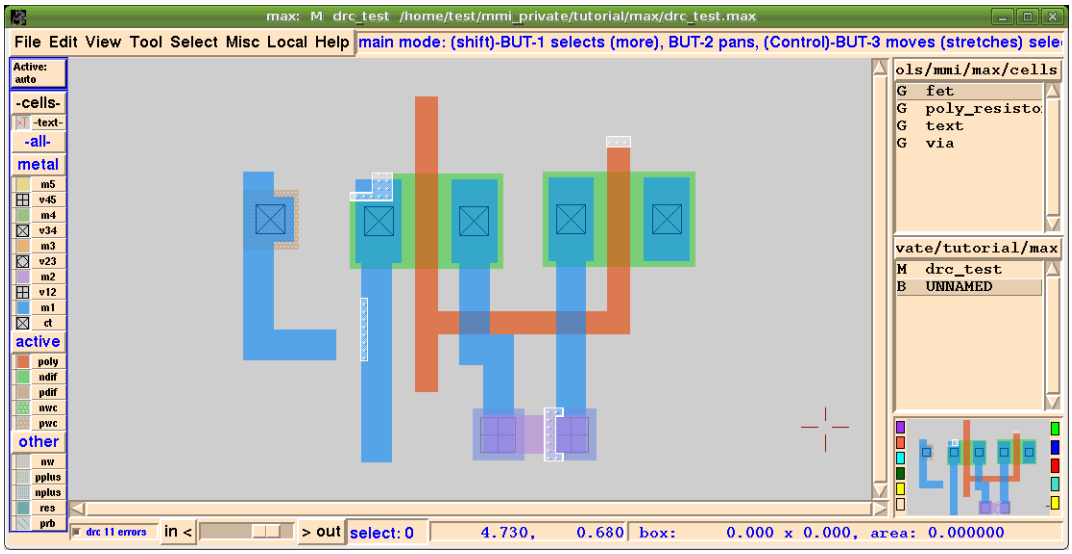
Step 1

- Select **Open...** from the **File** menu. This will open a layout file that is in the MAX format.

Step 2

- Select **`drc_test.max`** and click on **OK**. You should now see something like Figure 51.

Figure 51: Loading "drc_test.max" File



Notice that MAX displays DRC errors as dotted white rectangles. (DRC colors can be easily modified; we'll cover this in the section <ExampleSmallBold>Continuous DRC (page -88).)

Step 3

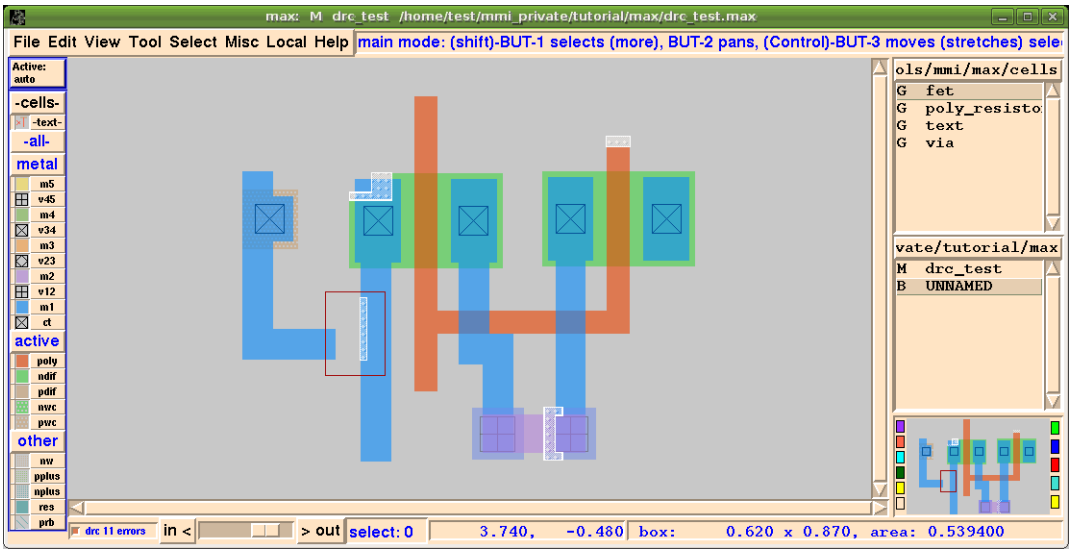
- Look at the box at the lower left corner of the MAX window and notice that it says "**`drc 11 errors`**". This means that there are 7 DRC errors in this cell.

There are a number of ways to look at the DRC errors. Let's say you're interested in finding out what a specific DRC error rectangle represents. You can draw a box around that error and ask MAX what it represents.

Step 4

- Type the hotkey **b** or select **Make/move Box** from the **Misc** menu. Hold down **Button-1** and drag a box around the lower left DRC error, as shown in Figure 52.

Figure 52: Dragging Box Around Lower Left DRC Error



You could have also have simply dragged out a box around the DRC error without using the **Make/ move Box** command, but this would have also *selected the layout* under the box.

Step 5

- Type the hotkey **Shift-y** or select **Explain DRC under Box** from the **Misc** menu. In the Message Area at the top of the MAX window you should see:

```
DRC: m1 minimum spacing = 0.32 um.
```

- If you drag a box around multiple DRC errors, the MAX message error will display the number of DRC errors under the box and tell you to look at the MAX command window (the shell window from which you started MAX) for details.

Step 6

- Another way to find out what the DRC errors are is to step through them.

  Type the hotkey **Shift-n** or select **DRC Find Next Error** from the **Misc** menu. MAX will zoom in on a DRC error and display the text of the error in the MAX Message Area.

  Continue to type **Shift-n** to step through the remaining DRC errors.

The **Shift-n** hotkey can be very useful if you're looking at a reasonably large block and MAX informs you of a DRC error (bottom left corner of the MAX window). Sometimes you can't see where the error is if it's small, and you can use the **Shift-n** command to find the DRC error.

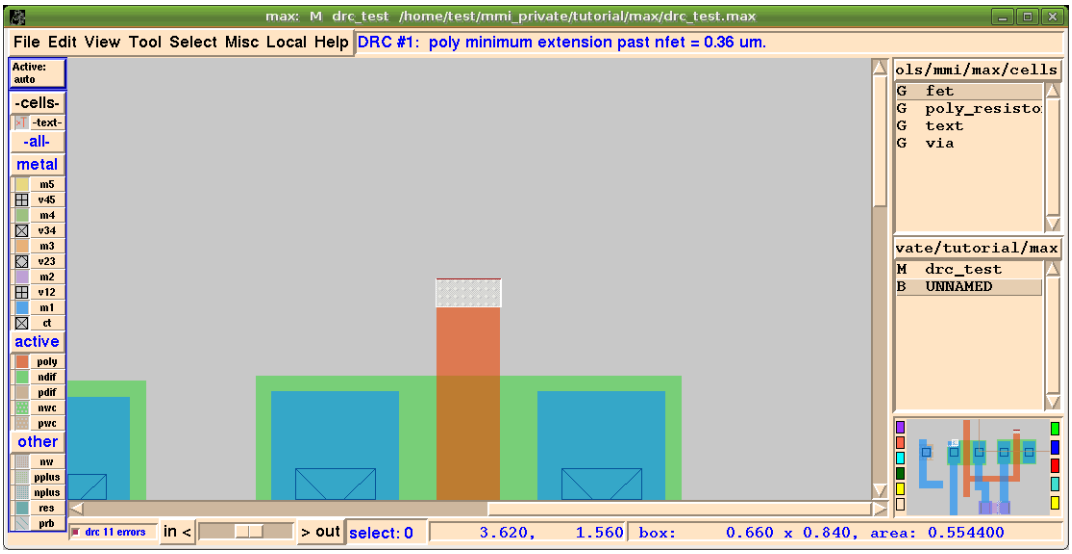
Fixing DRC Errors

As you are stepping through the DRC errors, you can fix them on the fly.

Step 1

- Step through the DRC errors using the **Shift-n** command until you see **`DRC #1`** in the Message Area and you see something similiar to Figure 53.

Figure 53: Using "Shift-n" To Find Error 'DRC #1'

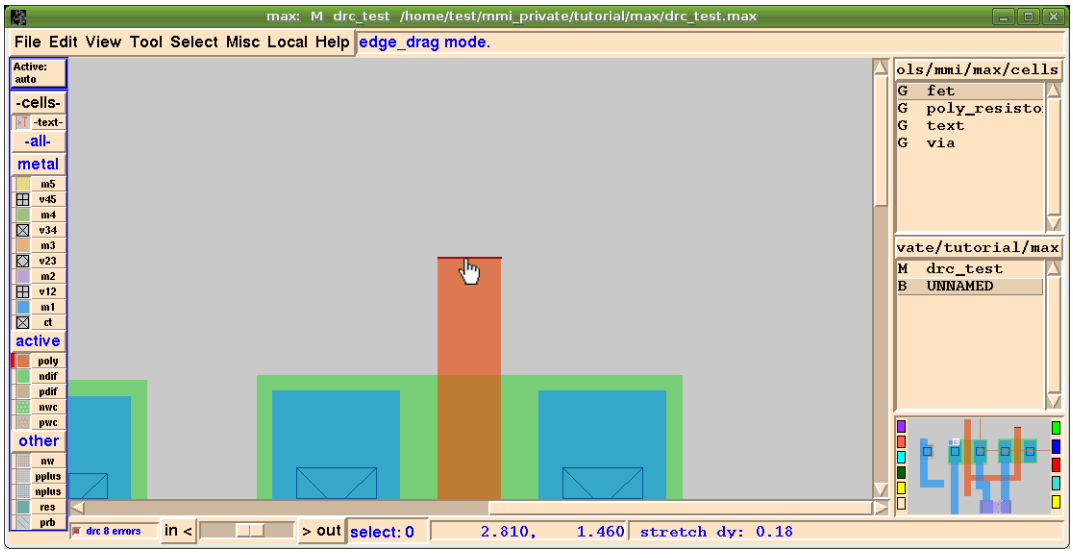


Step 2

- Type the hotkey **a** or select **Edit Edge** from the **Edit** menu. Notice the cursor has now changed to a hand with a pointing finger, as shown in Figure 54.

  Move the cursor near the upper edge of the poly. Hold down **Button-1** and drag the mouse upwards until the DRC error disappears.

Figure 54: Editing Edge To Remove DRC Error



Step 3

- Let's fix another DRC error. Type **Shift-n** until you see **DRC #8** in the MAX message area. You should see something similiar to Figure 55.

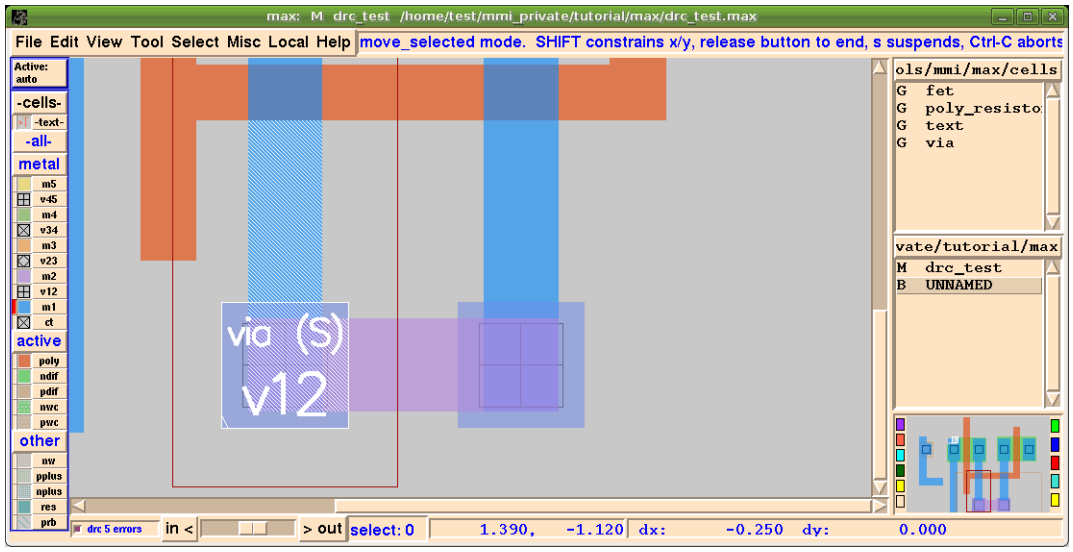
Figure 55: Using "Shift-n" To View DRC Error #8

Step 4

- We'll use the **Edit Wire** command to fix this DRC error.
  Type the hotkey **Ctrl-w** or select **Edit Wire** from the **Edit** menu.

  Move the cursor over the lower left **m1** segment as shown in Figure 55, ***above***. Hold down **Button-1** and slide the mouse to the left until the two vertical pieces of M1 are aligned as shown in Figure 56 ***below***.

Figure 56: Using the "Edit Wire" command to fix DRC Errors



You should now only have 5 DRC errors left. Look at the DRC status box at the lower left corner of the MAX window.

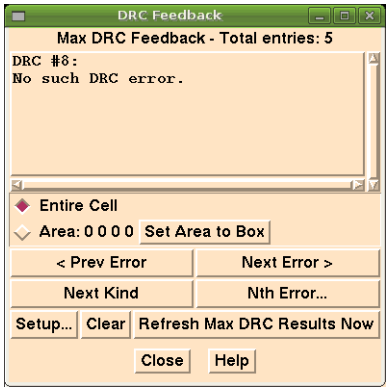
DRC Feedback Window

We'll now look at a third way to step through you DRC errors using the **DRC Feedback** window.

Step 1

- Go to the **Misc** menu and select **DRC Results** or type the **Ctrl-y** hotkey. A pop-up like Figure 57 will open.

Figure 57: DRC Feedback pop-up



The **DRC info** section of the pop-up may say:

```
DRC #8:
No such DRC error.
```

Remember we just fixed **`DRC error #8`**, so it doesn't exist any more. The **DRC Feedback** window comes up showing the most recent DRC error you were viewing.

Step 2

- Click on the **Next Error** button to step through each of the 5 remaining DRC errors and fix them as we did earlier.

  Close the **DRC Feedback** window.

Viewing Calibre® DRC Errors

MAX does not check all DRC rules; for example, antenna rules or wide metal rules. To check for these errors, you need to use an external DRC checking tool. MAX includes an interface to Mentor Graphics' Calibre® tool.

For this tutorial we assume you don't have the Calibre® interface available, so we've already run Calibre® on this cell.

Step 1

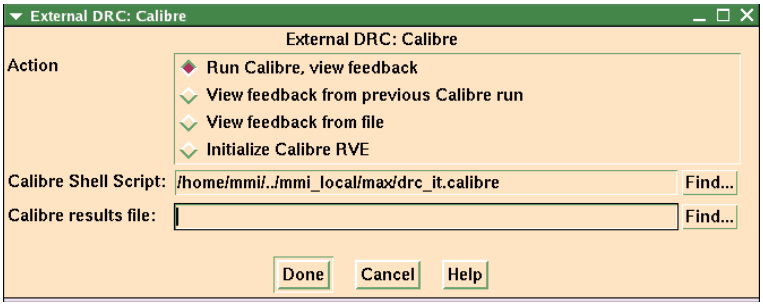
- Since Calibre® was run on the cell with all 7 of the DRC errors, we need to first get back to the original cell. Either type the **undo** command (hotkey: **u**) multiple times to step back through all 5 DRC errors, or go to the **File** menu and select **Revert to Last Saved.**

  Click on **Yes** when asked:
  "`Really throw away changes to cell 'drc_test'?`"

Step 2

- Now go to the **Tool** menu and select "**Calibre DRC...**" to open a form like Figure 58.

Figure 58: Calibre DRC... Pop-up Menu



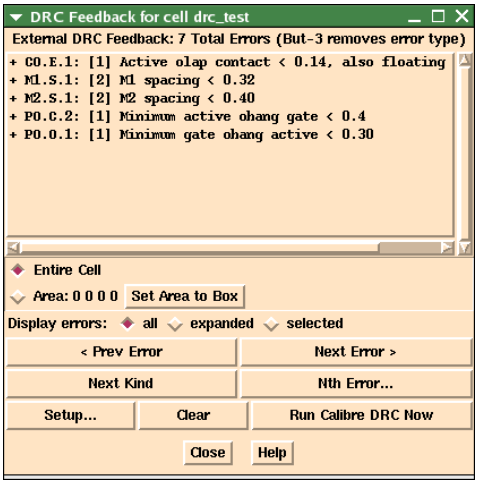
If the Calibre® interface ***is*** set up at your site, you can run Calibre® directly from MAX and then view the results. For this example, Calibre® has already been run.

Step 3

- Select **View feedback from file** and then click on **Done**.You should now see a pop-up form like Figure 59.
- By default, MAX looks in the same directory as your cell to find the Calibre® results file. If it is named **`<cell_name>.drc_maskdb`**, then it will be found automatically. Otherwise, you can specify the file using the **Find...** button.

> **Caution** If you forget to select **`View feedback from file`**, the Calibre® output file could get overwritten. If that happens, you can click on the **Find** button and specify the Calibre® results file as: **`drc_test.drc_maskdb.save`**.

Figure 59: Viewing Calibre Feedback Pop-up Form

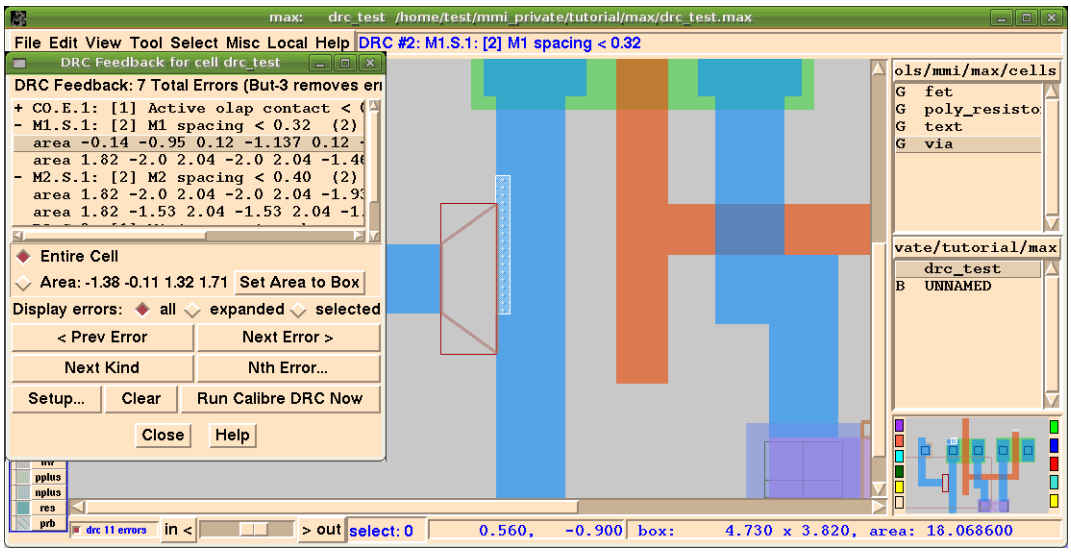


The form lists each of the DRC errors reported by Calibre®. Clicking on the error types expands or collapses that error type.

Step 4

- Click on **Next Error**. The MAX window should now look similiar to Figure 60, with the DRC error polygons showing brown.

Figure 60: DRC Pop-up Showing Error Listed, and MAX Window Zoomed In on Error



MAX automatically zooms you in on the first DRC error. You can also click on a specific DRC error in the list and MAX will zoom to that error location. In the above example, error #2 has been selected.

Refer to the *MAX User Manual* for more information on the Calibre® DRC interface.

Changing Color of DRC Errors

If you don't like the color used to display the location of DRC errors, you can always change it in the **Color Editor**.

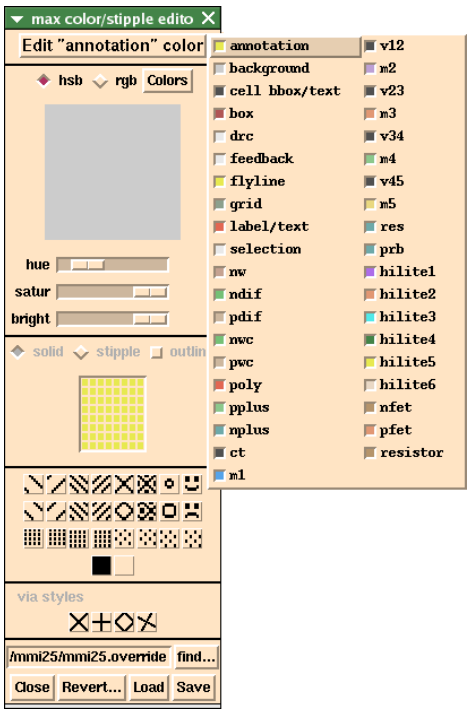
Step 5

- Go to the **File** menu and select **User Preferences** and then **Color Editor...**
- At the top of the editor panel, click and hold down the button displaying **Edit layer "nw"** and then select **annotation** from the list, as shown in Figure 61.
- Hold down the **Colors** button and select **yellow**, the last color in the list.

Step 6

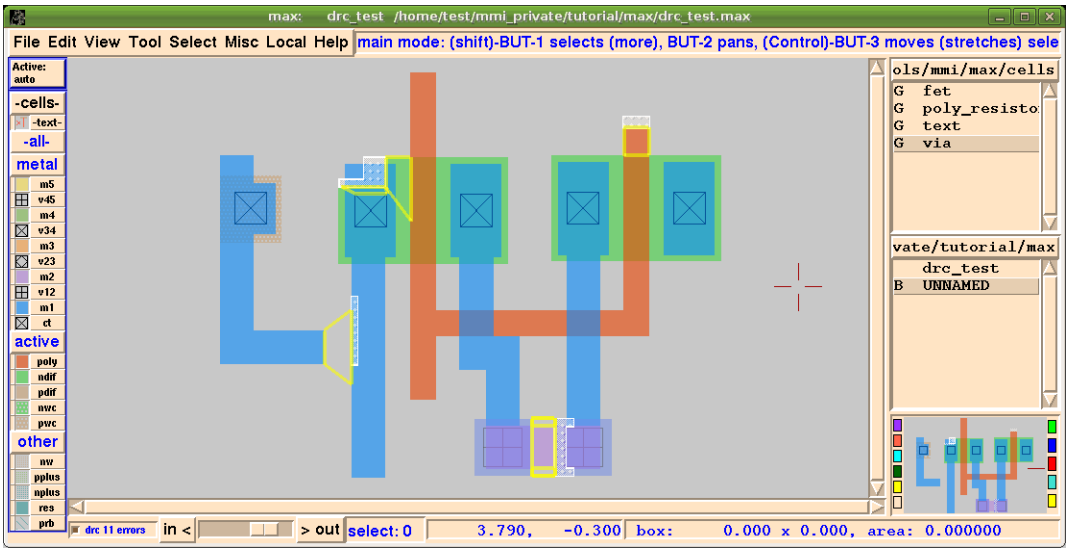
- Click on **Close** in the **Color Editor**.

Figure 61: Color Editor Showing “annotation” Layer Changed to Yellow.



- You should now see a display similiar to Figure 62. Notice that the DRC error polygons are now yellow.

Figure 62: DRC Error Color Changed to Yellow



In this fashion, you can customize the MAX display colors as desired, and see the changes instantly.

Now we’ll go on to try something really fun.

Viewing Layout in 3D

Yes, it's true! MAX and MAX-LS provide a symbolic three-dimensional view of your layout, generated real-time, on the fly. While there is no true commercial use for a three-dimensional view yet, it can be quite informative to see how layers of a chip actually interact.

Please keep in mind that this is a symbolic or representational 3D view, not an actual one, and meant more for informative purposes.

In MAX and MAX-LS, Z-axis dimensions are estimated and can be specified in your tech file if needed. Distances between layers are also estimated in the 3D view. Refer to the *MAX User Manual* for information about setting z-axis dimensions and coordinates.

The 3D view is not as fast as the standard layout view. Smaller cells work best and are easiest to see, so we'll be selecting one of the smaller cells from the **Cell List Box**.

VIEWING IN 3D

If you have exited MAX and do not still have **TOP_CHIP** loaded, you first need to load it.

Step 1 Go to **File** > **Import File**.

- Select **Load GDS File using current mmi25 max technology file**.
- Click on **Find...** and select **TOP_CHIP.gds**, then click on **Done**.

First we'll put the cells in alphabetical order to make it easier to find cells.

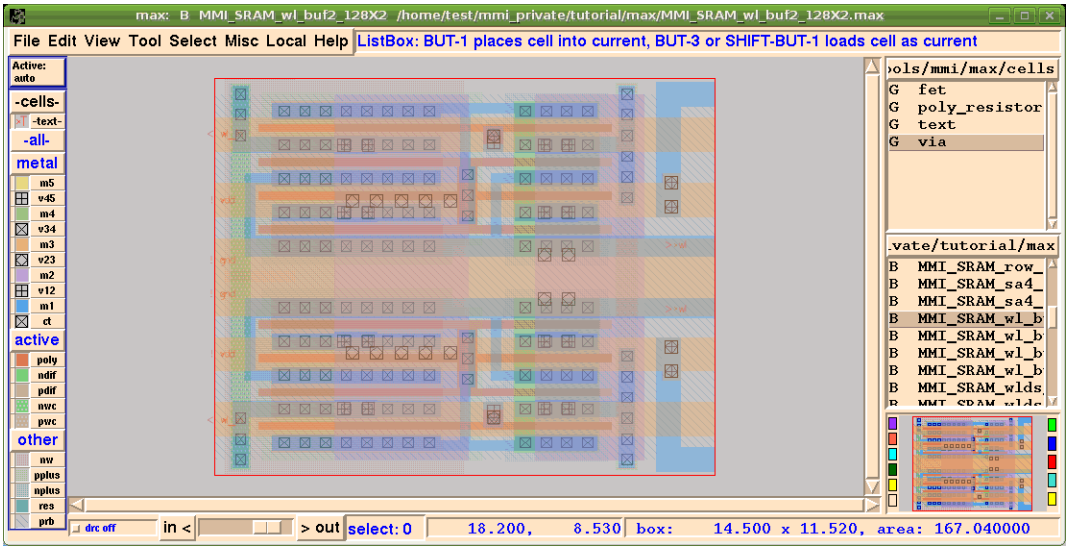
Step 2
- Hold down the title bar at the top of the cell list (in the illustration below, it says "**/home/test/mmi_private/tutorial/max/Samples**") and select **Alphabetize** from the menu options.

Step 3
- Click on "**MMI_SRAM_wl_buf2_128x2.max**" with the **RIGHT** (**Button-3**) **mouse button**. It's the first **MMI_SRAM_wl...** , shown highlighted in Figure 63, below.

  You should see this cell (notice that the cell name is displayed along the top):

Step 4
- If you can't see the internals of the cells, type the hotkey **i** (**View Internals**).

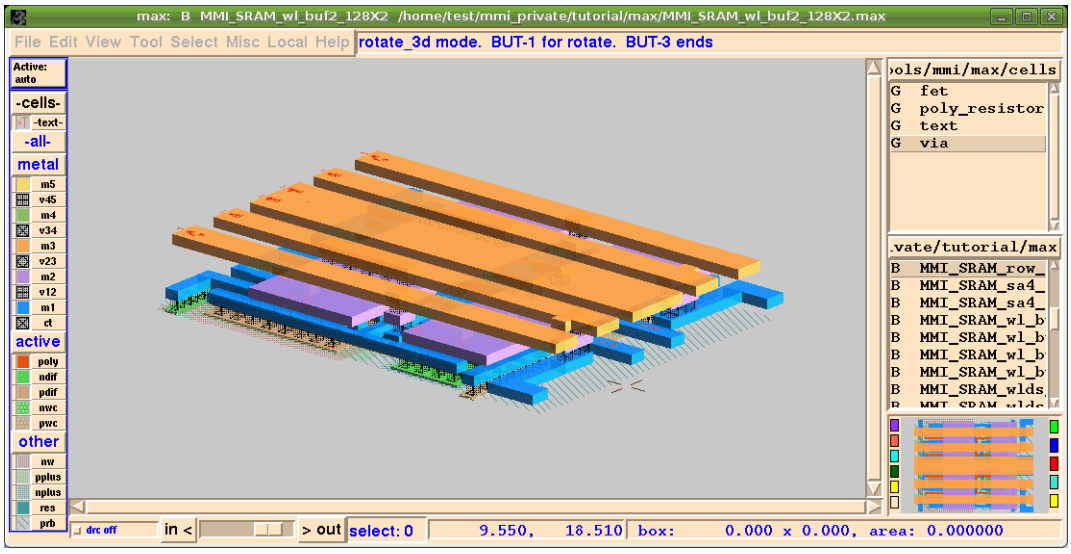
Figure 63: MMI_SRAM_wl_buf2_128x2.max



Step 5

- Now, from the **View** menu, click on **Display 3D View**, or use the hotkey **Alt-z**. The cell display immediately changes to a standard orthogonal 3-D view, as shown in Figure 64
- From here, you will be able to rotate and zoom in/out of the view using the mouse buttons. The button functions are described in the **MAX Message Area.**

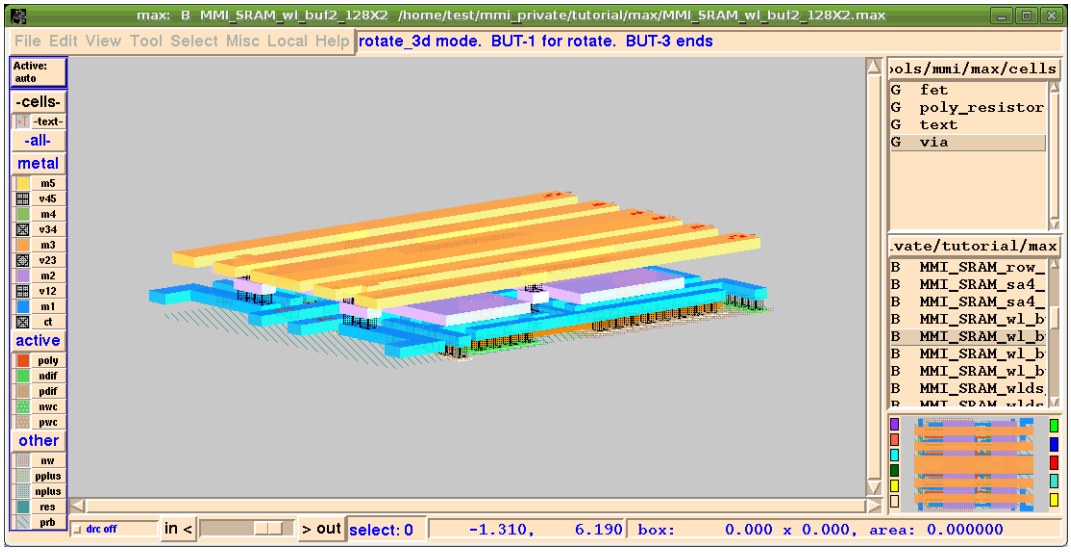
Figure 64: 3D View of MMI_SRAM_wl_buf2_128x2.



Step 6

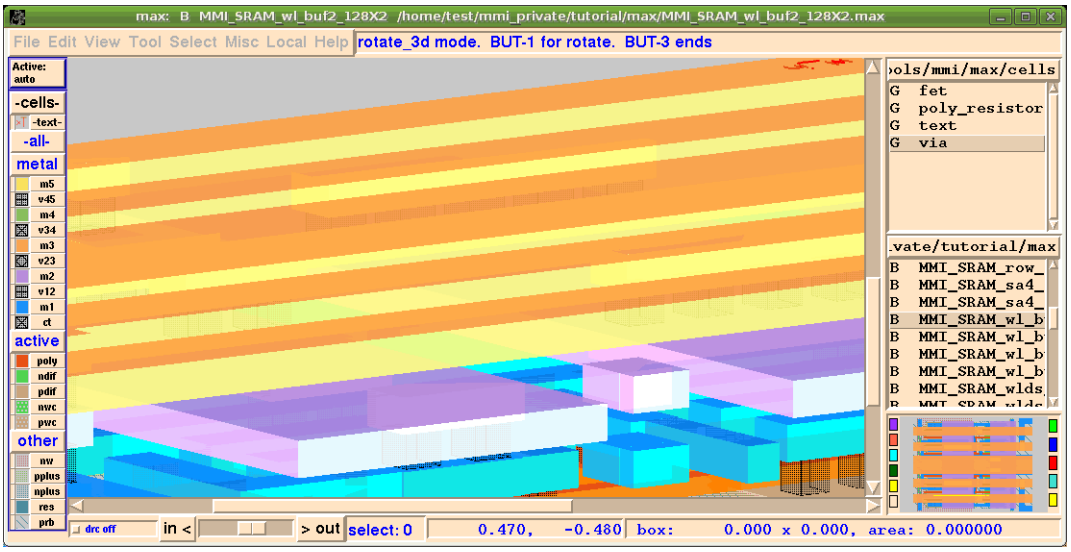
- Rotate the view using **Button-1**. Press and hold down **Button-1** and drag around the window to see the view rotate, as demonstrated in Figure 65.

Figure 65: Rotated 3D View of the Cell



- Zoom into or out of the view using the scroll-wheel or zoom keys.

Figure 66: Zoomed In on 3D View



- Pressing the hotkey **v** will re-center the view in the window.

As MAX supports true transparency, layers underneath show slightly through the ones on top. Transparency values can be set in the **Display Options** section of the **User Preferences** menu.

NOTE: Editing is not possible during the 3D viewing mode. You must revert to 2D to continue editing your cells.

RETURN TO STANDARD VIEW

Step 7

- Clicking **Button-3** will restore the original layout view (2-D).

  Remember that the **Message Area** displays the mouse button functions available during 3D View.

By now you should have a good grasp of MAX's potential. In the next section, we will start creating layout.

Part 3 MAX-LS

In this chapter we will start creating layout using the **layout generator** which is part of MAX-LS. A separate license is required to run MAX-LS. If you do not have a MAX-LS license, skip to Part 4, **Simple Layout** (page 81) where you will create a NAND gate manually.

MAX-LS Features

MAX-LS includes all of the standard MAX features, as well as the following additional ones:

- Auto-layout Generation of SUE schematics in MAX.
- Interactive Cross-probing between SUE and MAX.
- SUE base version is required for MAX-LS

One reason for the power of MAX-LS is that both MAX and SUE have complete Tcl/Tk interfaces. This means that you can write and execute full Tcl programs in either tool. Tcl also provides a means for inter-program communication.

SUE and MAX use the notion of "send" commands to talk to each other. Cross-probing is one example of this inter-program communication. Automatic layout generation and fly-lines are also features gained by using both SUE and MAX.

We are going to use MAX-LS for this next example. Don't worry if you haven't used SUE before. SUE and MAX are both part of the Micro Magic, Inc. chip design suite, so they have similar interfaces. You can also launch the SUE tutorial if you wish to learn more about SUE.

Automatic Layout Generation and Fly-lines

To see how SUE and MAX can work together we are going to bring up a simple NAND gate in SUE.

LAUNCHING SUE

Step 1

- First, if you haven't already done so, save your previous work in MAX and then quit out of MAX using **Exit** from the **File** menu.

Step 2

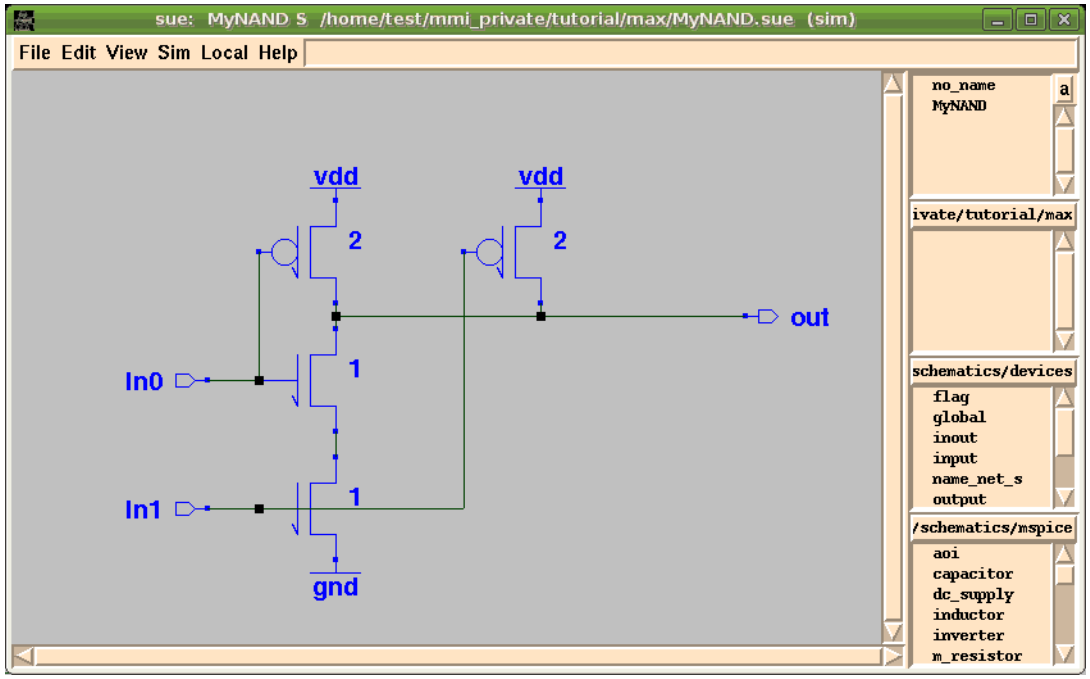
- Now bring up SUE by typing

```
sue MyNAND
```

This will launch SUE and automatically load in the **`MyNAND.sue`** circuit.

Your SUE window should look like Figure 67.

Figure 67: SUE Schematic For "MyNAND"



NETLISTING AND CROSSPROBING

Step 3

- Go to the **Sim** menu and select **sim netlist**. It's the top choice.

If the top choice is set to something else, like **spice netlist**, then select **Change Simulation Mode** from the **Sim** menu and click on the **Sim** box when the **Change Simulation Mode** dialog box comes up.

The layout generator uses the Sim netlist for placing the devices and showing connectivity.

Step 4

- Now from the **Sim** menu select **MAX Cross Probe Init.**

The **Cross Probe** pop-up menu will appear.

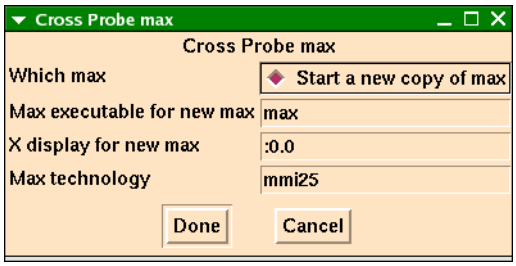
Step 5

- If you have other copies of MAX open (in our example, there is no MAX running), be sure and select **Start a New Copy of MAX**.

Step 6

- For **MAX Technology**, fill in ***mmi25***, as shown in Figure 68. Then click **Done.**

Figure 68: Cross Probe Menu.



This will launch a new Xterm window, and start up MAX from that window.

GENERATING LAYOUT

Step 7

- You'll see a message saying there is no existing MAX layout for **`MyNAND`**. Click on **new** to generate a new cell.

Step 8

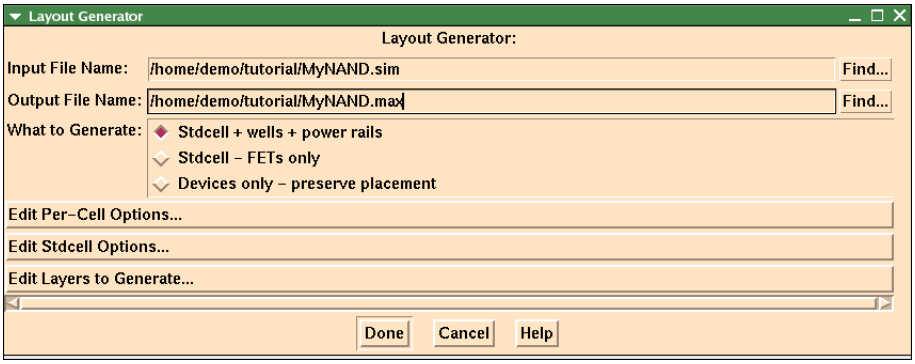
- Now go to the **Tool** menu in MAX and select **Layout Generator.**

Step 9

- When the Layout Generator popup appears, click on the **Find...** button to the right of the **Input File Name** field, select **`MyNAND.sim`** from the **Cell List**, and click on **OK**.

The **Layout Generator** popup window should now look like Figure 69.

Figure 69: Layout Generator Pop-up



This window has several options.

- **What to Generate:**

  Stdcell + wells + power rails is shorthand for "give me all of the wells, well contacts, power straps, etc. needed to make a standard cell-like layout".

  Stdcell - FETs only is a shorthand for "just give me the devices with flylines". It still shares src/drn regions and places the routing pads.

  Devices only - preserve placement is a shorthand for "place the devices matching relative placement from the schematic with flylines".

- If you click on the **Edit Per-Cell Options** button you have various options such as using gcells or paint for fets, enabling flylines, and automatically folding fets larger than a specified size.

  The default is to **share_contacts**, so the **Layout Generator** will automatically share contacts and diffusions for you.

- The **Edit Stdcell Options** box gives you several options for producing standard cell-like layout.

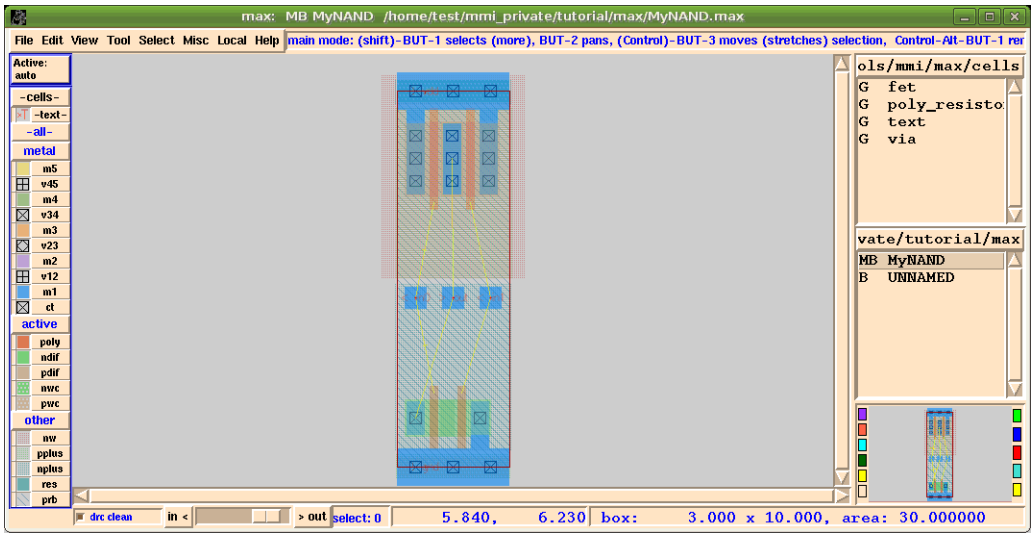
Step 10

- Click on **Edit Per-Cell Options**. To find out what each of the options does, click on the **Help** button. When you are done looking, **Close** the **Help** and **Cancel** the **Edit Per-Cell Options**.

Step 11

- Once you are finished reviewing the many options the **Layout Generator** has, simply click **Done** and the layout for **MyNAND** will be generated for you automatically. It should look like Figure 70.

Figure 70: Layout Generator Result



Notice that the devices have already been placed and sized correctly. Where possible, the **Layout Generator** has even shared contacts and diffusions for you. Also, notice there are fly-lines connecting the various nodes together. These fly-lines tell you how to wire things up correctly — so let's do it.

To begin, let's wire up the left-most poly gates.

Wiring up Gates

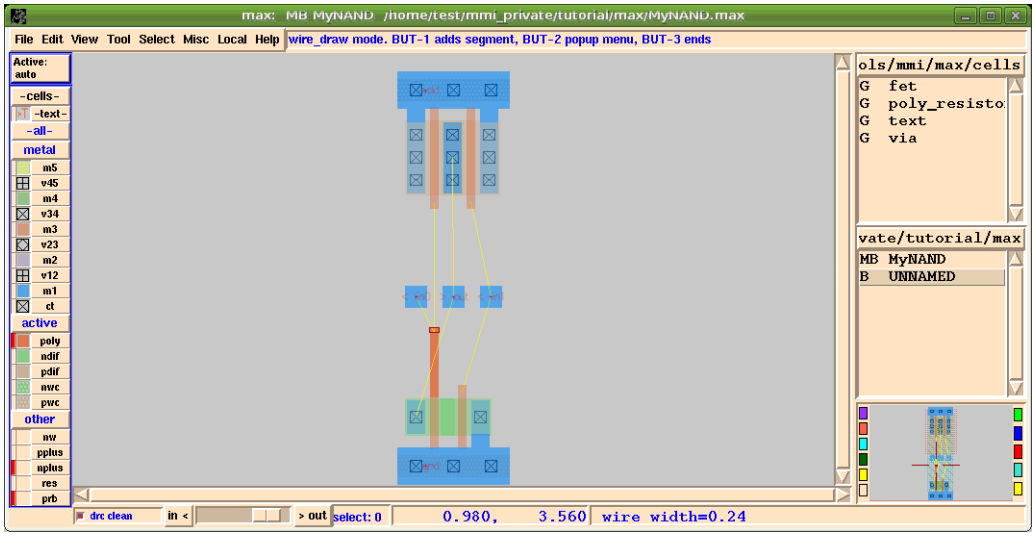
Step 1

- First, ***turn off the visibility*** of the other layers by clicking on **other** in the **Palette** with **Button-1 (left mouse button)**. This will make the layout less cluttered.

Step 2

- To draw the wire, simply hit the **w** hotkey or select **Add Wire** from the **Edit** menu to get into **wire mode**, then click the **LEFT (Button-1)** mouse button over the lower left poly gate and drag the mouse upwards, as shown in Figure 71.

Figure 71: Drawing a Wire

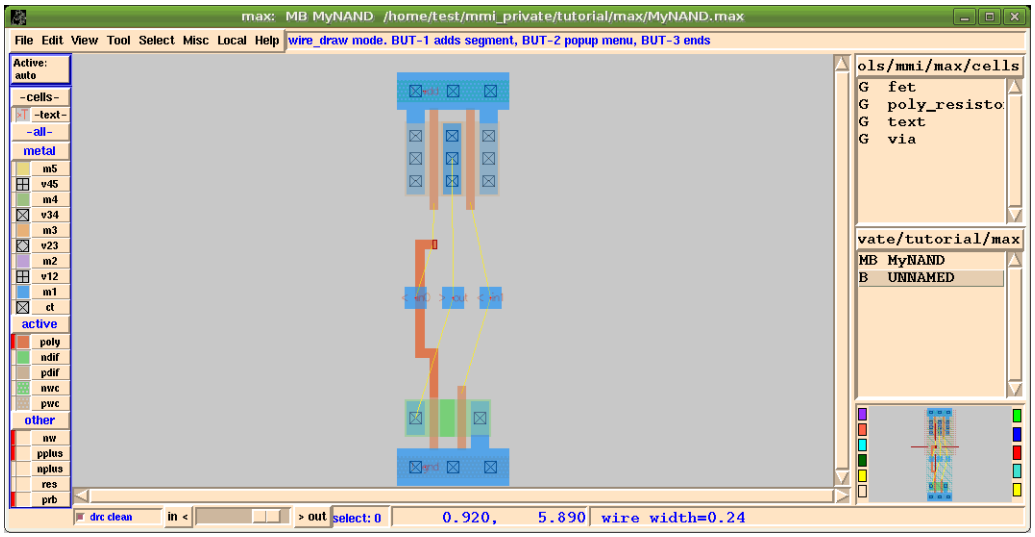


Notice that the fly-line tracked as you drew the wire. This feature makes it easy to hook up cells correctly. All you need to do is follow the fly-lines!

Step 3

- To add corners, click with **Button-1**. Add corners to the wire so that the poly wire goes under the **<in0>** routing pad and then back over to line up with the upper gate as shown in Figure 72.

Figure 72: Drawing a Wire: Wire Follows Cursor



You can undo whatever you have just done in MAX. Use the **u** hotkey or select **Undo** from the **Edit** menu. You can also **Redo** what you have just undone using the **Shift-u** hotkey. There are 99 levels of undo in MAX. If you can remember back more than 99 items please call us, we would love to meet you!

While in wire mode, the **u** hotkey will undo the previous corner, via, etc. Typing **Ctrl-C** while in wire mode *cancels* the current wire.

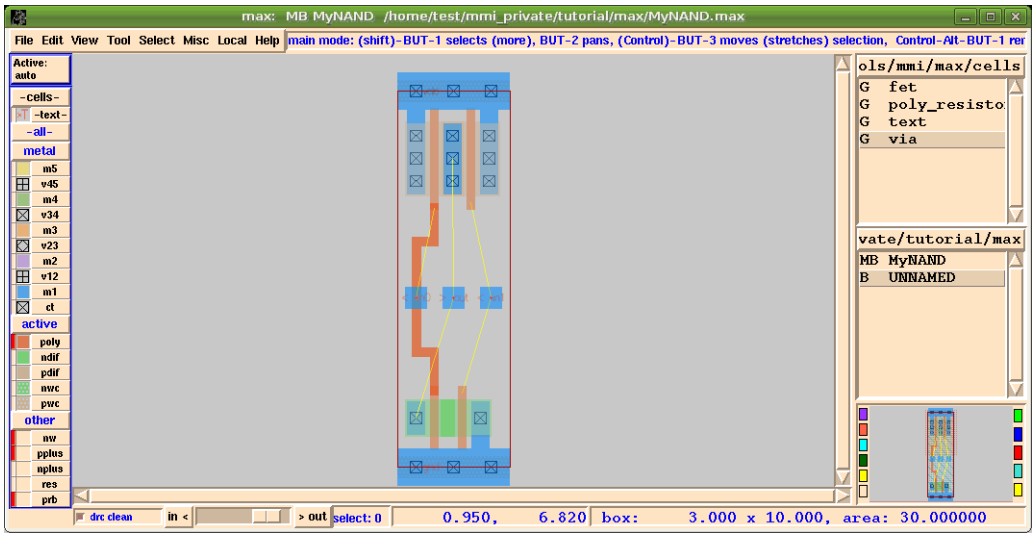
Step 4

- End the wire by clicking with the **right mouse button** (**Button-3**) over the poly gate upper left fet.

  When you click with **Button-3**, you don't have to be exactly over the middle of the gate. MAX automatically snaps the wire to the gate. You should now see something like Figure 73.

- Note that there is still a flyline between the upper gate and the routing pad. This tells you that the net is not connected to the routing pad.

Figure 73: Ending Wire Using Right Mouse Button



ADDING VIAS

To complete this connection, you will need to add a via between the **m1** routing pad and the poly wire.

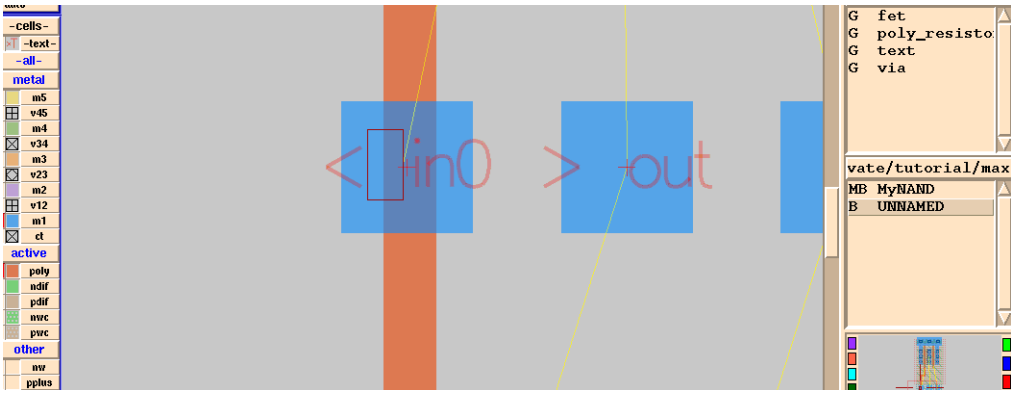
Step 5

- To make it easier to see, you may want to zoom in on the routing pad as shown in Figure 74.

Step 6

- To add a via, type the **w** hotkey and click with **Button-1** on the **m1** routing pad. The wire starts in the top routing layer under the cursor, in this case m1.

Figure 74: Adding a Via Between Routing Pad and Poly Wire

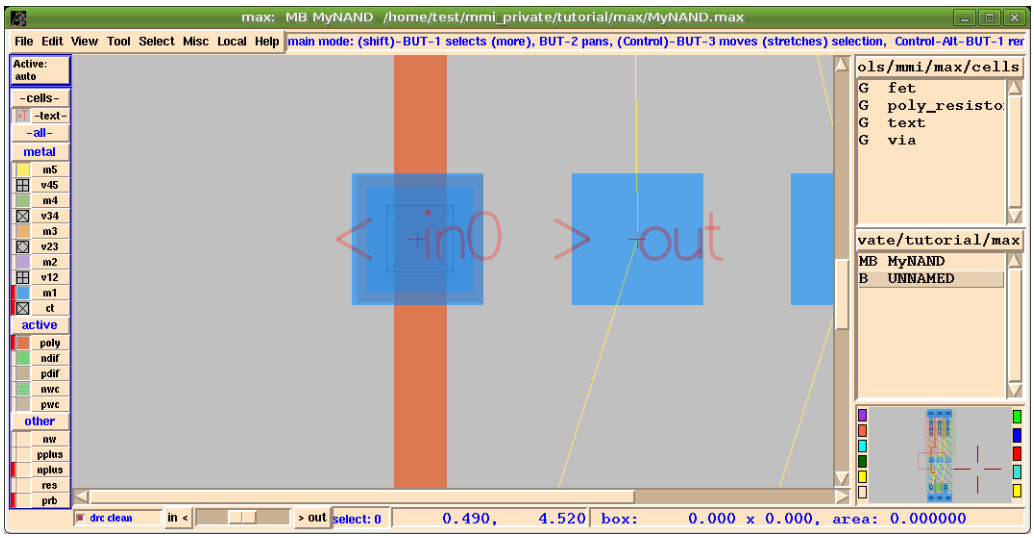


To add a via down to poly, use the **Shift-d** hotkey.

Then, end the wire at the same location by clicking with the **RIGHT mouse button** (**Button-3**). Your poly net is now connected to the **in0 m1** routing pad. Notice that the flyline has disapperared.

Your layout should now look similiar to Figure 75.

Figure 75: Wiring the Cell



WIRING THE CELL

OK, now let's wire up the rest of the cell.

Step 1

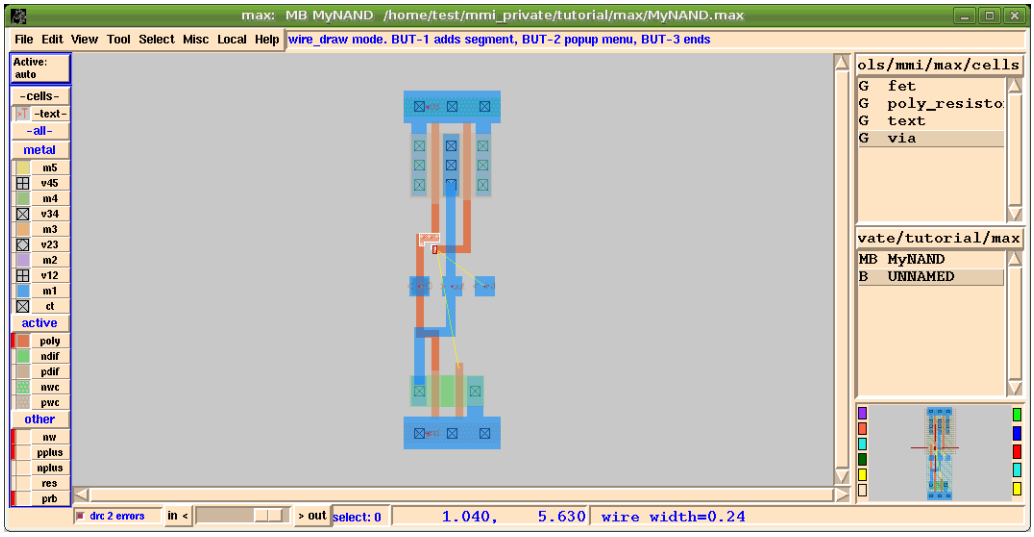
- Wire the two diffusion areas to the **out** router pad using the flyline as a guide. The **w** hotkey starts the wire, clicking with **Button-1** adds corners and clicking with **Button-3** ends the wire.

Step 2

- Now wire the two right gates. Start the wire (**w** hotkey) and add a corner (**Button-1**).

  Notice that if you drag the mouse to the left, you will see white rectangles appearing as shown in Figure 76. This indicates DRC errors. As you wire things up, you want to make sure there are no DRC errors. This example is simple, so there shouldn't be any issues with DRC errors.

Figure 76: DRC Errors appearing while drawing Wire



Step 3

- Finish the wire by adding corners so that the wire goes over the **in1** routing pad.
  End the wire with **Button-3**.
  Add a via between the routing pad and the poly wire.
  Start a wire (**w** hotkey), ***drop a via down*** (**Shift-d** hotkey) and ***end the wire*** (**Button-3**).

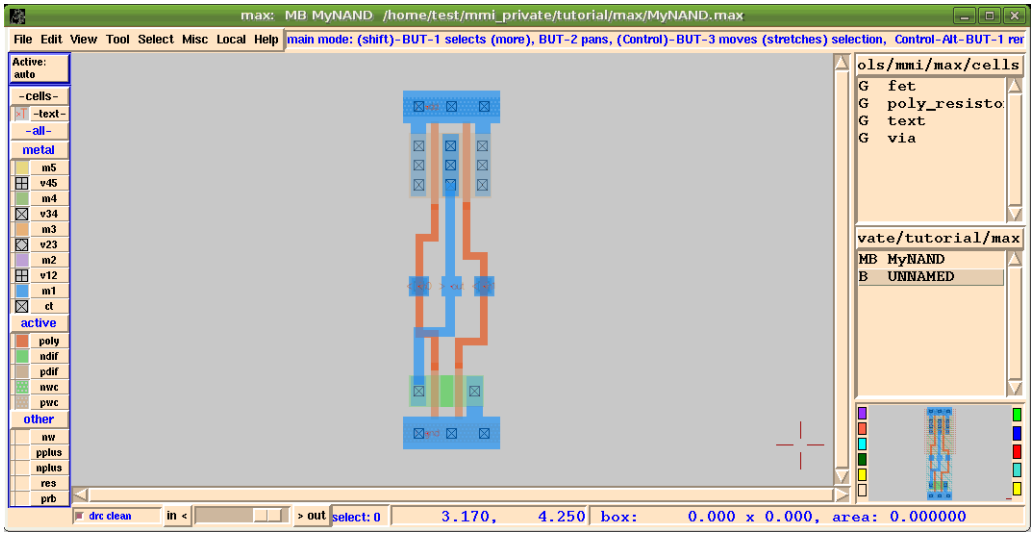
Step 4

- **Add a via** between the routing pad and the poly wire:

If you ever forget any of the wiring tool options, remember the status box next to the **Help** menu will tell you what the buttons do, and you can always hold down the middle mouse button (**Button-2**) to get the **Wire Tool** pop-up menu.

Your circuit should now look something like Figure 77. Make sure there are vias on the two input routing pads connecting them to the poly wire.

Figure 77: Wired "MyNAND" Gate



SAVING EDITS

Step 5

- Save your edits by using **Ctrl-s** or selecting **Save** from the **File** menu.

Cross-Probing with SUE

Ensuring that your circuit is wired up correctly is very important. MAX-LS provides flylines to help you accomplish this. But what if you import some layout from another tool, or create the layout without the flylines and you want to make sure it's correct?

MAX-LS has a powerful feature known as **cross-probing**. This allows you to select a piece of layout and highlight the corresponding object in the schematic, or vice versa. You can initiate cross-probing from either SUE or MAX.

To start the cross-probe from SUE you would select **MAX Cross Probe Init** from the **Sim** menu just as you did to start up MAX.

Cross-Probing: SUE to MAX

This time let's set up cross-probing from the MAX side.

CROSS-PROBING SUE TO MAX

Step 1

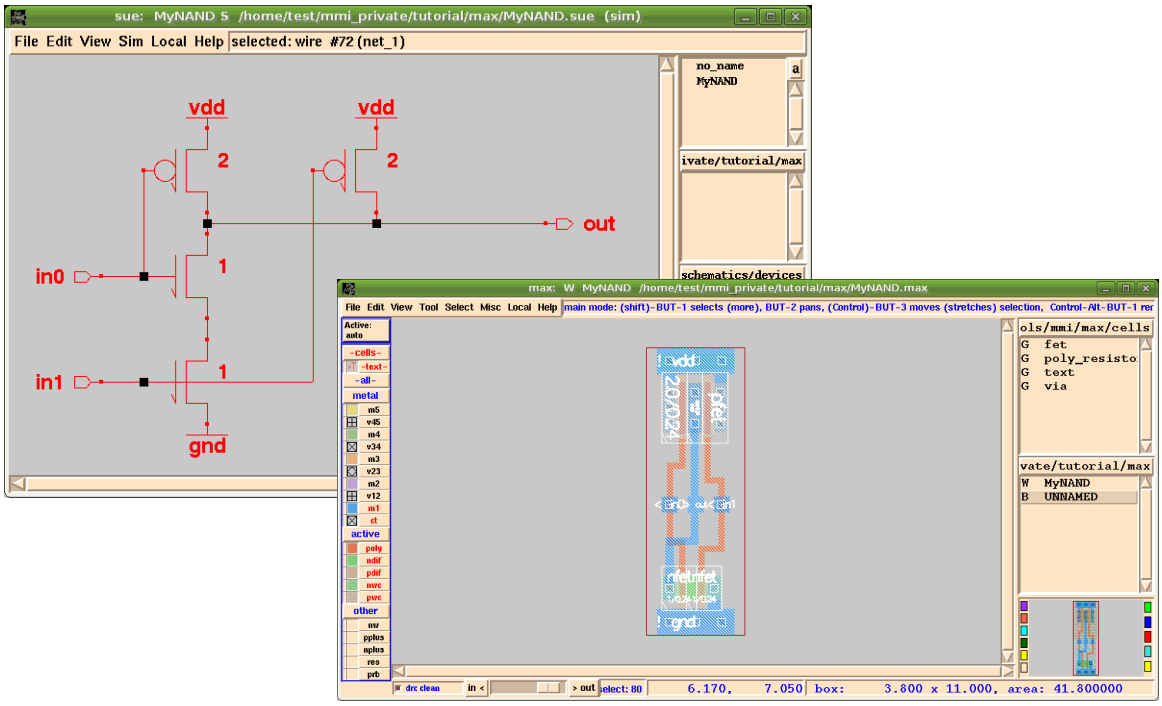
- Select **SUE Cross Probe Init** from the **Tool** menu in MAX.

Step 2

- Assuming you only have one copy of SUE running, select **sue**. Don't start a new copy. Click on **Done**.

Once MAX and SUE are done communicating, SUE will highlight the nets and devices it and MAX agree upon in red, as shown in Figure 78-a. MAX will highlight the same nets and devices in white, as shown in Figure 78-b.

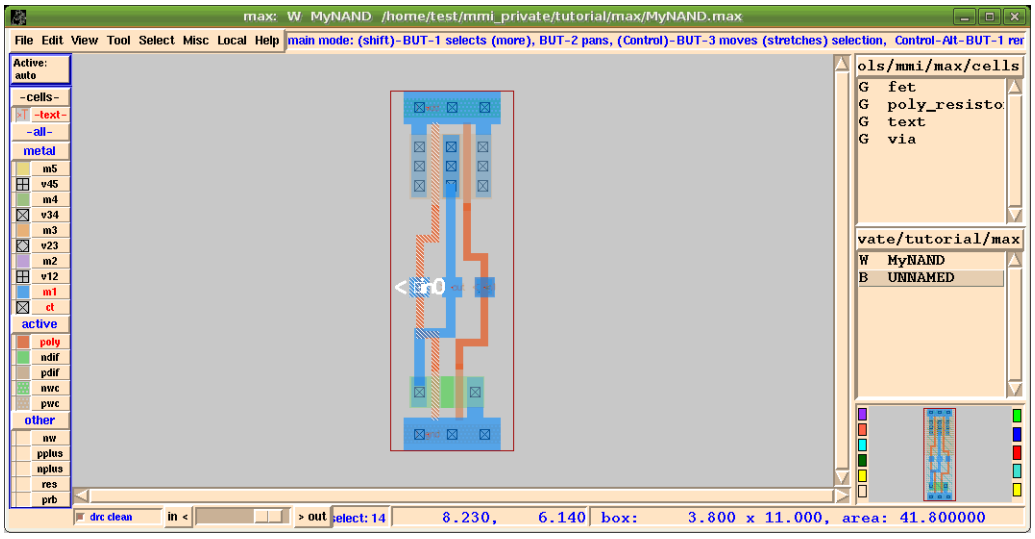
Figure 78: a) Matching Nets in SUE; b) Matching Nets in MAX



Step 3

- Now select the port labeled **`in0`** in the SUE schematic by clicking on it with **Button-1**.
- Then type **k**, or select **MAX Cross Probe** from the **Sim** menu. Notice that the wire labeled **`in0`** on the MAX layout is now highlighted in white! See Figure 79.

Figure 79: Corresponding Net "`in0`" In MAX



Cross-Probing: MAX to SUE

CROSS-PROBING

You can also cross-probe from MAX to SUE.

Step 1

- Select the wire labeled **out** in MAX by clicking on it with **Button-1 (left mouse button)**.

Step 2

- Type **k**, or select **SUE Cross Probe** from the **Tool** menu. Notice that the wire labeled **out** in the SUE schematic is highlighted in red.

This is yet another way SUE and MAX help you keep track of your design.

You can also cross-probe devices between SUE and MAX. If you select a fet in MAX and type **k**, the matching fet in SUE will be highlighted, and vice versa.

Check Connectivity

CHECKING CONNECTIVITY

By default MAX-LS doesn't report if you incorrectly connect nets. You can turn this checking on. If **Check Connectivity** is turned on, the flylines will reappear if a wire is cut.

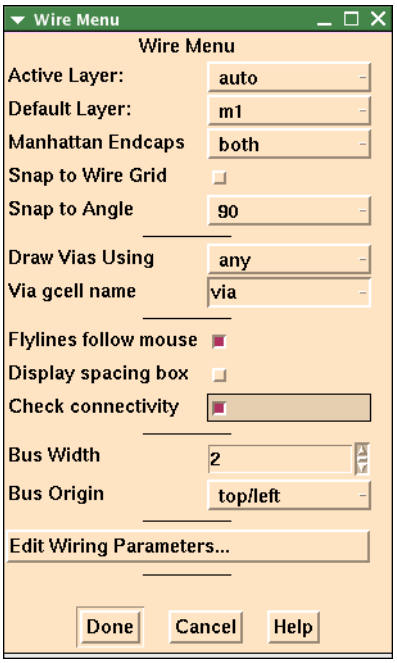
Step 1

- From the **File** menu, select **User Preferences** and then **Wire Setup**.

Step 2

- Click on the **Check connectivity** toggle button and then click on **Done** menu as shown in Figure 80

Figure 80: Check Connectivity Selected in Wire Menu



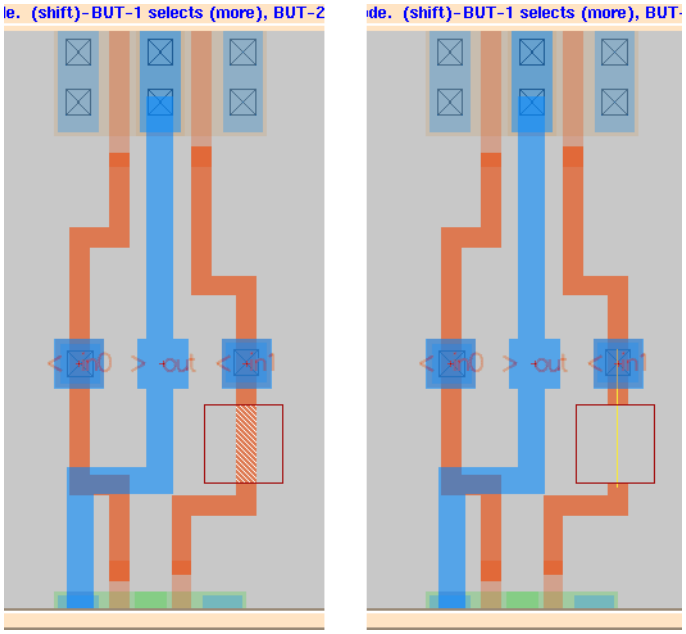
Step 3

- In the layout, drag with **Button-1 (left mouse button)** around part of the right poly wire, as shown in Figure 81-a.

Step 4

- Delete this portion of the poly wire by typing the **q** hotkey, or select **Delete** from the **Edit** menu. Notice that the flyline reappears as shown in Figure 81-b.

Figure 81: Checking Connectivity: a) Select Wire Section; b) Deleted Section Showing Flyline



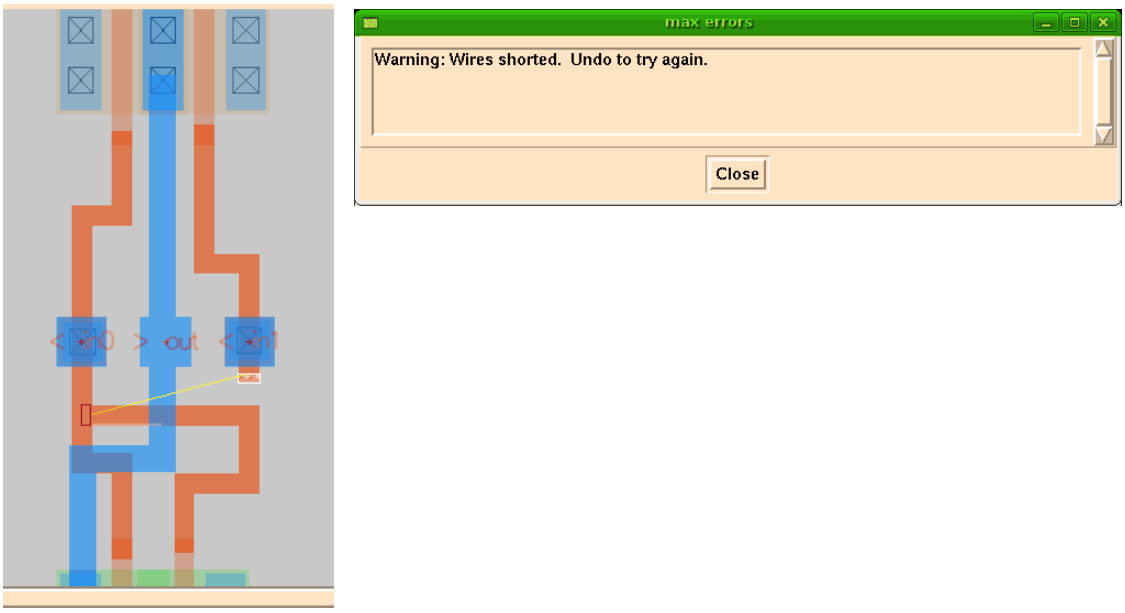
Step 5

- Now connect a wire between the **in1** poly wire and **in0** poly wire as shown in Figure 82. As soon as you click with **Button-3 (right mouse button)** to end the wire on **in0**, a pop-up appears telling you that you are creating a short.

  Notice that when you click on **Close**, MAX lets you create the short but gives you the warning message.

  Type the **undo** hotkey **u** to undo the wire.

Figure 82: Short Created and Error Message



Advanced Features

There are several advanced features found in MAX which are NOT covered in this tutorial.

For example, customization is possible over a wide range, from minor user preferences (controlled by the **`max.rc`** file) to megacell generators. See **MAX Manual** under the **Help** menu for more details.

To Learn More About MAX and SUE

To learn more about MAX go to **MAX Manual** under the **Help** menu, or refer to the Micro Magic, Inc. *MAX User Manual*.

To learn more about SUE, go to the **SUE Tutorial** or **SUE Manual** under **Help** for on-line information, or refer to the Micro Magic, Inc. *SUE Tutorial* and *SUE User Manual* documentation.

For additional documentation on any of the Micro Magic, Inc. chip design suite, use the on-line reference **MMI Documentation Guide** under the **Help** menu.

Part 4 Simple Layout

OK, let's get started on some layout. If you completed the previous part using MAX-LS, some of that information will be repeated in this part of the tutorial.

For this section, we will be using the ***mmi18*** technology.

Step 1

- If you still have MAX running, exit MAX (**ctrl-d**). Start MAX with the command:

```
max -tech mmi18
```

Step 2

- To find out what technology you are using, go to the **Help** menu and select **About MAX...** It should say that the technology is **`mmi18`**.

Step 3

- Go to the **File** menu and select **New...** This will bring up the **File Select** box.

Step 4

- Type in the cell name ***foo*** where it says **Filename:**. Then click **OK**, or hit **Return**.

The **UNNAMED** at the top of your MAX window should now say **foo**. This means that you are now editing the cell **`foo`**. When you save it out it will be saved as **`foo.max`**.

The top of your MAX window also has the path to your cell foo.max. In this example, the path is: "**`/home/test/mmi_private/tutorial/max/foo.max`**."

Also, notice that **`foo`** now appears in the **Cell List Box** on the right side of the MAX window. The '**`B`**' to the left of **`foo`** means that this cell only exists in memory (**B**uffer) and has never been saved.

— Other letters you will find to the left of cell names are:
"**`G`**" shows it is a **G**cell (explained later) or generator cell;
"**`M`**", indicating the cell has been **M**odified; and
"**`W`**" meaning the cell has been **W**ritten, or saved.

Using Gcells

While MAX can do very low level full custom layout, it also has a complete Tcl/Tk interpreter built in. Tcl is a language developed by John K. Ousterhout at UC Berkeley. Tk is the windowing tool kit. Books on both can be found at your local bookstore. The Tcl/Tk interface in MAX allows full access to MAX layout functionality, providing unprecedented power and flexibility.

A **gcell** is a ***cell generator*** written in the Tcl/Tk language. The gcell generates layout for a cell automatically from "properties" that you specify using a simple menu interface. MAX comes with gcells to generate FETs, Vias, Text, and a poly_resistor.

GCell Properties

Step 1

- Go to the **List Box** down the right side and select **`fet`** from the list by clicking on it with **Button-1**. The **`G`** next to the fet indicates that this cell is a **`gcell`**, or ***generator***.

- When you click the **left mouse button** (**Button-1**) on fet in the List Box, the fet generator window will pop up. It should look something like Figure 83.

If you do not see **`fet`** in the List box, click and hold the **left mouse button (Button-1)** over the List box header to display the directory list, then select the directory ending in **`cells`**. This is the directory that contains the **`fet`** and **`via`** gcells provided with the Micro Magic, Inc. software.

Figure 83: FET Gcell

Step 2

- Now, change the **`width`** to *2.0*. This will make the nfet 2.0µm wide.

Step 3

- Since we eventually want to use this device to make a 2 input NAND gate, change **`fingers`** to *2*, and **`contacts`** to *both*.

Contacts allows you to put contacts on the left side, the right side, both sides, between the devices (all), or no contacts at all.

(Click on **Help** or refer to the Micro Magic, Inc. *MAX User Manual* for more details.)

If you click the **left mouse button** (**Button-1**) on the word **both** it will change to the next option. Clicking the **left mouse button** (**Button-1**) on the little bar to the right of this option will bring up all of the possible options.

Step 4

- Now click **Done**.

Two nfets merged (stacked) together should appear, with the corsor attached to the lower left corner.

Step 5

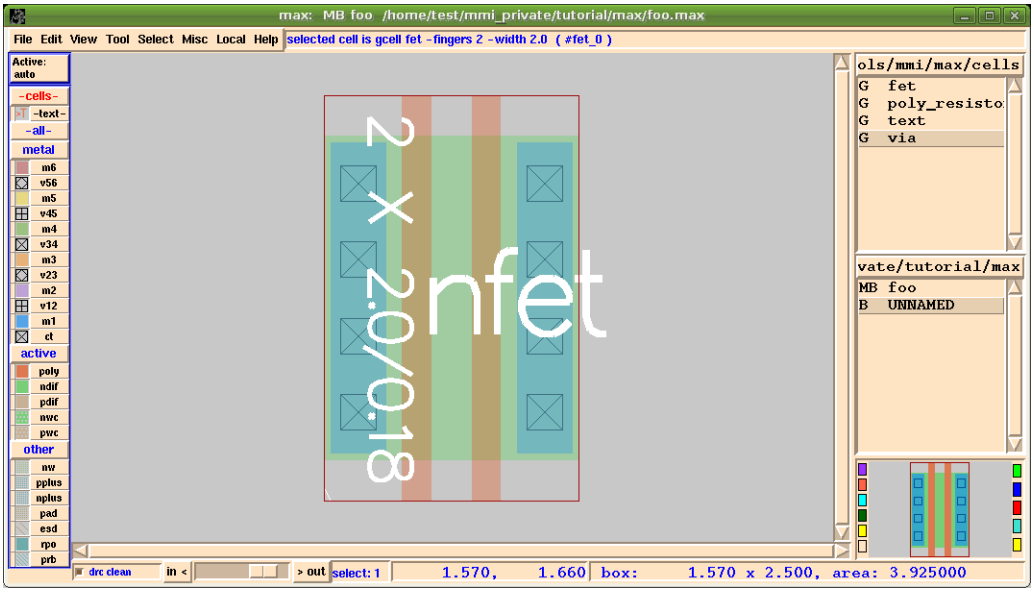
- Click **Button-1** to place the nfets in the window.

Step 6

- Type **v** (the hotkey for **Zoom To Fit Edit Cell** under the **View** menu) and the layout will be centered in the window.

Your screen should now look like Figure 84.

Figure 84: Generated nfet Gcell



The white text on the cell informs you that you are editing an nfet, and that it is 2 gates x 2 microns wide, at a .18 micron channel length.

Notice that the letter **M** appears to the left of **foo** in the Cell List Box. This tells you that **foo** has been ***Modified***.

Step 7

- Zoom out by typing **Shift-z**, or use **Zoom Out** in the **View** menu, or use the **scroll wheel** on your mouse (if you have one). You can also use the *Zoom Bar* at the bottom just below the scroll bars.

You can undo whatever you have just done in MAX. Use the **u** hotkey or select **Undo** from the **Edit** menu. You can also **Redo** what you have just undone using the **Shift-u** hotkey. There are 99 levels of undo in MAX. If you can remember back more than 99 items please call us, we would love to meet you!

Selecting and Moving Layout

There are two types of layout you can select and move in MAX: **objects** and **rectangles**.

Objects may be *sub-cells* (cells), *generated cells* (gcells) or *polygons*.

Rectangles are basically *flat layout*.

Be aware that rectangles may sometimes be refered to as **paint** in the MAX documentation. To create a rectangle, you draw out a box and fill it with "paint" of a certain layer.

There are many methods for selecting objects and rectangles.

- When MAX is in main mode (the default mode), if you simply drag out a region while holding down the **left mouse button** (**Button-1**), whatever is within that box will be selected when you release the button and will be highlighted in white.

  For ***rectangles***, only the portion of the rectangle that is enclosed by the box is selected.

  For ***objects*** (cells, gcells, or polygons), if any portion of the object in enclosed by the box, the object is selected.

Selecting Layout

Step 1

- Drag a box over the stacked nfets we just drew. When you release the mouse button, whatever is "selected", in this case the fet gcell, will be highlighted.

Manipulating Layout

Once you have selected an object or rectangle, you can do lots of things with it.

Step 2

- For example, you can ***rotate clockwise*** it by typing the **r** hotkey. The **R** (**shift-r**) hotkey will ***rotate counter-clockwise***. Try it.

Step 3

- Type **r** three more times to rotate the object back to its original position.

Step 4

- You can ***move*** layout up/down/left/right one grid at a time by using the arrow keys.

Step 5

- You can also ***move*** any layout by first selecting it, then clicking and holding down the right mouse button (**Button-3**) and dragging it around the screen.

MAX also supports **Cut**, **Copy**, and **Paste** in the same format you would see on any good Mac- or PC-based drawing or painting program

.

All of the zoom, move, cut and paste, rotate, etc. commands that are specified using hotkeys also have menu equivalents which can be found in the **Edit**, **View**, and **Select** menus.

Duplicating gcells

We now wish to create a couple of pfets. We could go back to the List box and select the fet generator again, but there is another way.

Select and Duplicate GCell

Step 1

- Simply select your nfet by either clicking the **left mouse button** (**Button-1**) over it, or by dragging a selection box around it using **Button-1**.

Step 2

- Now select **Duplicate** from the **Edit** menu, or type **d.** This creates a duplicate of the selected objects (or rectangles) slightly offset from the original.

Step 3

- Hold down the **right mouse button** (**Button-3**) and move the new nfet above the existing nfet.
- If you hold down the **Shift** key and the **right mouse button**, the move will align to the existing fet as you move horizontally or vertically.

Notice that when you selected the fet and held down the right mouse button (**Button-3**) the cursor changed to a **hand**. This change in the cursor tells you that you are in a mode other than ***main mode***. In this case you are in ***move mode***. Remember to look up at the message area to see what the function of the mouse buttons are in the current mode.

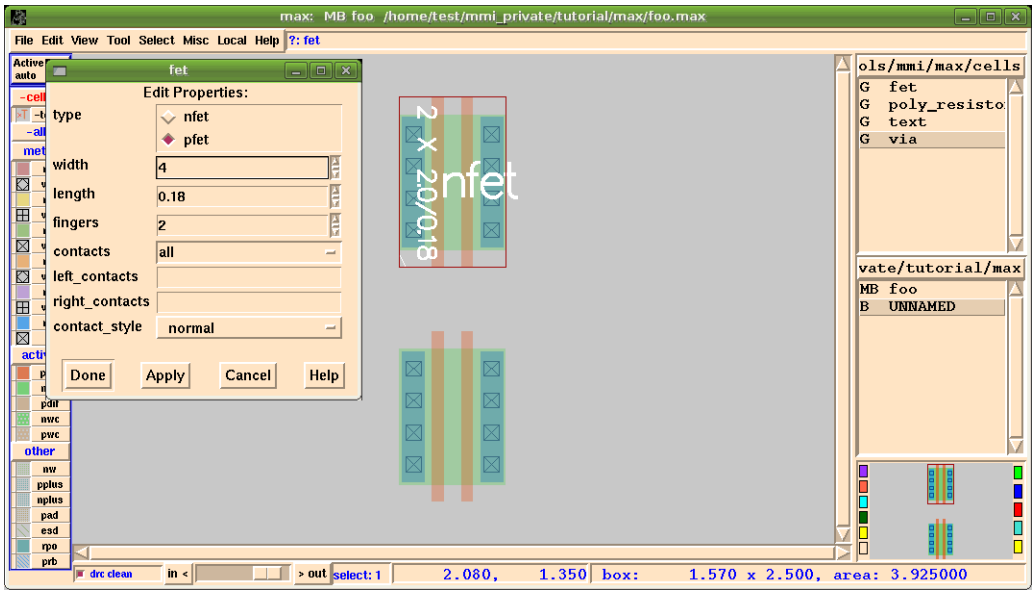
Edit GCell Properties

Now you will begin to see the true power of gcells.

Step 4

- Select the top nfets and then type **e**, or select **Push Into Cell** from the **View** menu. The pop-up menu shown in Figure 85 appears.

Figure 85: Edit Properties Form For fet Gcell



Step 5

- Click on **pfet** to change it to a **pfet**.

Step 6

- Change the **width** to **4**, to make the pfet 4µm wide.

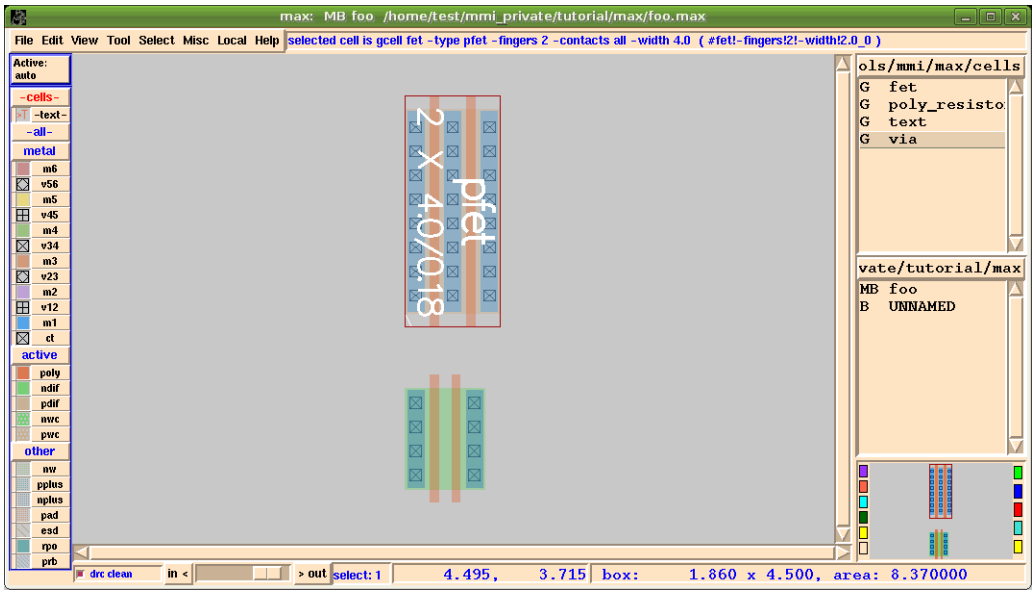
Step 7

- Change **contacts** to **all** by either clicking several times on the box next to the word **contacts**, or hold down **Button-1** on the little bar on the right side of the box next to **contacts** and then select "***all***".

Step 8

- Once you are finished click **Button-1** on **Done** to invoke the generator. This will change the old nfets to magically become new 4µm wide pfets with contacts in the middle and on both sides. **Zoom to fit** (hotkey: **v**) and you should now see something similiar to Figure 86.

Figure 86: Two fets Generated



Stretching gcells

As you have seen, gcells can be used to create fets and vias. The wiring tool can also automatically drop gcell vias. You can change the size of a gcell fet by:

- Using the **e** hotkey, and accessing the **Edit Properties** box, or
- Doing an **Stretch Selected** from the **Edit** menu (hotkey: **Ctrl-Button-3**).

STRETCH PFET

Try this on your pfet:

Step 1

- ***Select*** the pfet by clicking on it with **Button-1**.

Step 2

- Move the mouse near the top border of the pfet.

Hold down the **Ctrl-Button-3** hotkey (the cursor will change into a double-headed 'stretch arrow') and drag the mouse up. Release the mouse button.

Notice that as you stretch the pfet, additional contacts are added automatically.

Step 3

- To return to the original width, you can ***Undo*** the new width with the **u** hotkey or edit it again and change the width back to 4.

You can stretch via gcells in the same way, except the outcome is placing multiple vias!

You can stretch a well contact to help you with things like quickly building guard rings.

Aligning objects

It would be nice if our new fets were lined up. One way to align objects is to draw a ruler (hotkey: **Control-r**), zoom way in, and carefully move the objects until they are aligned with the ruler. But a much easier way is to use the **Align Objects** command.

Step 1

- If you aligned the two fets when you duplicated the nfet, move one of them with the **right mouse button** (**Button-3**).

Select Objects to Align

First, select all the objects to be aligned.

- One easy way to select multiple objects is to hold down the **Shift** key while clicking on them with the **left mouse button** (**Shift-Button-1**).
  - Using **Shift-Button-1** means "*add something under the mouse to the selection*".
  - **Alt-Button-1** *subtracts* what's under the mouse from the selection.

You can tell when the gcell is selected because its outline is highlighted, and its name and size are also displayed in white. If there are multiple objects under the cursor, use the **Selection Probe** (as demonstrated earlier in this tutorial) to select exactly what you want.

Step 2

- Click with **Shift-Button-1** over the two gcells until they are both selected.

Now you will use "**the Box**" to tell MAX how the gcells should be aligned. By selecting the gcells using **Shift-Button-1**, the "box" has automatically been placed over the *last* gcell you selected.

The gcells will be moved so they align with the box: in this case, it means the first gcell you selected will be moved so it aligns with the second gcell you selected.

You could instead draw the box somewhere else (**box mode**, hotkey: **b**) and have all of the objects aligned to the box (as shown in Figure 87).

Align the Objects

Finally, use the **Align Objects** command.

Step 3

- Choose **Align Objects** from the **Edit** menu (hotkey: **Control-a**).

Step 4

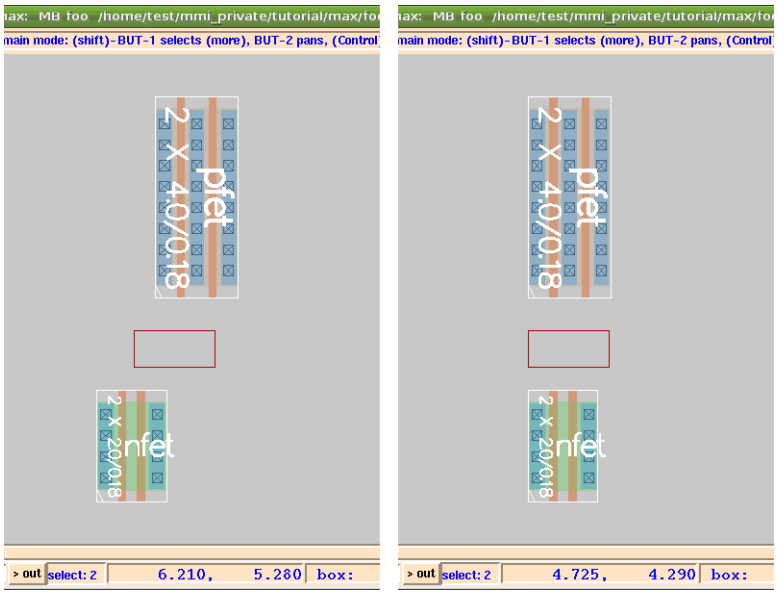
- Make sure that **left sides** (the default) is selected (has a red dot next to it.)

Step 5

- Click **Done**. The gcells are now aligned vertically on their left sides.

Figure 87 shows both fets being aligned to the box, which in this case was drawn separately (hotkey:**b**).

Figure 87: Aligning fets Using The Box: a) Drawing the Box; b) Aligning "Left"



Continuous DRC

We are now going to see a really powerful feature in MAX, real-time DRC.

Step 1

- With the new pfets on top of the nfets, select the pfets.

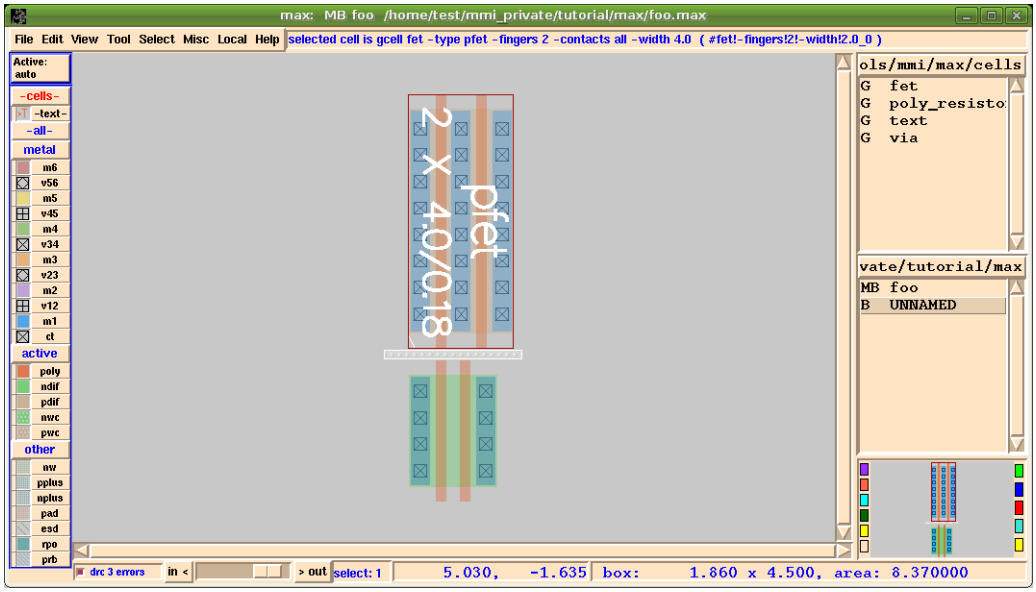
  You can move the fet using the **arrow keys** (best for precise placement) or by holding down **Shift** key and the **right mouse button** (**Shift-Button-3**).

  Using the **Shift** button along with **Button-3 locks the move** in the vertical or horizontal direction.

Step 2

- Using the **arrow keys** move the pfet just above the nfet, as shown in Figure 88.

Figure 88: Real-time DRC



- If you move the pfet too close to the nfet, little white dots will appear. These little white dots tell you there is a ***Design Rule Check error*** (DRC error).
- Notice that as you move the pfet closer or further away the DRC errors show up in "real" time! This is one of the powerful features in MAX.

The Continuous DRC means you don't even have to learn the DRC rules, or count grids. Just move things closer together until you see the white dots, and then back off a little. The small DRC error box, to the left of the zoom bar, displays the number of errors.

VIEWING DRC ON LAYOUT

If you are curious about what the DRC error is, you may view the results on the layout.

Step 3

- Drag a box around the white dots and type **Shift-y** or choose **Explain DRC under Box** from the **Misc** menu.

> **Tip**
>
> Remember that if you drag out a box using just mouse **Button-l**, the box is drawn *and* everything underneath it is selected.
>
> To draw a box only, type the **Make/move box** hotkey **b** and then drag out the box using **Button-1**.

- If the box is over only one DRC error, that DRC error will be displayed in the **Message Area**.
- If more than one DRC error lies under the box, the number of DRC errors is listed in the **Message Area** and the list of all DRC errors under the box are displayed in the MAX command window (the window from which you started MAX).

VIEWING DRC RESULTS ON FORM

Another method of viewing DRC errors is to use the **DRC Results** form.

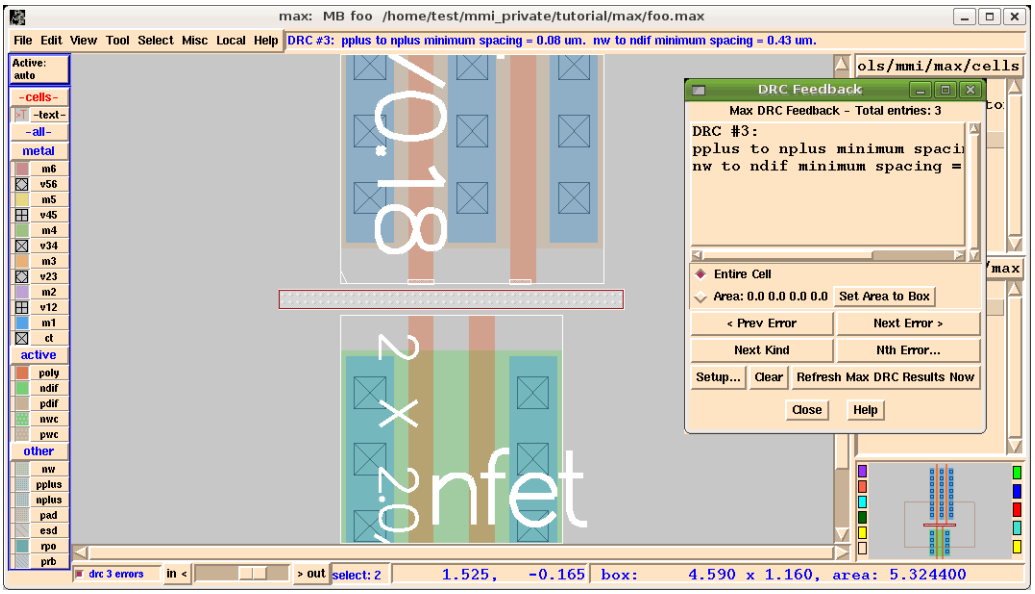
Step 4

- Move the pfet close to the nfet, as shown in Figure 88, so that DRC errors occur.

Step 5

- Select **DRC Results** from the **Misc** menu or type the hotkey **Ctrl-y**. You should see a pop-up window similar to Figure 89 .

Figure 89: DRC Results Pop-up Window



Step 6

- Click on **Next Error** to step through all of the DRC errors. Notice that each DRC error is highlighted in the layout, and the text of that DRC error is displayed in the **DRC Feedback** window as well as the MAX Message Area.

Step 7

- When you are finished looking at the DRC errors, click on **Close** in the **DRC Feedback** pop-up window.

Refer to the *MAX User Manual* for more details on the **DRC Results** pop-up window. This window can also be used to view results of DRC runs with other tools, such as Mentor Graphics' Calibre.

Step 8

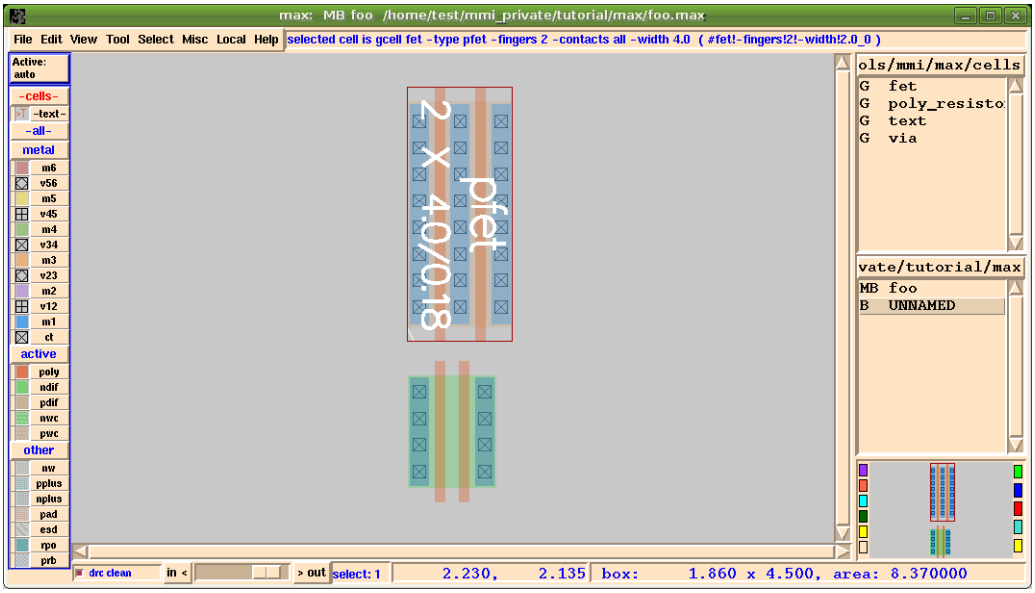
- Move the pfet above the left nfet so that the gates of the pfet and left nfet line up (this should already be the case after you aligned them).

Then move the pfet up (**arrow keys**) until it is DRC correct as shown in Figure 90.

To get it DRC correct, move up until the there are no white dots showing, and the DRC status box on the lower left of the MAX window says **`drc clean`**. Sometimes there can be DRC errors even if you can't see any white dots, especially if you are zoomed out.

If the DRC status box says there are still DRC errors, but you cannot see the white dots, you can use the **DRC Find Next Error** command in the **Misc** menu or type the hotkey **Shift-n**. MAX will zoom to the DRC error and describe the error in the MAX message area.

Figure 90: FETs Lined Up



The Continuous DRC feature uses design rules defined in the **`MAX technology file`**. This single plain text file defines all the design rules needed by MAX's extensive DRC. The technology file uses a simple table format for most rules, resulting in a compact, easy to understand file format that can be as short as a single page.

Micro Magic, Inc. provides common CMOS technology files as a starting point to build your own. In addition, you can build a prototype technology file automatically from an existing GDS file by choosing **Import File** from the **File** menu.

IMPORT PDKS

Technology information afrom a PDK, generally provided by the foundry, can be converted to MAX formad using **cds_convert**. This will be covered further in **Part 6** of this tutorial.

IMPORT OPENACCESS

Technology information from a PDK for the process may also be imported using an OpenAccess database. We will address OpenAccess further in **Part 7** of this tutorial.

Wiring Mode

Now you will route up the poly. You could route the poly by drawing rectangles and then filling them with poly (red) paint, but that's a lot of work. There's a much easier way — use MAX's built-in wiring tool.

WIRE TOOL

Step 1

- To use the wiring tool type **w**, or select **add wire** from the **Edit** menu.

Notice the cursor has changed. Remember, that's to let you know you are in a different mode. In this case, you are in **wire mode**.

Step 2

- Place the cursor over the poly gate of the right hand nfet (fet on the bottom) and click the **left mouse button** (**Button-1**).

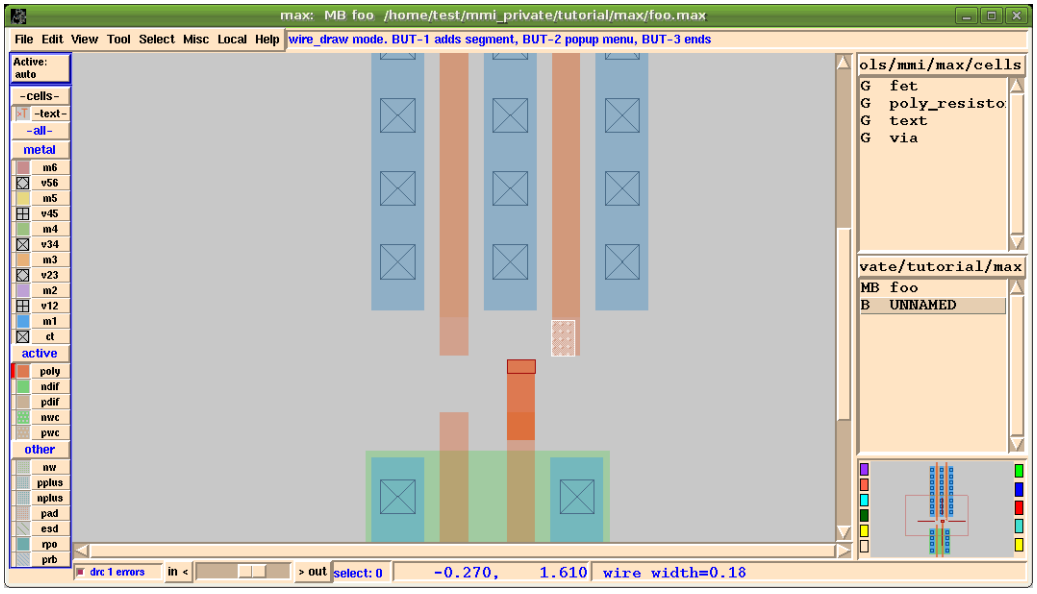
Step 3

- Now move the cursor up. A poly wire should follow the cursor, as shown in Figure 91.

  If the wire doesn't start in poly, check and make sure the ***Active*** layer is set to ***auto*** (the upper left corner of the MAX window).

The wiring starts the wire in the active layer (very top of the palette). If the **`Active`** layer is set to ***auto***, the wire starts in whichever layer is under the cursor. If there are multiple layers under the cursor, it picks the highest layer. If you set **`Active`** to a specific layer (i.e. **`m1`**), then the wire will start in that layer no matter what is under the cursor.

Figure 91: Drawing A Wire



- If at any time when in wire mode you wish to bail out and start over, you can do so by typing **Ctrl-c.**

ADDING CORNERS IN WIRES

As the pfet is not directly above the nfet we need a "kink" or corner in the wire. You do this by simply clicking the left mouse button (**Button-1**) where you want the kink.

Step 4

- Move the cursor up and then click with the **left mouse button** (**Button-1**) to add a kink. Notice that as you move the mouse, you also move the corner up and down. When you click the **left mouse button** (**Button-1**) again, the horizontal portion of the poly wire will lock in place.

Step 5

- Now move the cursor to the right until it's directly under the pfet poly and click the **left mouse button** (**Button-1**) again to add another kink or corner.

Step 6

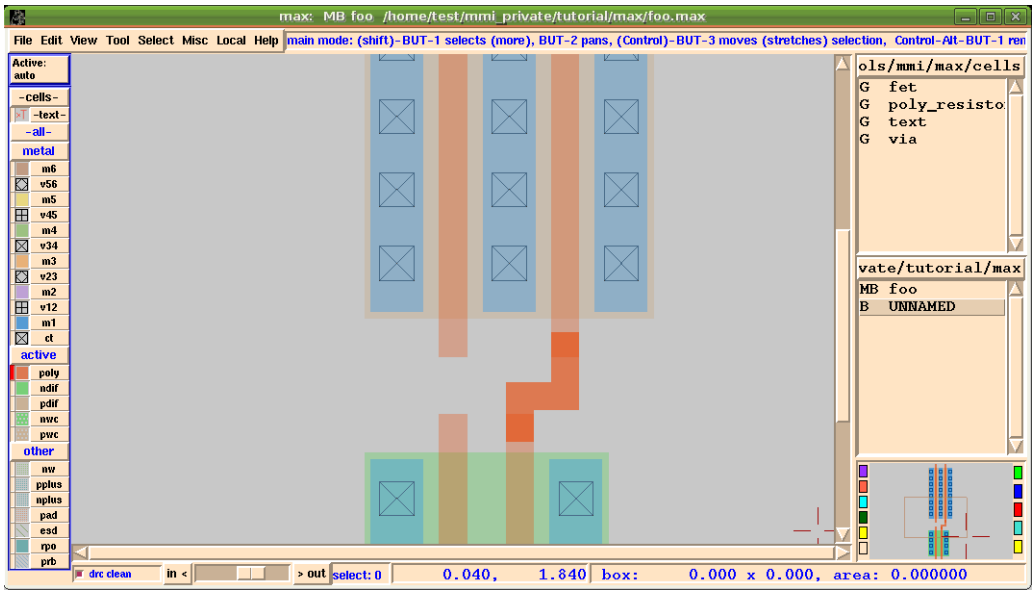
- Finally, move the mouse up until it's over the right pfet poly gate. If you glance up at the **MAX Info Bar,** notice that it says "**`BUT-1 adds new segment BUT-3 ends`**". This means that when you click **Button-3** it **ends** the wire.

- In fact, MAX does even better than that. If you click the **RIGHT mouse button** (**Button-3**) over the poly but are not exactly in the middle of the wire, MAX will actually snap the wire into place for you and end it. How about that?

If you didn't put the wire exactly where you wanted it don't worry. You can always undo.

Your layout should now look like Figure 92.

Figure 92: Drawing Poly Wire



If you want to back up one step in the wire, use the **Undo** hotkey, **u**. You can undo (**u**) back to the beginning of the wire.

If you want to **cancel** the current wire, use the **Ctrl-c** hotkey. **Ctrl-c** always aborts any sub-mode and returns you to main mode.

You might have noticed that the little piece of poly you just added is a brighter color than the poly that was part of the gcell fets. This is a feature in MAX that is designed to help you know what you are editing. Rectangles or objects drawn in the cell you are currently editing show up brighter than the cells you are not editing. This includes gcells. Therefore, since you are not editing the gcell fets, they show as dimmer than the cell you are editing.

- If you wish to have all of the layers show up with the same brightness (even in the gcells or subcells) then go to **File - User Preferences**, select **Display Options...**, then select **Dim Non-Edit Cells** and click **Done**. The radio button should go "off" with the non-edit cells no longer dimmed.

Editing a Placed Wire

Once a wire has been placed, you can edit the wire. The **Edit** menu contains commands to **Move**, **Stretch**, and **Fill** any rectangles, including wires. There is also the **Edit Wire** command as we saw earlier in this tutorial.

You may find that it is sometimes even faster to simply redo a wire if you need to make a number of edits.

- If you just want to move the wire a little you can select the wire segment you wish to move and then nudge it using the arrow keys. The arrow keys will do a "stretchy" move.
  - If your segment has a via at either end, you need to use the **Edit Wire** command.

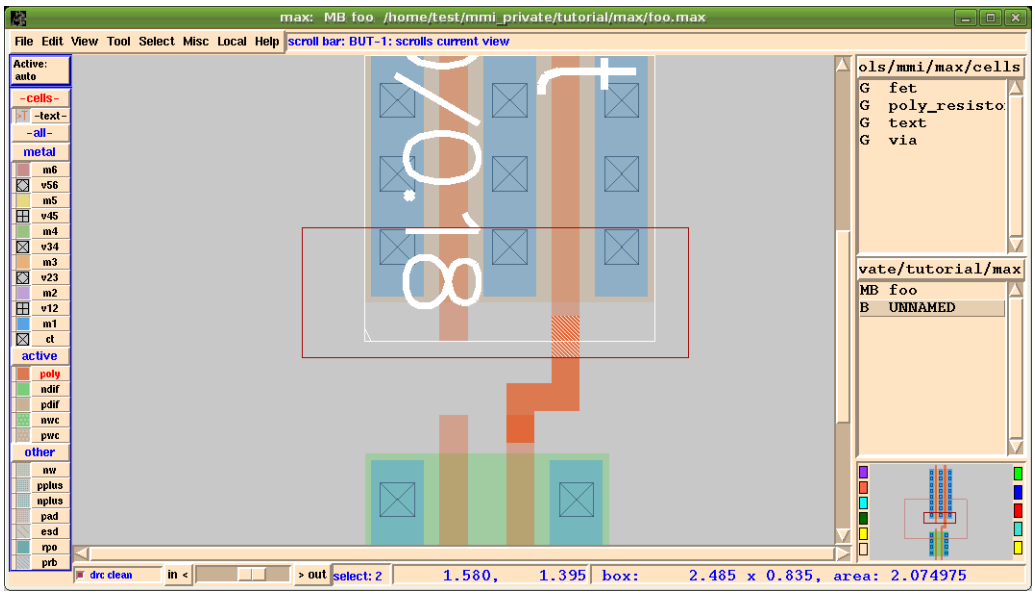
STRETCHING WIRE

Let's try a stretchy move with our connected fets.

Step 1

- Draw a box by holding down and dragging **Button-1** so that it encloses part or all of the pfet, and part of the vertical section of the poly wire, as shown in Figure 93.

Figure 93: Stretchy Move



Step 2 ■ Press the **up arrow** key a few times and notice that the poly wire stays connected.

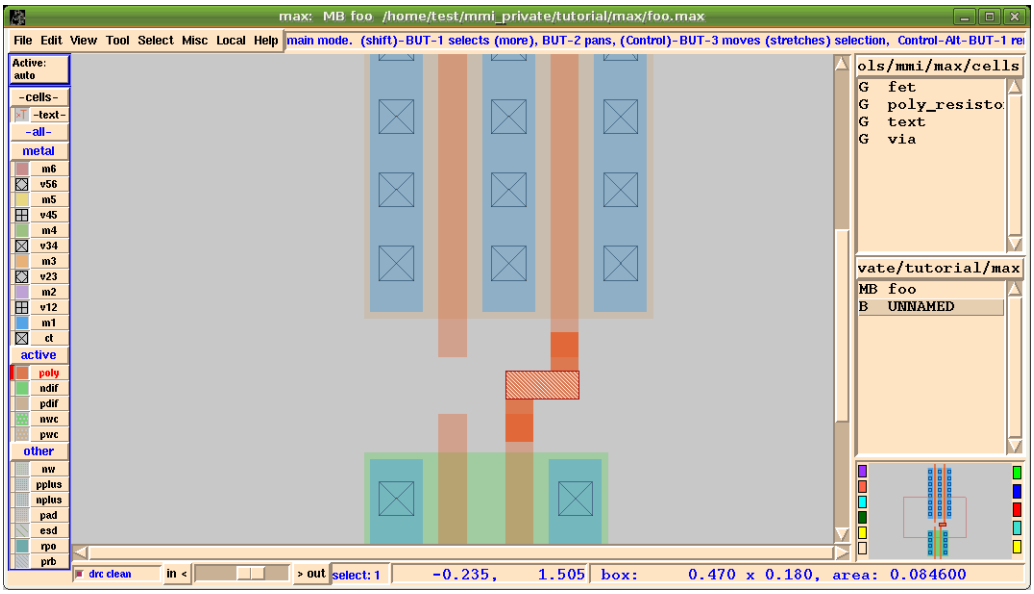
Step 3 ■ **Undo** your stretchy move with the **u** hotkey.

Moving a Wire

Now let's move the middle segment of the poly wire.

Step 4 ■ Select the horizontal section of the poly wire by clicking on it with **Button-1**, as shown in Figure 94. You may need to click multiple times to select the entire horizontal section of the wire.

Figure 94: Moving Wire Segment



Step 5 ■ Use the up and down arrow keys to move the segment. Notice that the wire stays connected.

If you want to move (and keep the net connected) the segment a long distance, you can use **Ctrl-Button-3**. Using **Button-3** without the **Ctrl** will move the segment but will not maintain connectivity.

If you are using the arrow keys for the move and do NOT want the wires to stretch, hold down the **Shift** key when moving the selected layout.

Step 6 ■ Finish wiring up the fets gates by drawing the second poly wire as shown in Figure 95 using the **wire** (hotkey: **w**) command.

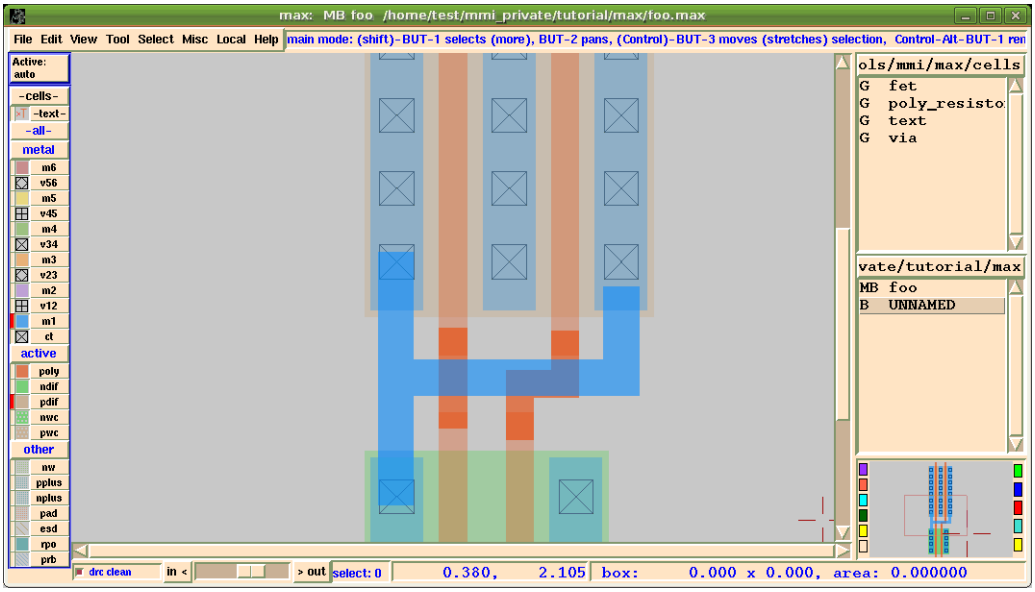
Wiring Up Metal

Now wire up the metal just as you did the poly.

Step 7

- Enter **wire mode** (hotkey: **w**) and then click on one of the contacts and draw the metal so it looks like Figure 95. First wire the two left contact regions and then add the connection to the right pfet contacts.

Figure 95: Wired 2 Left Poly Gates



When starting a new wire, the **Active Layer** box (remember it's on the top left just under the **File** menu) tells you what layer the wire (or circle or polygon) is going to be drawn in. If it is set to ***auto*** it picks the layer under the mouse.

If you want to tell it exactly which layer to start drawing on, then hold down the **left mouse button** (**Button-1**) over the **Active Layer** box. When the pop-up appears simply place the mouse over the layer you want and then release the button. All wires will now start in this layer.

To **change the layer of the wire** while you are in wire mode (before you start the wire or before you drop a via), type the hotkey: **l** (ell- lower case L)

If you hold down the **middle mouse button (Button-2)** while in **wire mode (w)**, the **Wire** menu will appear. The **Wire** menu changes based on whether or not you have already started the wire.

Also, remember that if you type the **Space** hotkey, the list of current hotkeys will appear for the current mode.

SAVE EDITS

Since you have done a fair amount of work you should now save your layout.

Step 8

- Type **Ctrl-s**, or select **Save** from the **File** menu.

  Notice that the `M` next to the `foo` in the **Cell List** went away. There is now a `W` next to **foo** which means that the cell has been ***written***.

Adding the Power Rails

We are ready to put in the power rails. Let's say we were laying out this NAND gate for a standard cell library. Furthermore, assume that the power and ground rails are run in metal 1 (m1) and that they are 2µm wide.

Before adding the power rails, you need some more information about the wire mode, the box and the palette.

We could use the wire tool to draw the power rails, by drawing wires with width set to 2µm.

- To do this, you would start drawing a normal wire (hotkey: **w**) in layer M1, positioned above or below the fets.

- Then, press and hold the **MIDDLE mouse button** (**Button-2**) to access a pop-up menu for wiring options, including the current wire width. Here you can set the wire width of the current wire segment(s) to 2µm, or the width desired.

- You can also set the default width, spacing, and snap grid for each wire layer in the **Wiring Parameters** menu. It is found under **User Preferences** in the **File** menu, then choose **Wire Setup...** (or just use the **Shift-w** hotkey), then choose **Wiring Parameters**.

However, this is a good opportunity to use rectangles directly. MAX has excellent capabilities for low-level layout "rectangle hacking", and this is an ideal way to put in the power rails. To use rectangles effectively in MAX, we will first have to learn to manipulate the *Box* and use the *Palette*.

The Box

The Box is important in MAX because it is used by many commands to determine where you are going to place, or do, something. For *painting* (creating rectangles of a specific layer), the Box marks the region where paint is going to be drawn or erased. We have already seen the Box on the screen while doing the commands above; for example, the **Align Objects** command.

- You can create a box by simply holding down the **left mouse button** (**Button-1**) and dragging the outline around a region.

Drawing a box by holding down **Button-1** also automatically selects what is under the box, so don't drag a box around an entire chip! Use **Box Mode** (below) for that.

Assuming you were in **main mode** (the default), any paint within the box is selected. This is the way we have done things thus far.

- You can also position the Box exactly by typing **Shift-b**, or selecting **Box Dimensions** from the **Misc** menu, or by clicking on the **Box Size** window in the lower right corner of the display. Any of these will open a menu that allows you to precisely set the box size.

Box Mode

Box Mode is useful when you need to do detailed layout. You can resize the box to the exact size you want, and place it exactly where you want it, without having to worry about corrupting any existing layout that you might have inadvertently selected.

Dragging out a box in **Box Mode** does NOT select anything.

After typing **b**, (or **Make Box** in the **Misc** menu) you can do any of the following:

- ***You can specify a new box position*** by holding down the **left mouse button** (**Button-1**) as you drag out a region, then releasing **Button-1**. The cursor shows as a hand with the pointing index finger.
- ***Resize the existing box*** by moving the mouse over the sides or corners of the existing box until the cursor icon changes (to either a 'stretch-arrow' or a 'corner'), then drag that side or corner by pressing and holding the left mouse button (**Button-1**).
- ***Move the box*** by holding down the **RIGHT mouse button** (**Button-3**) and moving the mouse (a hand cursor appears).

Remember, the above commands function while you are in **Box Mode**. You can always look at the **MAX Message Area** (to the right of the menus) to determine your current working mode.

The Palette

A few more words about the ***Smart Palette*** (along the left side of the MAX window).

The Smart Palette provides many features. It allows you to control what you can see, what you can select, what's under the cursor, what can be drawn as rectangles, and what the layers look like.

- Remember the **MAX Message Area** (directly to the right of the **Help** menu) will tell you what the available options are if you place the mouse over the palette.

  Here's a reminder of how to use the palette.

  - To control ***which layers are visible***, click the **left mouse button** (**Button-1**) over the little colored square (to the left of the layer labels - **`m5...v45...m4`**, etc.).

- To control ***visibility by group***, click the **left mouse button** (**Button-1**) on the ***group button***: **`metal`**, **`active`**, or **`other`**. This is a very useful feature for reducing clutter when you are working on a subset of the layers.

- To control ***which layers are selectable***, click the **left mouse button** (**Button-1**) on the ***layer name*** (such as **`m2, v12, pfet`**, and so on). The layer name button will turn grey, and that layer will be *disabled* (NOT selectable).

  Or click the **right mouse button** (**Button-3**) over the **`group`** button to toggle selectability for that entire *group*.

- Layers which are ***under the mouse*** are indicated by a small rectangular red LED just to the left of the colored boxes.

- Layers which are ***currently selected*** are indicated by the layer name(s) changing from black to red.

- Finally, you can ***change the color or stipple patterns*** of any of the layers by clicking the **middle mouse button** (**Button-2**) over either the colored box or the layer name. This brings up the **MAX Color/Stipple Editor**. Using the editor, you can even change the colors of things like the background (for example, make it black), the grid, labels, etc.

  - While the grid color is changed in the **MAX Color/Stipple Editor**, the ***grid size and style*** are changed in **Grid Setup...** under **User Preferences** in the **File** menu, or by typing the **Shift-g** hotkey.

Painting the Power Rails

Now we are ready to add the power rails as paint rectangles.

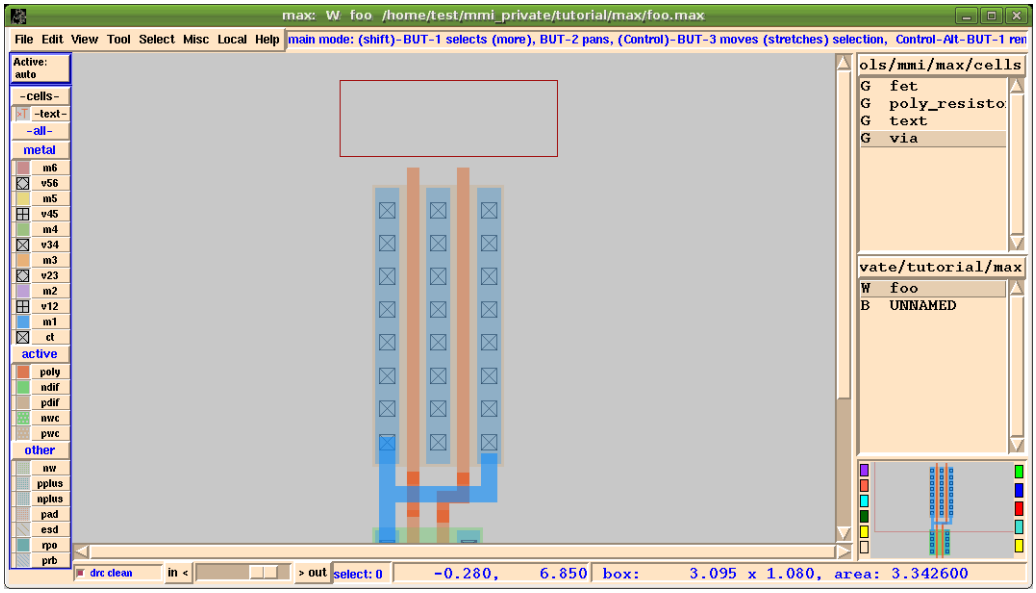
Step 1

- Type the **Add Box** hotkey, **b**.

Step 2

- Hold down the **left mouse button** (**Button-1**) and drag out a region where you want to paint the new **`Vdd`** power rail, as shown in Figure 96.

Figure 96: Drawing a Box for Painting Power Rails



Step 3

- Place the cursor over the **M1** button in the palette (either over the name **m1** or the bright blue square to the left of the name), then click the **paint** hotkey **p** .

> **Tip**
>
> You can also type the **p** hotkey over any piece of **m1** in the layout. Be sure there are no other layers under or over **m1**. MAX will fill the box with all of the layers under the cursor.
>
> **If you click the p hotkey over a place with NO layout, then the layout of all layers in the area under the box will be *erased*.**

Resizing Rectangle

If the box isn't the size you want (see the lower right corner for the box size) you can make the box exactly 2µm tall or you can edit the rectangle. Notice in the figure above that the size of the box is 3.65 x 1.355.

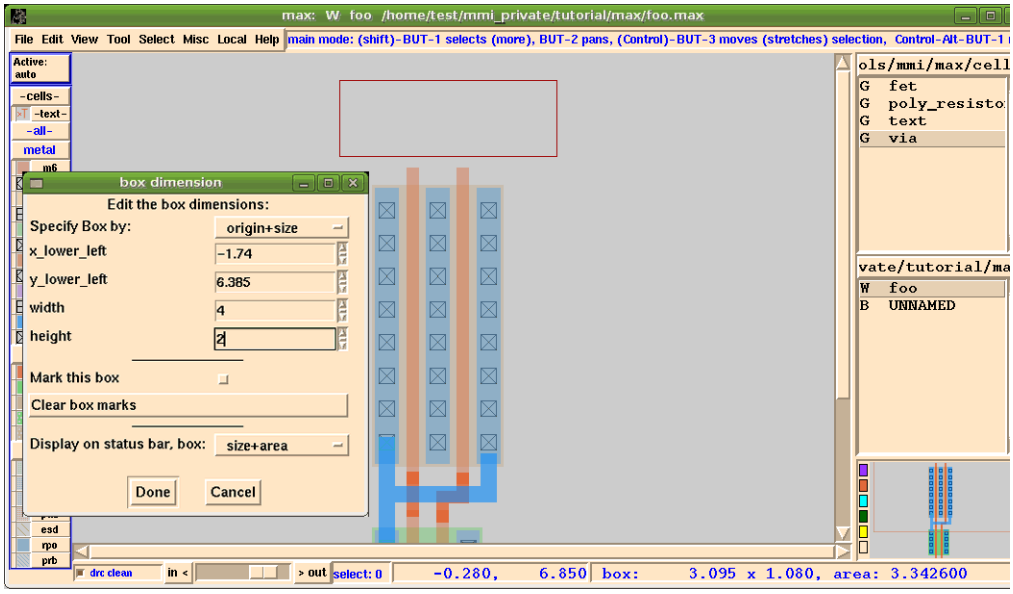
Step 4

- Undo (**u**) the **m1** paint before we resize the box.

Step 5

- To make the box an exact size type **Shift-b**, or select **Box Dimensions** from the **Misc** menu. A pop-up menu, as shown in Figure 97, appears.

Figure 97: Box Dimensions Pop-up Form



Step 6

- Make sure the **Specify Box by:** is set to **origin+size**. Then type in *4.0* for the width and *2.0* for the height, then click **Done**.

Step 7

- Fill the box with **m1** again by clicking **p** (paint) on '**m1**' in the palette or any **m1** in the layout.

Stretching Rectangle

You can change the size of a rectangle by stretching an edge using the **Edit Edge** command (hotkey: **a**) found in the **Edit** menu.

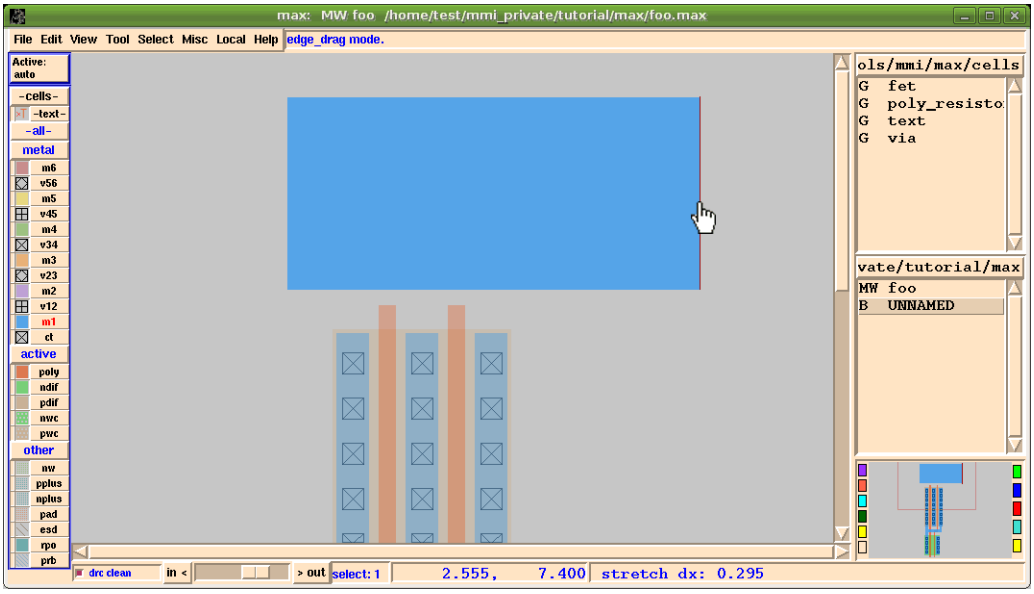
Step 8

- Type the **a** hotkey. The cursor changes to let you know you are in **Edit Edge** mode.

Step 9

- Move the cursor (shown as a finger) over the right edge/side of the **m1** rectangle that we just drew. A select line will show you which edge you are over as shown in Figure 98.

Figure 98: Editing Edge of Power Rail Rectangle



Step 10

- Hold down the **left mouse button** (**Button-1**) and move the mouse to the right to stretch the edge. Release the button when the edge is where you want it.

EDIT PROPERTIES OF RECTANGLE

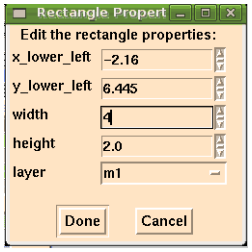
You can also change the size of a paint rectangle by first selecting it, and then selecting **Edit Properties** from the **Edit** menu (hotkey: **Ctrl-p**).

Step 11

- Let's change the width of the rectangle back to 4 by editing its properties. Select the **m1** rectangle by clicking on it with **Button-1** and type the hotkey **Ctrl-p**.

  You should now see a pop-up similiar to Figure 99.

Figure 99: Edit Rectangle Properties pop-up



Step 12

- Change the *width* back to **4** and click on **Done**.

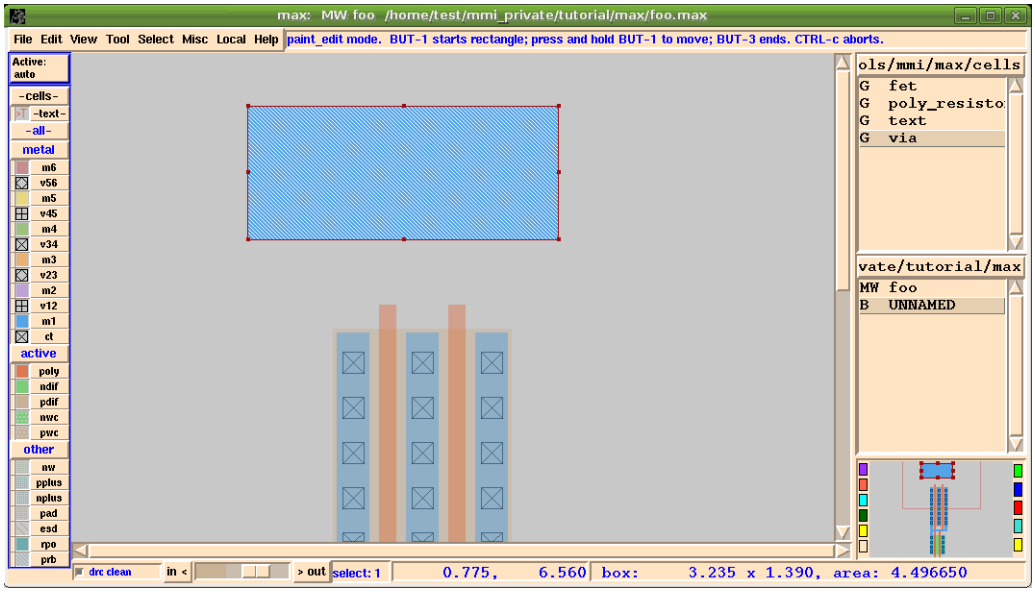
PAINT EDIT MODE

One other way you can edit paint rectangles is to use the **Paint Edit Mode**.

Step 13

- Select the power rail again, and type the **e** hotkey. (The command can be found in the **View** menu: **Push into Cell**. MAX is smart enough to know that because a paint rectangle has been selected it should go into **Paint Edit Mode**.) You will now see the paint rectangle outlined with dots at the 4 corners and in the middle of each edge, as shown here in Figure 100.

Figure 100: Paint Edit Mode for m1 Rectangle



As always, the **MAX Message Area** tells you what mode you are in and the function of each mouse button in that mode.

- Holding down the **left mouse button** (**Button-1**) in the middle of the rectangle moves the rectangle.
- Holding down **Button-1** on one of the dots, resizes the rectangle.
- The **right mouse button** (**Button-3**) exits out of **Paint Edit Mode**.

Step 14

- Try resizing and moving the rectangle. Click **Button-3** to exit **Paint Edit Mode**. Type the undo command (hotkey: **u**) to move the rower rail back to it's original position and correct size.

Duplicating Rectangle

Once you have painted the top power rail you can simply duplicate it and move it down for the bottom rail.

Step 15

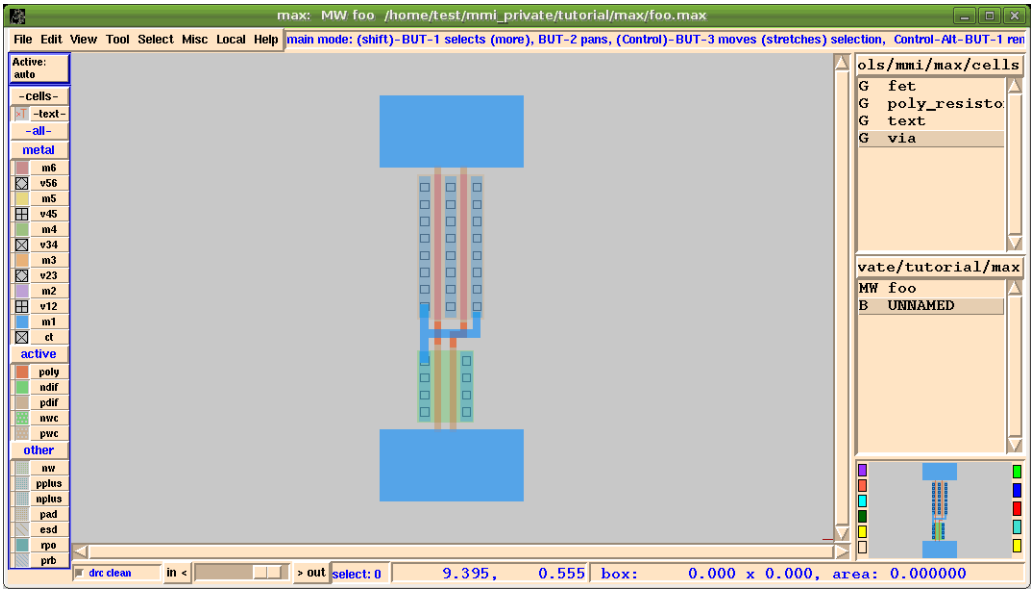
- Select the power rail using the left mouse button.

Step 16

- **Duplicate** the top power rail (hotkey: **d**) and move it down with **Shift-Button-3** as shown in Figure 101.

If you ***duplicate*** something and hold the **Shift** key down while moving it, the duplicated item will stay lined up with the original.

Figure 101: Power Rails Placed



Step 17

- You can move both of the power rails as close as possible to the fets, as shown in Figure 101 (above) by selecting each power rail and using the up and down arrow keys while watching the **DRC status box** to make sure there are no DRC errors.

Wiring Up Rectangles

Now that you have painted in your power and ground rails you want to wire them up using the **Wiring Mode** as before.

Step 18

- After you have entered the **Wire Mode** (**w**), hold down the **Shift** key and click the **left mouse button** (**Shift-Button-1**) over the middle of the pfet contact region. This will start an **m1** wire using the width of the **m1** under the cursor.

  Click with **Button-3** on the **m1** power rail to terminate.

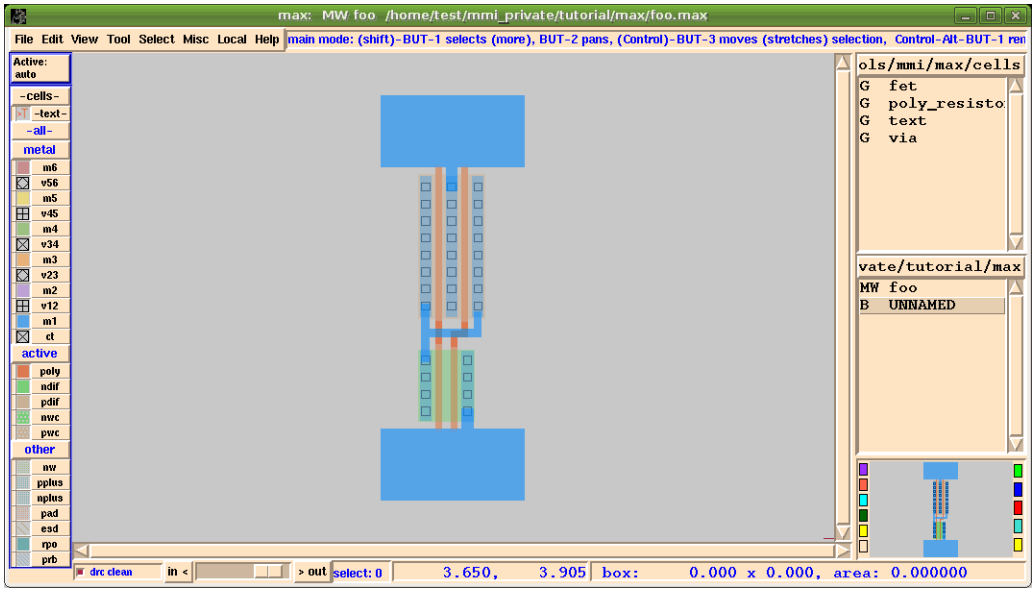
By holding down the **Shift** key you are telling the wire tool to use the width of the wire under the cursor and NOT the minimum wire width.

Step 19

- Now connect the right nfet contact region to the ground rail.

Your cell should now look like Figure 102.

Figure 102: Nand Wired to Power Raill



Wiring Mode - Changing Layers

Notice that the inputs and outputs are all found within the power straps. What if they need to be brought out so a router can get to them?

Let's assume the router requires all signals to be at the top of the cell and in **m1** . You need to route the poly wires over the **m1** power straps and then change to **m1** .

Wire Mode in MAX can make this job easier since it can change layers for you.

CHANGING WIRE LAYER

Step 1

- To ***route the wire***, type **w** (**Wire Mode**) and click the **left mouse button** (**Button-1**) over the upper end of one of the poly gates.

Step 2

- Drag the mouse up and over the **m1** power rail, drawing the poly wire.

DROPPING A CONTACT/VIA

Step 3

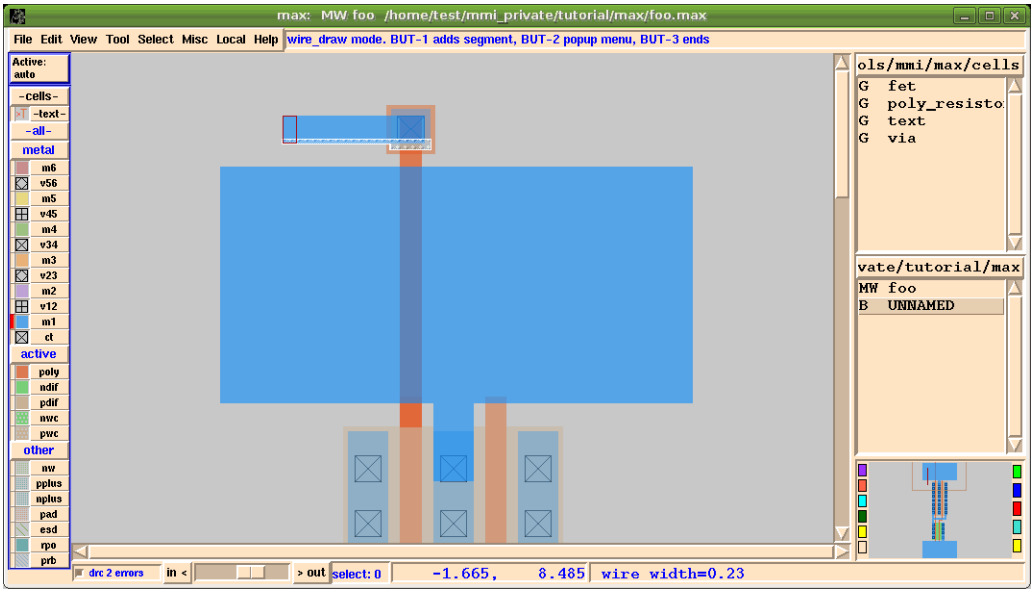
- Type **d**. This will ***drop a poly to m1 contact*** for you, which you can then move around.

Step 4

- Now try moving the mouse to the left. This draws an **m1** line left of the contact. While holding the mouse to the left try moving it up and down ().

Notice that the contact tracks the vertical location of the mouse as you move it. Also notice that the DRC is working while you are moving the contact. Whenever you get too close to the **m1 Vdd** line, the little white DRC dots appear, as you can see in Figure 103.

Figure 103: Active DRC Showing Errors As Wire Is Drawn.



Step 5

- Move the mouse around to get the contact where you want it (no DRC errors showing), and type the hotkey **a** to 'freeze' or anchor the contact in place. Remember, you may need to refer to the **DRC Status Box** to make sure there are no DRC errors. Then drag the mouse upward.

To access the commands in **Wire Mode**, press and hold the **middle mouse button**(**Button-2**). Next to each command is the hotkey for that command. Another way to find out the hotkeys while in wire mode is to type the **Space** bar.

So, to freeze the via in place, you could also have selected **anchor vertex** from the **Wire Mode** pop-up menu.

As you continue dragging the mouse upward notice that you are now in **`m1`**. If you type **d** (***drop a contact***) again, you will add a **`via1`** and automatically change to **`m2`**. This will continue until your technology runs out of metal layers.

The generic technology file we have included (**mmi18**) has six layers of metal.

You can zoom in on an area while in wire mode. Click the hotkey **z** and zoom in on the desired area using **Button-1**. You are then returned to wire mode. You can also zoom out (**Shift-z**) or zoom to fit (**v**) while in wire mode.

Step 6

- ***End the wire*** by clicking the **right mouse button** (**Button-3**) at the desired location, as shown in Figure 104.

> **Tip**
>
> Typing **d** in **Wire Mode** ***drops a contact*** and raises you to the ***next higher layer***.
>
> If you want to ***go down a layer*** simply type **Shift-d** and the wiring tool will drop a contact or via, and bring you down to the next lower layer.

There are LOTS of other options in the wiring tool, such as **snap to grid**, **wire in 45's**, **change wire layer**, and more.

- To see the **Wire Mode** menu simply hold down the **middle mouse button** (**Button-2**) while in wire mode. This opens the **Wire Mode** pop-up menu.

- One of the Wire Mode options is **Shift-w** which brings up a more extensive **Wire menu** (also found as **Wire Setup...** in **File - User Preferences**). This menu gives you such options as **Active Layer** (which can also be set via the **Active Layer Box** in the upper left corner of MAX), the **Default Layer**, **Snap options**, and you can even override any or all of the wiring parameters.

> **Tip**
>
> The same hotkey can be used for different functions in different modes.
>
> For example, while in **Wire Mode** the **Shift-w** hotkey brings up the ***Wiring Menu***, in the **Main Mode** the **Shift-w** hotkey does an ***Add Wire Bus***.

Remember, for a list of all the options (hotkeys) available in wiring mode, hit the **Space bar**, or select **hotkeys** from the **Help** menu.

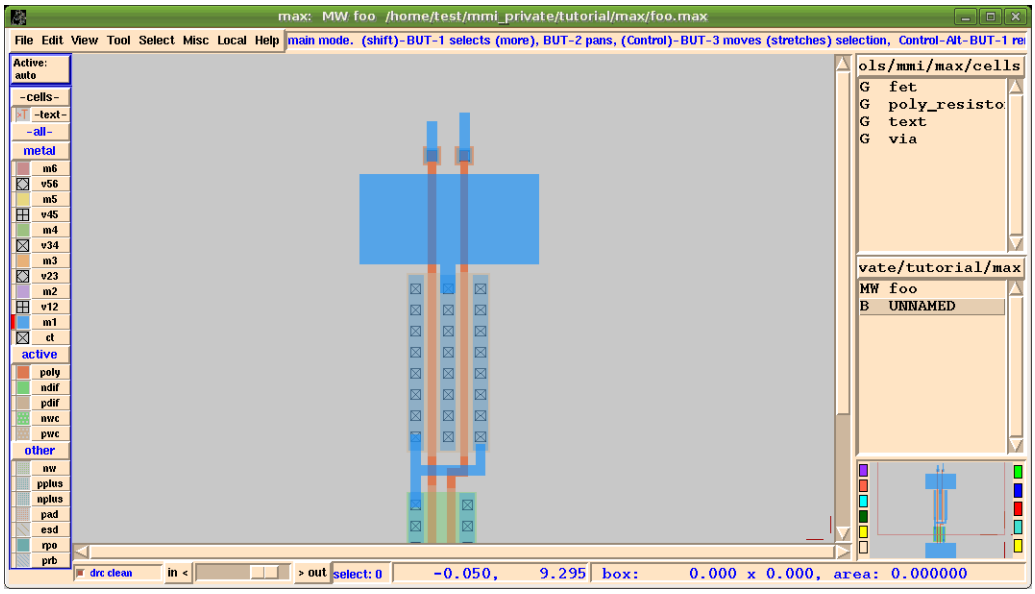
The **Space bar** hotkey option works for ALL modes in MAX.

Step 7

- Wire up the other poly input.

Your cell should now look like Figure 104.

Figure 104: Inputs of Nand Brought Outside



ALIGNING WIRES

If the top of the **m1** wires are not aligned as shown in Figure 104, there are a number of ways to align them.

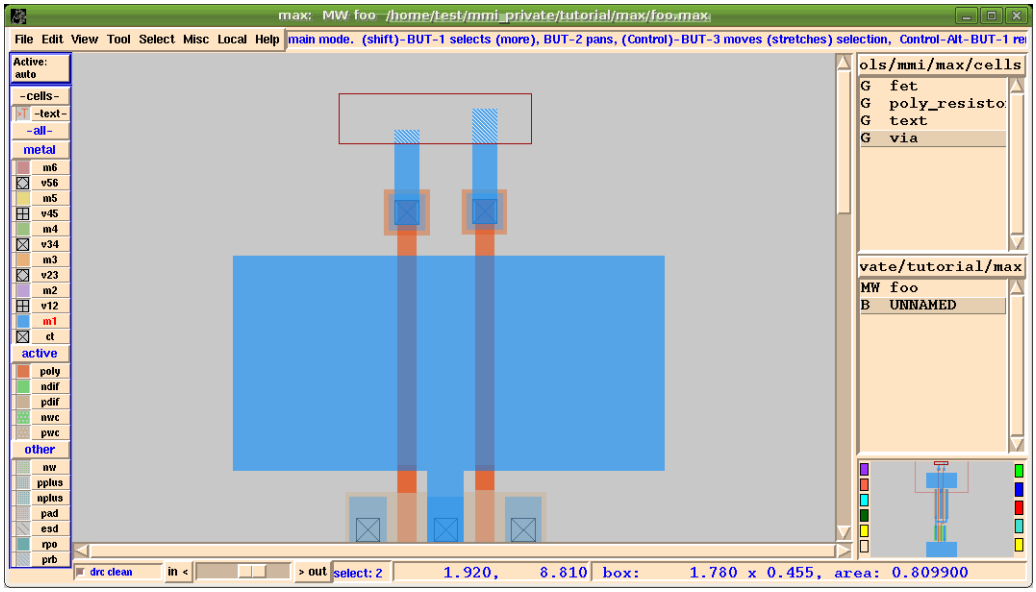
Step 8

- The easiest way is to draw a box and select the top edges of both wires, as shown in Figure 105.

  Then click the **delete** hotkey **q** and the selected paint will be erased.

- If there are multiple layers selected and you only want to delete a single layer (i.e. **m1**), move the mouse over **m1** in the palette or over a piece of **m1** in the layout and type the **erase** hotkey **o**.

Figure 105: Aligning Wire Ends



You can also use the **Fill** command in the **Edit** menu to extend both top edges of the **m1** wires up to the top edge of the box. (Refer to the Micro Magic, Inc. *MAX User Manual* for more details.)

Changing Layers

We are getting ready to finish this cell and your boss has just informed you that the power rails have been changed from **m1** to **m2**. We'll show two ways of changing the power rails to **m2**.

1st Method of Changing Layers

You'll see later that there is an easier way to change layers for this rectangle, but this method can be useful for other types of edits.

Step 1

- To change the first power rail, simply click the **left mouse button** (**Button-1**) over the upper (**Vdd**) rail to select it. You may have to click **Button-1** twice to get the entire rectangle. Notice that the Box encloses the last thing you selected.

Step 2

- Now if you type the ***Erase*** command (hotkey: **o**) over blank space (background) on the screen it will erase everything within the box. But wait! You also have some poly within the box. If you erase everything inside the box your poly will also go away.

Step 3

- Undo (**u**) your last change.

MAX allows you to ***selectively erase*** layers.

Step 4

- The power rail should still be selected. If not, select it again with **Button-1**.

Step 5

- Use the ***Erase*** command (hotkey: **o**) over a piece of **m1** in the layout, or over '**m1**' in the palette. The ***Erase*** command (**o**) tells MAX to erase those layer(s) under the cursor.

Once you have erased the **m1** layer, notice that your Box is exactly the size it needs to be for the **m2**.

Step 6

- To repaint the erased **m1** with **m2**, simply click the **p** hotkey (***fill with paint***) over '**m2**' in the palette.
- Instead of using the ***Erase*** command, you could also have used the **Delete** or **q** hotkeys to delete the selected item.

Delete will delete everything you currently have selected, including paint, polygons, gcells, and sub-cells.

As a reminder, there are several options for mouse selection.

- Clicking **Button-1** will ***select the object or rectangle*** of paint under the cursor.
- Holding down the **Shift** key while clicking **Button-1** will ***add to the selection***.
- Holding down **Button-1** while dragging out a region will ***select objects and paint within that region***.

2ND METHOD OF CHANGING LAYERS

An easier way to change the layer of a rectangle is once you have selected the layer, use the nifty little ***Change Layer*** feature found in **Edit Properties...** under the **Edit** menu.

- Let's change the lower (**GND**) layer **m1** and replace it with **m2**.

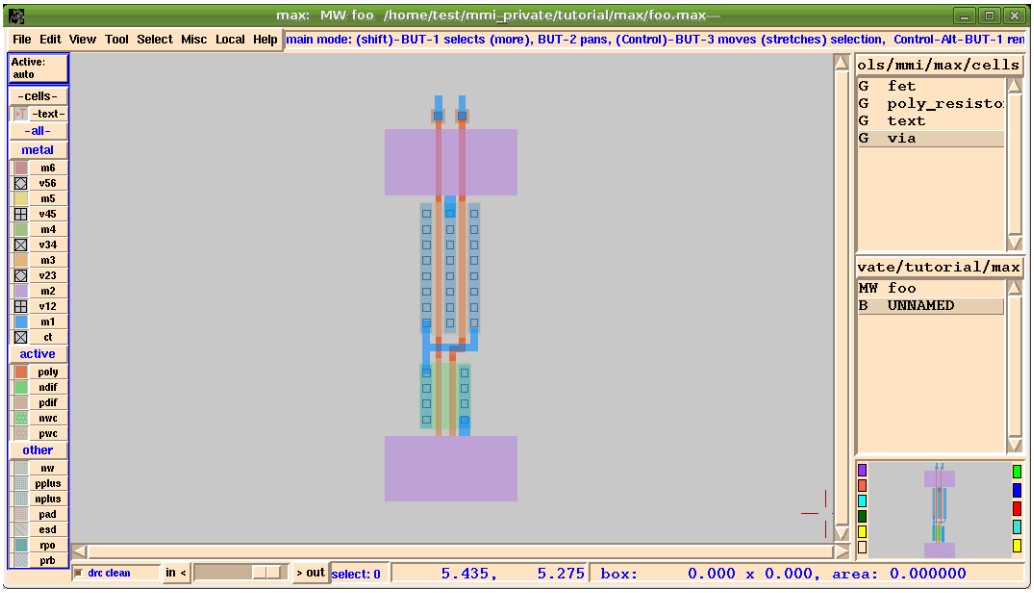
Step 1

- To do this simply select the **m1** rectangle, then choose **Edit Properties...** from the **Edit** menu, or type the **Ctrl-p** hotkey.

Step 2

- Change the layer to **M2** and click **Done**. You should now have something similiar to Figure 106.

Figure 106: Edit Properties... Layer “m1” Changed to “m2”



Finish Wiring the NAND Gate

You now need to attach the power and ground lines to the new **m2** straps.

To do this, use the **Wire Mode**.

Step 1

- ***Start the wire*** (**w**) from the **m1** wires you drew earlier using **Shift-Button-1**, so that the wire width will match.

Step 2

- When you are over the **m2** straps type **d** to ***add a via*** to **m2**

Step 3

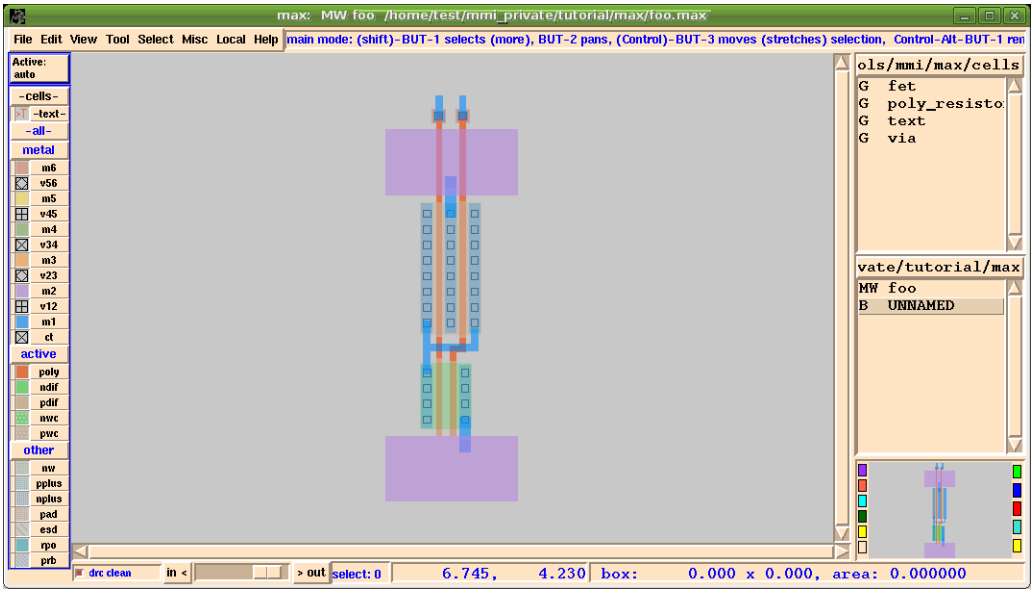
- Click the **right mouse button** (**Button-3**) to ***end the wire***.

Step 4

- Repeat for the second power rail.

You should now have something similiar to Figure 107.

Figure 107: Connected Power Rails

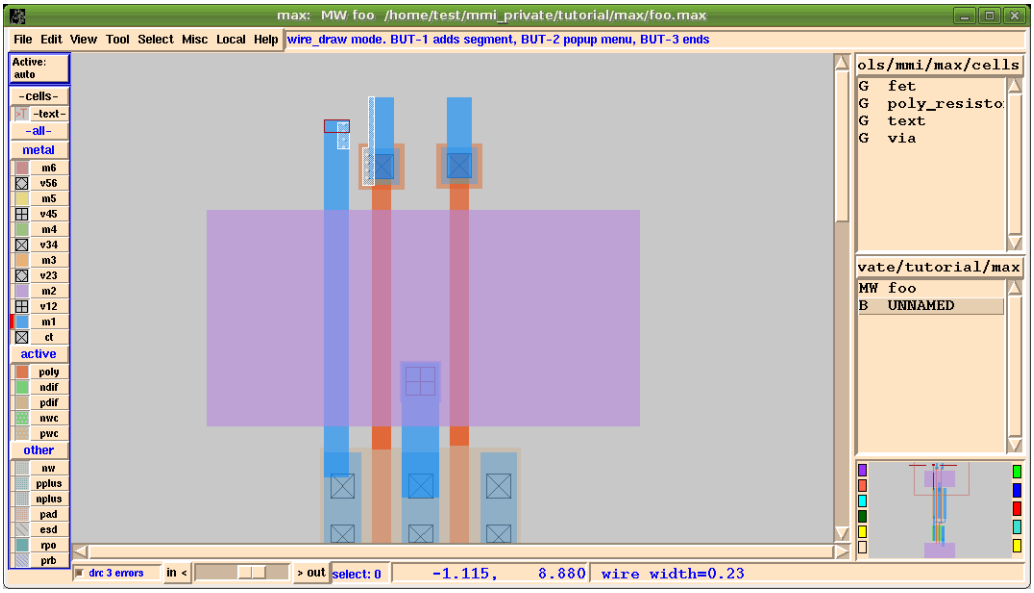


Next, we need to route the output of the top over the **m2** next to the inputs so the router can get to it as well.

Step 5

- ***Start a wire*** (**w**) over the left pfet contact region (**Button-1**). Move the mouse up.
- Notice that if you go straight up, you create DRC errors as shown in Figure 108.

Figure 108: Poly Gcells And M1 Wires Showing DRC Errors



Step 6

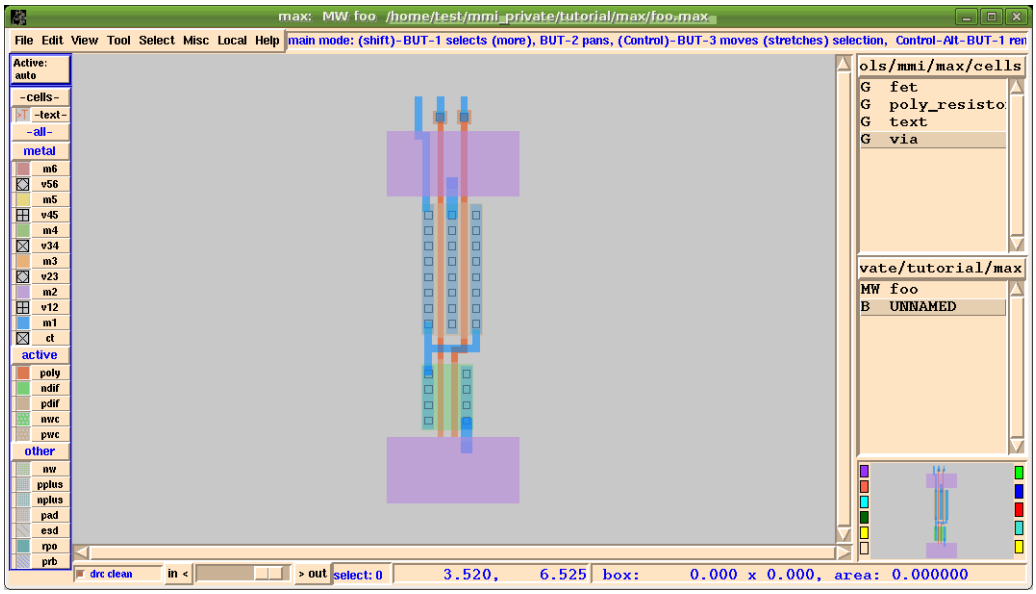
- So that there are no DRC errors, add two corners such that the **m1** wire makes a jog to the left, and end the wire.

Your design should now be DRC correct and look similar to Figure 109.

Step 7

- You've done a lot of work, so ***save*** it by typing **Ctrl-s**.

Figure 109: Nand Gate Wired Up



Text

There is one last thing before we are finished with our Nand gate.

The input and output nets of the Nand gate should be marked with unique names. This is accomplished by adding ***Text*** to the nets.

- To add Text, you ***first select the rectangle*** where you want to put text. Simply click the **left mouse button** (**Button-1**) over the rectangle, which will select the rectangle and place the Box around it and **Add Text** (hotkey: **t**).
- To ***edit text*** that has been placed, first select the text (it will turn white) and press **Shift-t** to bring up the **MAX Text Edit** dialog box.

Place Text

Step 1

- Select the ground (lower) rail (click with **Button-1**)

Step 2

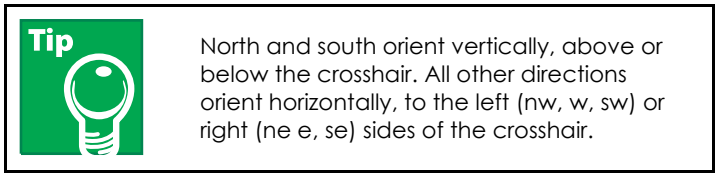
- Type **t** for ***Text***, or choose **Add Text** from the **Edit** menu. The **MAX Text Edit** dialog box will appear as shown in Figure 110.

Step 3

- Enter the name ***GND*** into the Text field.

The **MAX Text Edit** dialog box permits you to set the type of Text label: ***input***, ***output***, and so forth. Marking labels as inputs, outputs, global, etc. can be useful for use with other extraction or routing tools.

You can also specify the Text "position", such as ***n*** for north, or ***s*** for south. Specifying the orientation of the Text, relative to the crosshair that marks the Text location, places it on one side or another for easier viewing.



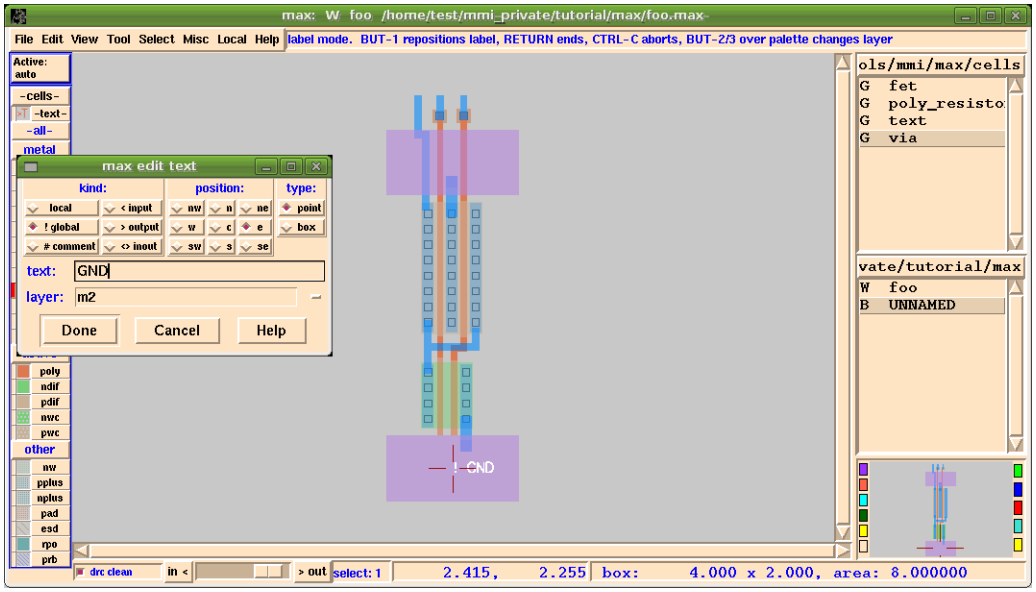
The Text "type" can be a ***point*** (the default) or a ***box***. The 'box' option produces text which marks a specified area, but is rarely used.

Step 4
- Specify the GND text direction to be **e** (***east***) and specify that it is a ***global*** signal.

Step 5
- Now move the mouse to the point on the layout you wish the text to be and click the **left mouse button** (**Button-1**).

Step 6
- Then click **Done** or hit **Return**.

Figure 110: Adding Text "GND" to Bottom Power Rail



In this tutorial:

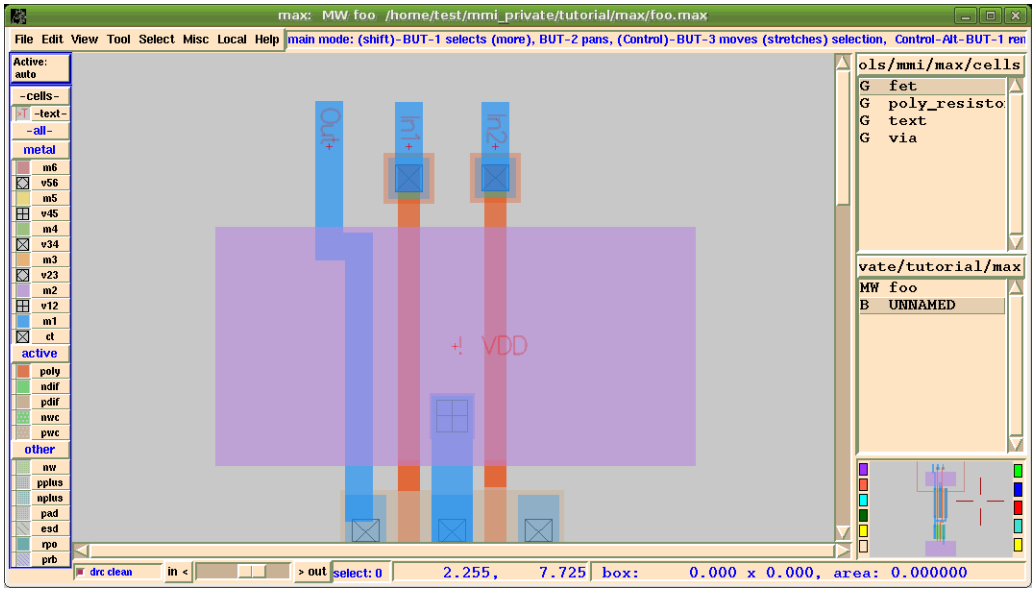
- **VDD** and **GND** are marked as *global*, and are positioned east (**e**). The default location for the text point of origin is in the center of the selected rectangle. Text was positioned at the far right side of the rectangle.

- The inputs (**In1, In2**), and output (**Out**), were marked as *local*, and are positioned north (**n**).

Step 7

- Add labels for **VDD, In1, In2** and **Out**, as shown in Figure 111.

Figure 111: Adding Text Labels

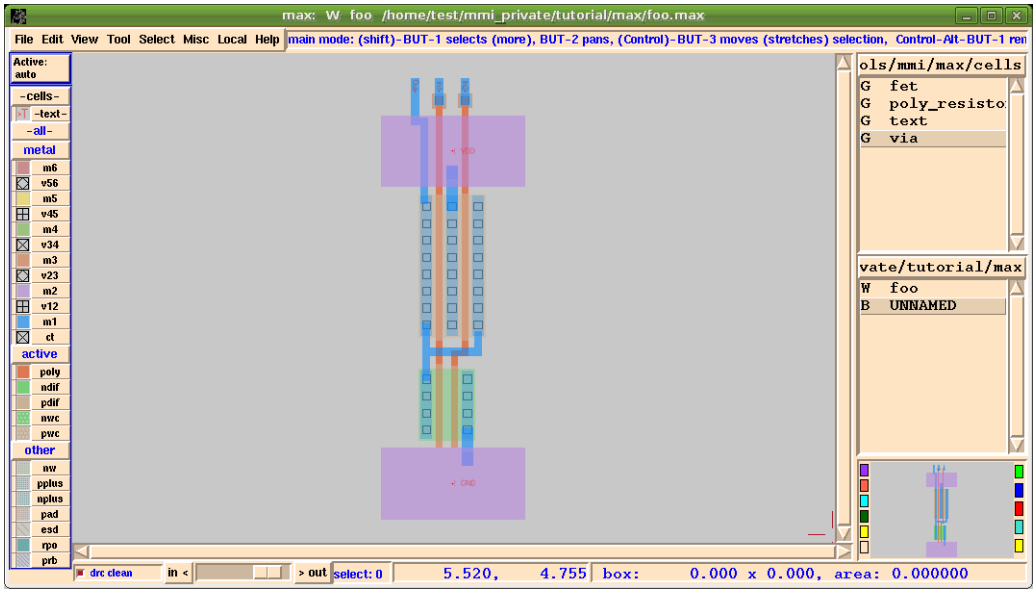


Step 8

- Remember to save your cell (hotkey: **Ctrl-s**).

At this point our little NAND gate example should be done, and yours should look something like Figure 112.

Figure 112: Finished Nand Gate



COPY CELL TO NEW NAME

You can copy the cell into a new name. Let's call it **my_nand**.

Step 9

- Select **Save As...** from the **File** menu.

Step 10

- Type in "**my_nand**" in the **Filename** field and click on **OK**.

You will now see both **foo** and **my_nand** in the List box. You are currently editing **my_nand**.

Selecting Nets

MAX can trace connectivity through vias and contacts to interactively show everything connected to a net.

- Place the mouse over any piece of metal, poly or diffusion and type **s**, or choose **Select Net** from the **Select** menu. MAX will automatically select the entire net that is connected to that piece of layout, and will also display the net name, if known, in the **MAX Message Area**. The net name(s) are taken from any Text (labels) attached to the net.

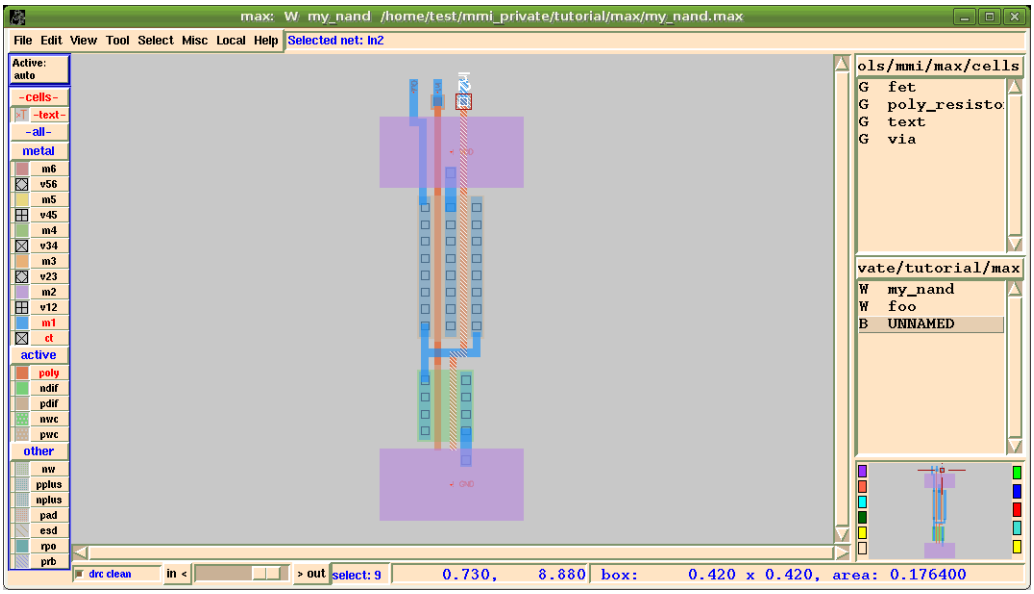
Step 1

- Move the mouse over the **m1** rectangle for '**In2**' in the upper right corner.

Step 2

- Type the **s** hotkey. You should now see the net highlighted as in Figure 113. Also, in the message area, you should see "**Selected Net: In2**".

Figure 113: Highlighted Net



If there are multiple layers under the mouse cursor, you type **s** multiple times to cycle through the nets.

One nice feature often used for debugging is that, when MAX selects a net, the name of all of the text labels on that net are displayed in the **MAX Message Area** (at the top, just to the right of the menus). For example, if you select **VDD** and the names **VDD** and **GND** both appear, you know you have a problem.

Additional Commands

Some of this is a repeat of earlier information. It's here again simply as a reminder.

- The **Cursor Probe** command is another way to see which layers and objects are under a particular point.

  — To ***Probe***, put the mouse over some layout geometry in your cell and select the **Cursor Probe** hotkey: **l** (lower case L).

  — You could also choose **Cursor Probe** from the **Select** menu, then point at the location you want to probe. The **Cursor Probe** menu that appears contains a list of all the layers and objects under that point.

  — To ***select a rectangle*** or other object, click on it in the pop-up with mouse **Button-1**. To deselect it, click again.

— By default, only items in the current edit cell are displayed, since those are the only ones you can effectively manipulate. But if you choose the **All Expanded Cells** radio-button, the list will contain everything in any cell under the point where you probed.

— You can also ***clear the selection*** by choosing **Clear Selection** from the **Select** menu.

- Another way of ***duplicating layout*** is to use the **Copy Cell Buffer** command in the **File** menu. This command will copy the current cell buffer to a new cell buffer in memory. The new cell will be saved to disk when you **Save** the cell (from the **File** menu.)

- The **Save As** command (also in the **File** menu) is similar to **Copy Cell Buffer**, but also immediately saves the cell to disk.

- If you are working on a cell and want to ***discard its contents***, perhaps to completely replace it with another cell, you can use the **Delete Cell Buffer** command (under the **File** menu) to delete the in-memory copy of a cell. This command does not affect the file on disk.

Part 5 Bigger Designs and Hierarchy

Now let's use our NAND gate and an inverter cell to build something a little bigger.

LAUNCH MAX USING MMI18

Step 1

- If you have quit out of MAX, start it using:

```
max -tech mmi18
```

Step 2

- Go to the **File** menu and select **New...**. Name the new cell "**row**".

You should now be editing **row.max**.

Look up at the title bar. It should say **max: B row**.

MAX does not automatically load all the cells in a library. Auto-loading all the cells can be done from the Cell List if all MAX cells in the directory use the same technology, or by adding it to your **max.rc** file.

Because the tutorial directory contains both cells in the **mmi25** and **mmi18** technologies, we'll load the cells manually.

Step 3

- Select **Open** from the **File** menu, select **INV.max** and click **OK**. Do the same thing for **NAND2.max**.

You should now see **INV** and **NAND2** listed in the Cell List box.

- Click on "**row**" with the **RIGHT mouse button (Button-3)** to return to your new cell.

DROP A NAND2

Step 4

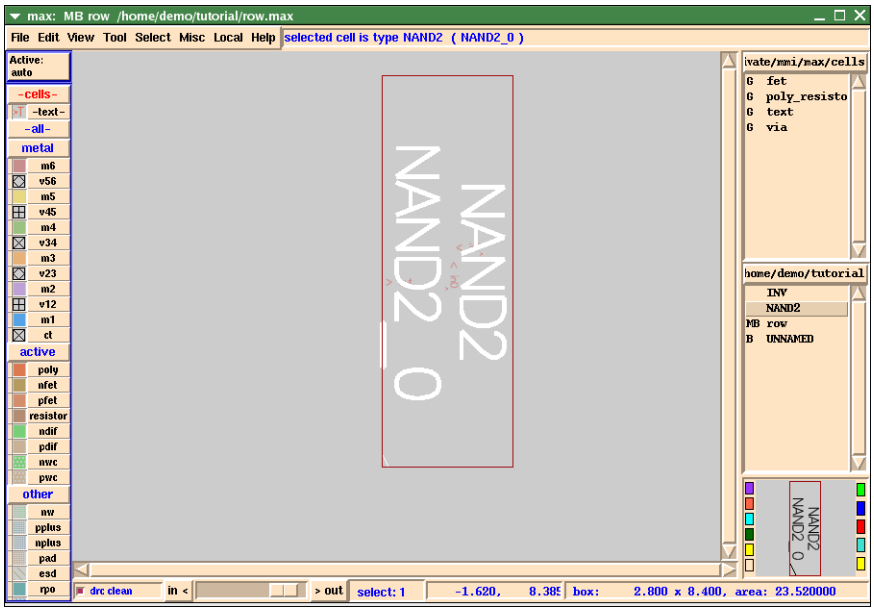
- In the Cell List box, click on **NAND2** with the **LEFT mouse button** (**Button-1**).

This ***drops an instance*** of **NAND2** into your row cell. Now you should see something like Figure 114.

You only see the *instantiation* of the **NAND2** cell and not the internals. We'll cover that later.

(Remember, clicking with the **RIGHT mouse button** (**Button-3**) ***loads*** that cell into MAX.)

Figure 114: Instantiation of NAND2 cell



Step 5

- This new cell should already be selected. If not, **select it** now by clicking on it with the **left mouse button** (**Button-1**.)

Set Up Array

Step 6

- Select **Array Cell...** from the **Edit** menu.

Step 7

- Enter *4* for the **columns** field and select **Duplicate Cell** for the **type**.

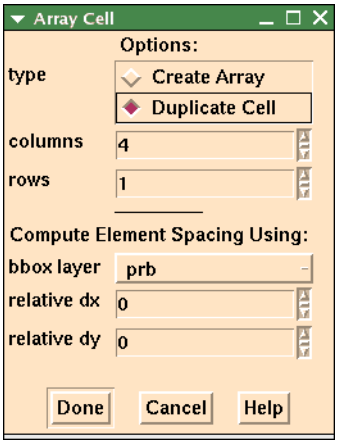
Step 8

- Look at **bbox layer**. By default it says **_bbox_** which is the rectangle containing all of the layout of the cell. For this cell the **nw** layer extends beyond the power rails, and we need to use the **prb** layer so that the wells overlap.
- Click on the rectangle to the right of **_bbox_**, scroll down and select **prb**.

The array cell pop-up should now look like Figure 115.

- Click on **Done**.

Figure 115: Array Cell Pop-up

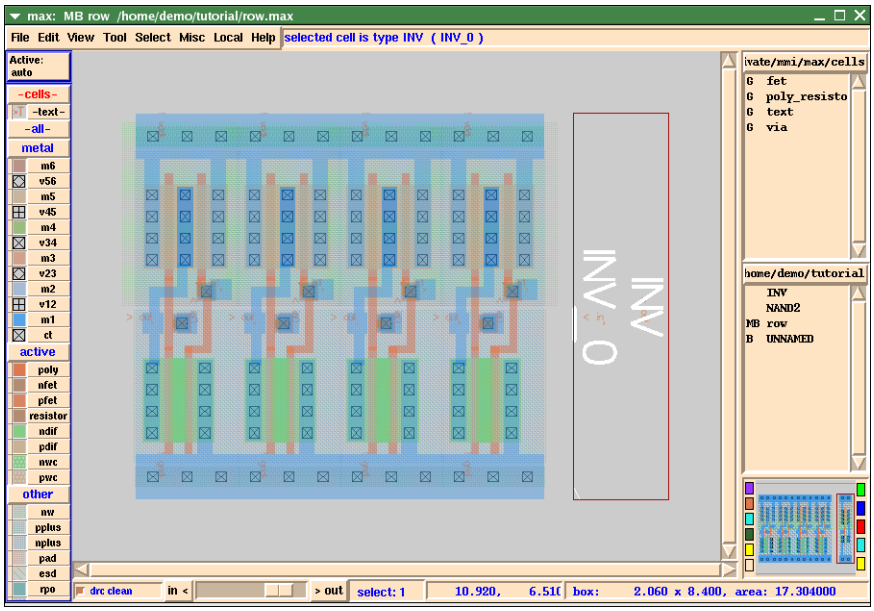


Step 9 ■ *Zoom out* (hotkey: **Shift-z**) so that you can see all of the **NAND2** instances.

Step 10 ■ Return to the Cell List box and click on **INV** with **Button-1**.

Step 11 ■ Place it to the right of the **NAND2** cells as shown in Figure 116.

Figure 116: "INV" Placed to the right of "NAND2" cell



POSITION INV CELL We now need to move the **INV** so that it abuts the **NAND2** gates.

Step 12 ■ The **INV** should still be selected. If not, select it by clicking it with **Button-1**.

Step 13

- Select one of the **NAND2** gates by holding down the **Shift** key while clicking with **Button-1**. You should now have the **INV** and one of the **NAND2** cells selected.

  The align command aligns all cells to the **last** cell selected. Select **Align Objects** from the **Edit** menu or type **Ctrl-a**. When the pop-up opens, align the objects to the **bottoms**. Then click on **Done**.

Step 14

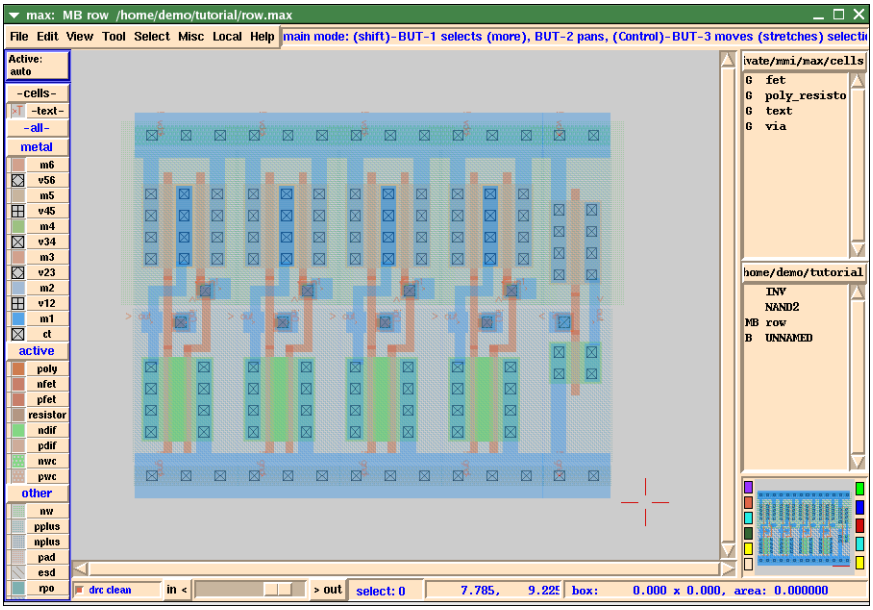
- Type the hotkey **i** to ***view the internals*** of all of the cells.

Step 15

- Select just the **INV** cell. We want to move it over so that the power rails abut. Hold down **Shift-Button-3** (***locks move either horizontal or vertical***) and move **INV** over until the power rails abut as shown in Figure 117. It will be easier to abut the cells if you zoom in on either the upper or lower power rails.

- You can also use the **left arrow key** to move the **INV** over one grid at a time.

Figure 117: MAX Hierarchy



While moving the inverter, white dots may appear indicating that the DRC check is working. DRC checking runs automatically as you go, and the dots disappear once the inverter is correctly positioned. The DRC status area in the lower left corner of the MAX window should say "**drc clean**".

Push, Pop, and Edit in Place

Let's look at editing hierarchical layout. At this point let's say our boss comes over again and says:

> "Sorry, but you need to bring the outputs to the bottom of the cells".

There are two ways to do this. We will use one method on the **INV** cell and the other (just to be different) on the **NAND2** cell.

First Method: Editing by Pushing Into Cell

EDIT BY PUSHING IN

Step 1

- First, select the **INV** cell by moving the cursor over **INV** and then using **f** or **Select Cell** from the **Select** menu. If you get a fet or row selected, type the **f** hotkey multiple times until **INV** is selected.

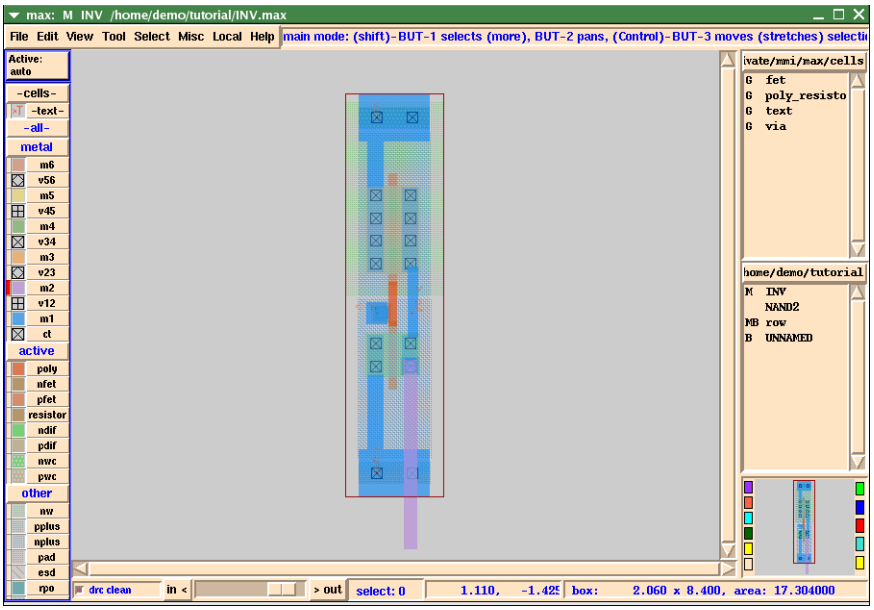
Step 2

- Now type **e** to ***edit the cell*** or select **Push into Cell** from the **View** menu.

Step 3

Once inside the cell, using the **wire mode** you'll:
start the wire (**w**) at the right nfet contact region, and using **Button-1** move the mouse down,
drop (**d**) a contact to **m2**,
anchor (**a**) the via, move the mouse downward past the **GND** power rail and
end the wire with **Button-3**. Refer to Figure 118.

Figure 118: Editing "INV" Cell - Wiring Output



Step 4

- Now type **Ctrl-e** or **Pop out of Cell** from the **View** menu to "pop" up a level and return back to **row.max**.

You should now see that the change you made is in the **INV** cell within **row.max.**

Second Method: Editing Cell or Object in Place

EDIT IN PLACE

Now let's edit the **NAND2** cell. To do this one we are going to use the **Edit Cell or Object in Place** option from the **View** menu.

Step 5

- Select one of the **NAND2** cells, then type **Shift-e** to **Edit in Place**.

Notice that the **NAND2** cell you selected appears darker than the other cells. This tells you that you are now editing that cell.

Step 6

- Go ahead and add your new wire just as you did for the **INV** cell. You will need to put the **m1** to **m2** via directly over the nfet contact region.

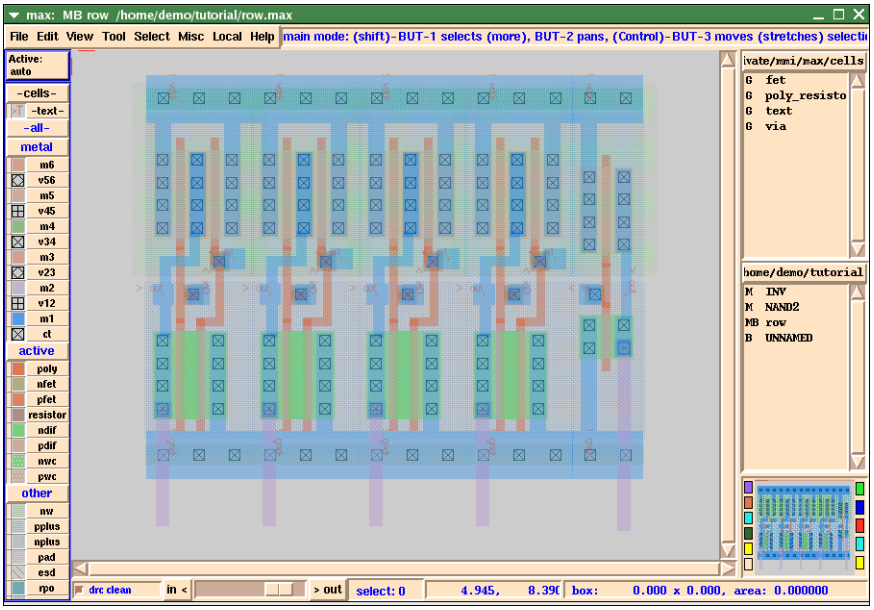
  Observe that the wire appears in ALL INSTANCES of **NAND2**, not just the one you are editing. Look down at the DRC status in the lower left corner of the MAX window and it should say **drc clean**.

Step 7

- Type **Ctrl-e** to ***pop back up*** to the top level (row).

Your row cell should now look like Figure 119.

Figure 119: Outputs Brought Out to Bottom



Now, just for grins, let's wire up two of the gates.

Since we want to wire them up in **row.max** and NOT in **NAND2.max**, we must first make sure **row.max** is our ***edit cell***.

NOTE: You can always tell which cell you are editing by looking at description in the **MAX Title Bar**.

To get back to **row.max** (if you're not there already) there are different methods:

- Type **Ctrl-e** a few times or until you are sure you have popped out of any cells you entered when using **Shift-e** or **Edit Cell or Object in Place** from the **View** menu. Watch the **MAX Title Bar**.

- You can also click with **Button-3** on **row** from the Cell List box.

In general, ***push***, ***pop***, and ***edit in place*** work well for cells in the same hierarchy, while using the Cell List boxes is the preferred method for traversing larger, less connected databases.

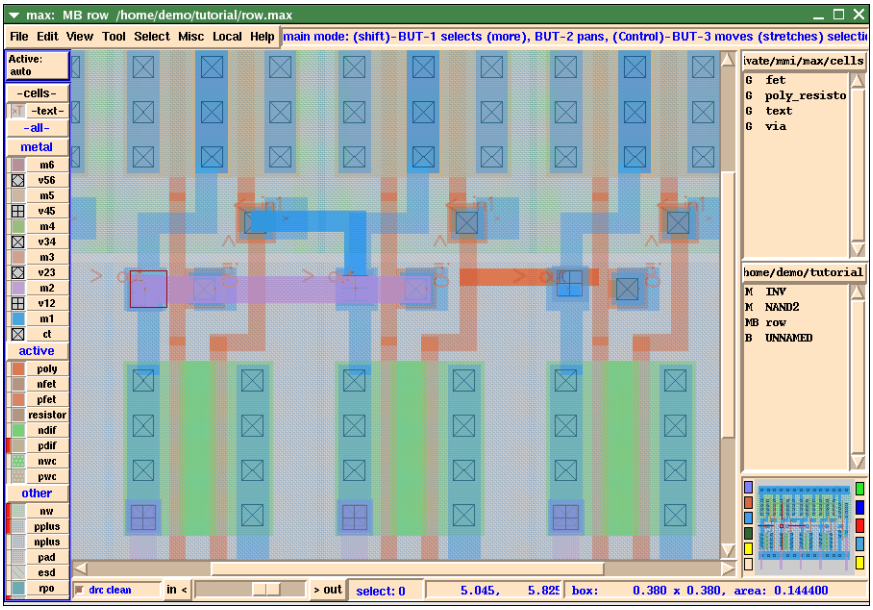
Step 8

- Now that **`row.max`** is your edit cell, use the **wire mode** to hook up a couple of wires.

  Notice that these wires are once again darker than the wires in the cells.

Figure 120 shows a zoomed in view of a couple of gates wired up within **`row.max`**. You can see that the new wires in **`row.max`** (the current edit cell) are darker than the wires contained within **`NAND2.max`** and **`INV.max`**.

Figure 120: Cells Wired Up



Let's save our work.

Step 9

- Select **Save Multiple** from the **File** menu, and then **Save Edit Cell and Descendents.** This saves the current edit cell row, as well as any modified cells that are instantiated in that row.

Step 10

- Exit out of MAX by typing **Ctrl-d** or selecting **Exit** from the **File** menu.

If you have made changes to cells since your last save, you'll get a warning pop-up message. You can either **Exit and Lose Changes**, or **Cancel** and save the cells.

Part 6
3D Designs

Introduction to 3-D Layout

In order to create and edit three-dimensional layout you need a MAX-3D license. If you do not have a MAX-3D license, skip this part of the tutorial and continue with the next section.

MAX-3D is a true 3-Dimensional layout editor, handling multiple technologies with true Through-Via capability. **Through-Si Via Wafer Stacking** is a technology allowing faster interconnects between discrete wafers. This is accomplished by connecting wafers of varying technologies together with vias through the wafers yielding a single 3-D stacked chip.

- For example, a Microprocessor in 32 nm technology can be combined with a Memory in 65 nm technology and an Analog device in 180 nm technology without writing a new technology file.

With MAX-3D, chip levels (wafer levels) can be edited separately, or concurrently — without writing a new tech file. Tech files for each wafer level (plane) are maintained individually, and you can edit technologies for different wafer levels in the same view. A simple 3D technology file needs to be created to describe the technology for each wafer level and how the wafers are connected with thru-silicon vias. We'll cover the 3D technology file at the end of this section.

MAX-3D comes with a sample technology, **mmi3d**. This **mmi3d** technology has three wafer levels, each with a different technology. The bottom level is in the **mmi25** technology. The middle level is in the **mmi18** technology and is flipped. The top level is in the **mmi15** technology and is also flipped.

```
mmi3d technology:

        CL3: mmi15 on top (flipped),
        viaT2T3: connect from m6 (CL3) to m1 (CL2)
        CL2: mmi18 in middle (flipped)
        viaT1T2: connect from m6 (CL2) to m5 (CL1)
        CL1: mmi25 on bottom (not flipped)
```

Each wafer **LEVEL** (chip level) is comprised of several different **LAYERS** used in its particular technology. Additionally, wafer/chip **LEVELS** also have **LEVELS OF HIERARCHY**, as defined by the design itself.

In this tutorial:
"**Level**" refers to the chip/wafer level;
"**Layer**" refers to the metal, silicon or poly used to create layout; and
"**Hierarchy Level**" is generally used with "**Level of Hierarchy**" describing the hierarchy of the layout.

Figure 121: 3D View of Layout

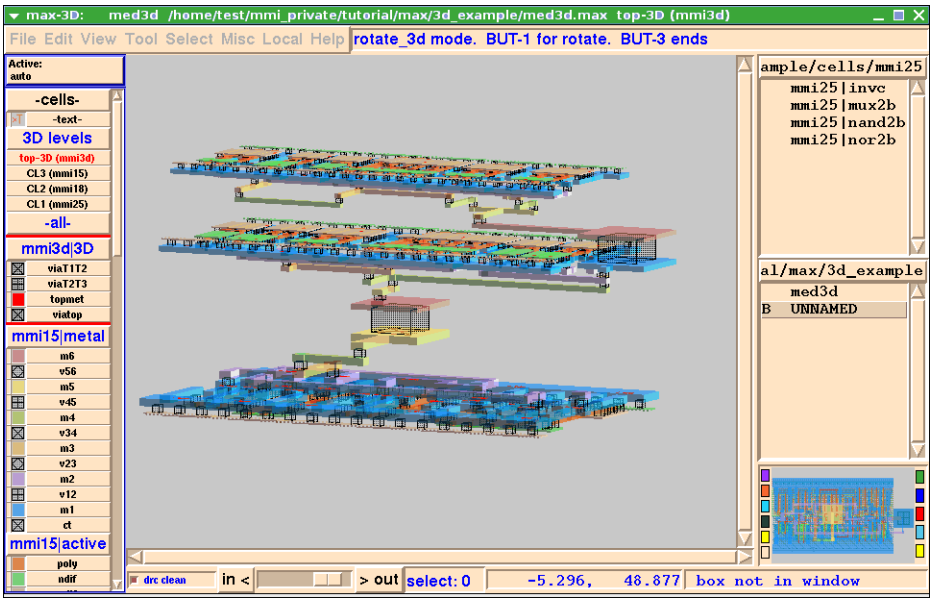


Figure 121 is the 3D view of the 3D layout. ***All editing is done in the 2D view.*** There are some standard cells in each of the 3 technologies.

- The bottom level, **CL1** is in the **`mmi25`** technology using 5 layers of metal.
- The next level, **CL2**, is in the **`mmi18`** technology using 6 layers of metal. This middle wafer level, **CL2**, is flipped, and there is a via (black 'mesh' of dots) connecting M5 in the bottom wafer level, **CL1**, up to M6 in the middle wafer level, **CL2**.
- Because the top wafer level, **CL3**, is also flipped, the via connects from M1 in the middle level, **CL2**, to M6 in the top level, **CL3**.

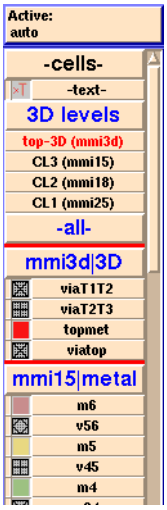
In order to edit the layout, you will need to understand how the MAX-3D Palette is arranged. All editing occurs in the 2D editing mode, on the layers of the currently selected chip level.

MAX-3D Palette

The MAX-3D palette is a combination of the palettes used in each technology, along with additional information concerning the 3D portion of the layout. At the top of the palette are the **3D levels** buttons, as shown in Figure 122.

- In this example there are three levels; **CL1**, **CL2**, and **CL3**. Notice that the technology used in that level is listed in parenthesis. The levels are also listed from top to bottom of the 3D stack.
- Above the three levels is **top-3D** which is the "top" level of the wafer stack. This is the level where the 3D thru-silicon vias and any metal which is not part of those 3 technologies goes.

Figure 122: Top of MAX Palette in 3D Mode



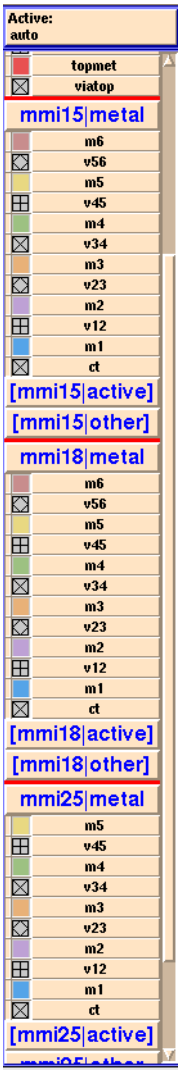
If you mouse over one of the levels in the palette, the functionality of the mouse buttons is displayed in the MAX message area; for example:

```
BUT-1 switches to level, BUT-2/3 toggles level visibility
```

To edit a chip level, that level must first be selected.

- Each level (or wafer level) contains different LAYERS as described in its technology file.
  - When using the "**Select Net**" command, the layer over which you execute the command must be in the currently selected chip level (wafer level) or **top-3D**. The selected net will be highlighted through all planes of the chip.
  - If the top plane, **top-3D**, is selected, **Select Net** works regardless of which plane the layout is in under the mouse.
  - Next in the palette is the **layer list** for the thru-silicon vias and top level metal. Any other connection layers which are part of the wafer stack and not part of the individual wafers are also listed here.
- Below the 3D layers is the list of layers for each technology. In Figure 122 the **-active-** and **-other-** layers have been hidden to make it easier to see all 3 technologies.
  - If you click with **Button-2** on a **group name** it toggles the hiding of layers in a group. The layers listed are taken from the technology files for each of the separate technologies.

Figure 123: Lower Section of MAX-3D Palette



Viewing Layout in MAX-3D

LAUNCH MAX-3D

Lets have a look at a sample 3D layout in MAX-3D.

Step 1

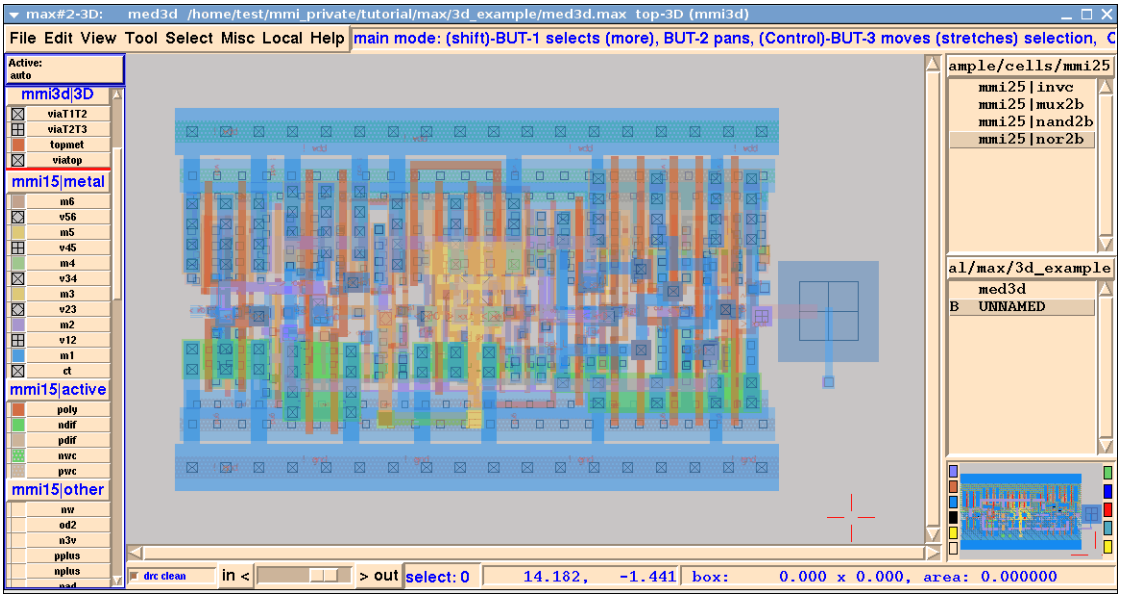
- If you still have a MAX window running, quit out of it (**Ctrl-d**). Then do the following:
- Quit out of MAX. Then, start MAX-3D using:

```
cd 3d_example
max3d med3d.max
```

You should now see something like Figure 124.

Each wafer level has some standard cells placed in a row and routed together. If you look at the palette, you'll notice that the visibility of the **other** group of layers for each technology has been turned off just to make viewing easier. This was done automatically in the **`max.rc`** file. The chip doesn't do anything; it's just a simple example so that you can see how MAX-3D works.

Figure 124: 3D Design Loaded into MAX-3D



Let's have a look at this layout in 3D view.

Step 2

- Type the "**Display View in 3D**" hotkey **Alt-z**.

You should now see something similar to Figure 126.

— The bottom of the wafer stack has some cells in the **`mmi25`** technology.

— You can see a thru-silicon via connecting up to the middle wafer which is in the **`mmi18`** technology.

— Finally, you'll see another thru-silicon via connecting up to the top wafer which is in the **`mmi15`** technology.

- If you remember from the MAX-3D viewing earlier in this tutorial, you hold down the **left mouse button** and move around to rotate and tilt the 3D view

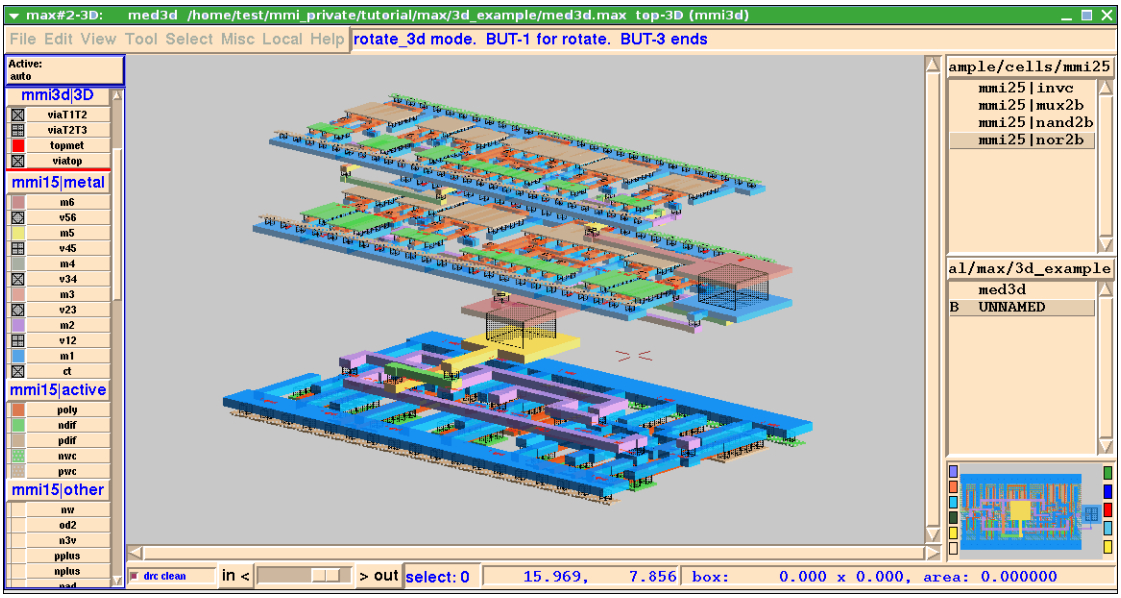
.

We're not viewing the actual thicknesses or spaces between layers or wafer levels. The distances between wafer levels is drastically larger the the distance between layers in a chip, so if we tried to view the actual distances we woul.dn't see much. The values for thickness and vertical space can be changed in the technology file.

Step 3 ■ Hold down **Button-1** and move the mouse around to tilt and rotate the layout.

Step 4 ■ Exit 3D viewing mode (click with **Button-3**).

Figure 125: 3D View of Sample Layout



CONTROLLING VISIBILITY OF LEVELS

Let's say we want to have a look at our bottom wafer which is CL1. We'll need to turn off the visibility of CL2 and CL3.

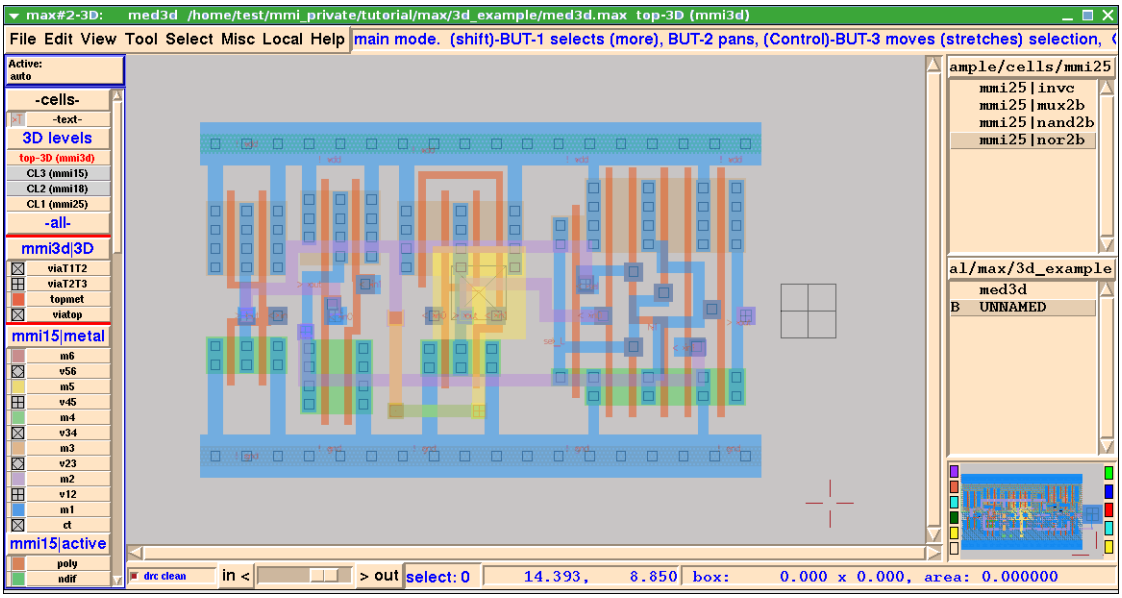
Step 5 ■ Click the **RIGHT mouse button** on the **CL2** and **CL3** buttons toward the top of the palette.

You should now see something similar to Figure 126.

— Notice that the **CL2** and **CL3** buttons are greyed out, meaning they are not visible.

— The text of the **top-3D** button is **red**, meaning this is the active level. So if a wire were started, it would start in **topmet** which is the only metal at the 3D level.

Figure 126: Visibility of CL2 and CL3 Turned Off



With **CL2** and **CL3** visibility turned off, we can easily see the layout the is in **CL1**. Notice that we also see layout on **top-3D**, in this case the two thru-silicon vias.

Step 6

- Select **CL1** as the current chip level and notice that the wires get darker/brighter You can switch between **CL1** and **top-3D** to see the change.

Only the wires are darker because, if you remember from earlier in this tutorial, only layout on the top level of hierarchy is darker. Since the rest of this chip level is comprised of instantiations of standard cells, their layout is in a lower level of hierarchy.

Step 7

- Click on **CL2** and **CL3** with **Button-3** to turn visibility back on.

Creating and Editing Layout in MAX-3D

We're going to create an even simpler example to help see how MAX-3D works. First we need to create a 3D cell into which we'll place our 3D layout.

Step 1

- From the **File** menu, select **New**.
- Notice that you can create a cell in the current technology (whichever level name is highlighted in red), or specifically determine the technology. Just to be safe (in case you accidentally have a different level selected):

Step 2

- Click on New mmi3d cell

Step 3

- For the Filename, type my_3d and click on OK.

Now we are going to add a cell to each chip level. We're going to be placing the cells "next" to each other so it'll make it easier to understand. Normally wafer levels are placed on top of each other.

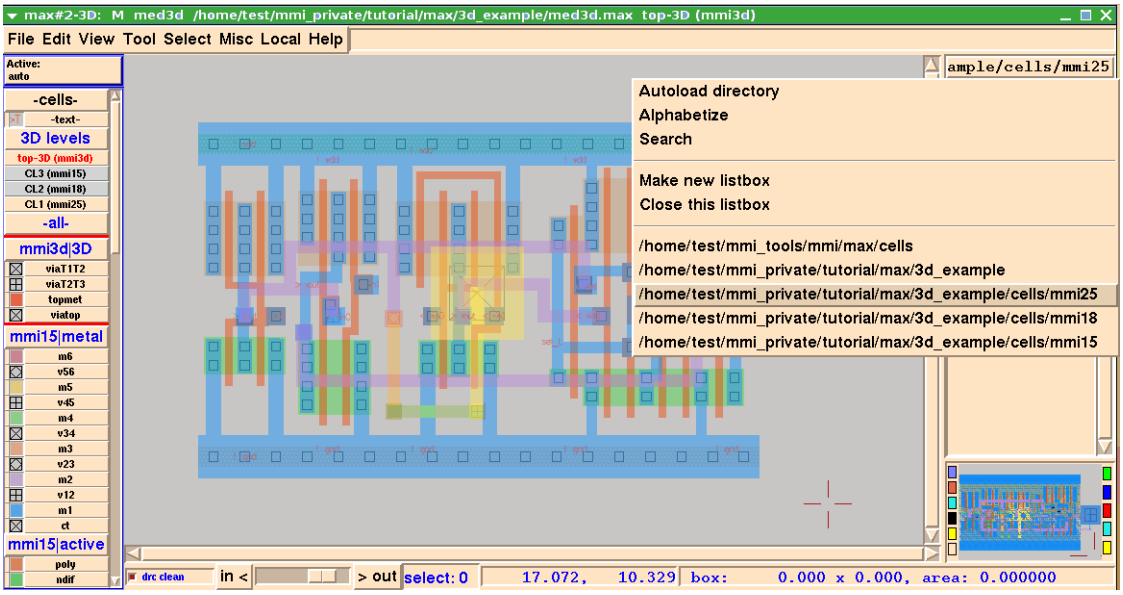
Step 4

- With the **LEFT mouse button**, click on **CL1** in the **3D Levels**. The text **CL1(mmi25)** should now be **red**.

Step 5

- Go over to the top cell list which should be listing the **mmi25** cells. If not, hold down the **Button-1** over the title on top of the cell list and select "**.../cells/mmi25**" as shown in Figure 127.

Figure 127: Selecting Directory for "mmi25" Cells



PLACING CELLS ON BOTTOM WAFER

Now, we'll place a cell on the bottom wafer level.

Step 6

- Click on **mmi25|nor2b** with **Button-1**.

An instance of **mmi25|nor2b** is now placed in our 3D cell **my_3d**. Notice the "**mmi25|**" prepended to all of the cells in the cell list. This means all these cells are in the mmi25 technology. As well see later on, we have cells named **invc**, **mux2b**, **nand2b**, and **nor2b** for each of the 3 technologies.

— MAX differentiates between each cell by prepending the technology name. The name is only changed in the MAX database. If you export one of the 2d levels to GDSII, the original cells names will be used.

Step 7

- View the internals of the cell by typing the hotkey **i**.

PLACING CELLS ON NEXT WAFER UP

We'll now place a cell in the next wafer level up, **CL2**.

Because each chip level in our 3D example uses a separate technology, MAX will automatically change to the correct level based on the technology of the cell you are placing. Since this is often not the case and multiple levels may have the same technology, it's a good idea to get used to selecting the correct chip level before placing instances.

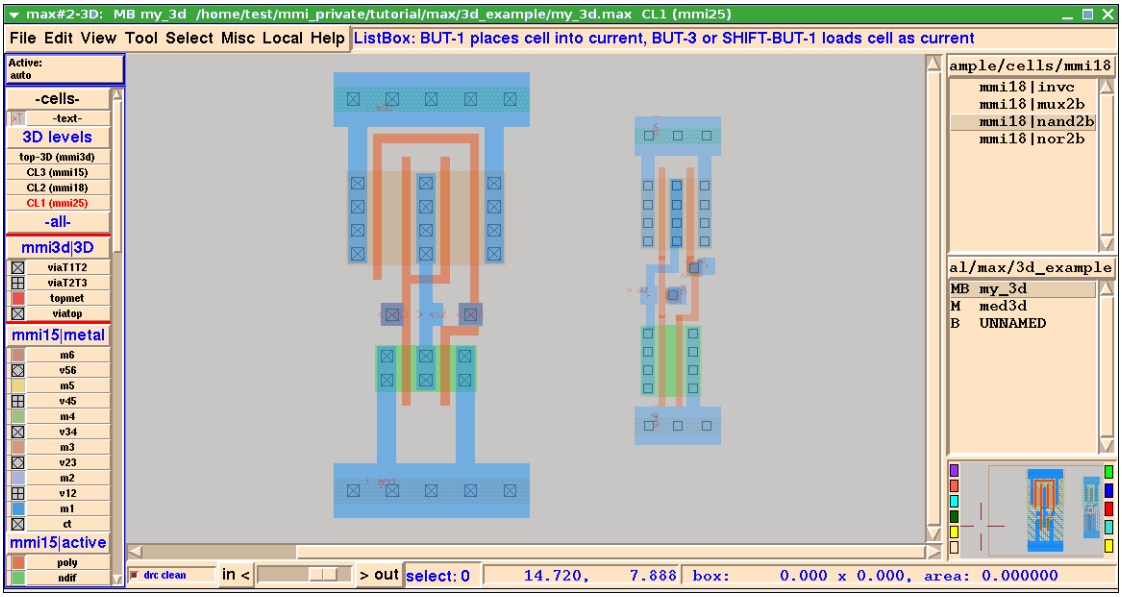
Step 8

- Click with **Button-1** on **CL2** in the palette to ensure the text **CL2(mmi18)** is red (active and selected).
- Then go the the top cell list, hold down **Button-1** on the title bar and select "**.../cells/mmi18**".

Step 9

- Click on **mmi18|nand2b** and place it to the right of the **mmi25|nor2b** that we placed earlier. View the internals (hotkey: **i**).
- You should now see something similar to Figure 128. We can tell that this is definitely a different technology as the cell is significantly smaller.

Figure 128: Cells Placed in Two Wafer Levels



Placing Cells at Top Wafer Level

Finally, we'll place a different cell at the top wafer level.

Step 10

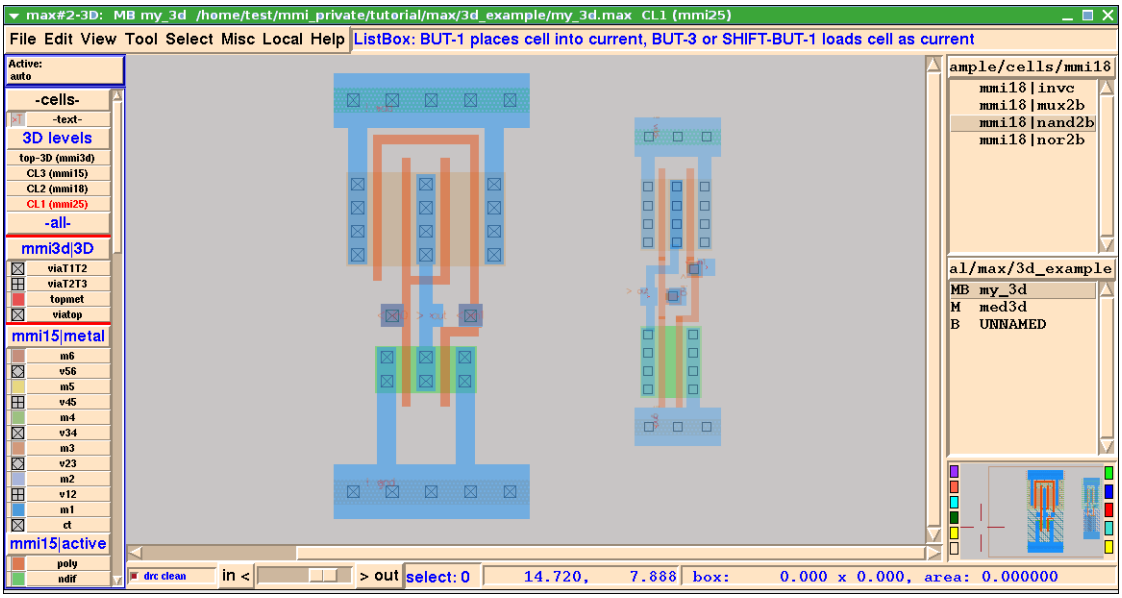
- Click with **Button-1** on **CL3** in the palette so the text **CL3(mmi15)** is red. Then go the the top cell list, hold down **Button-1** on the title and select "**.../cells/mmi15**".

Step 11

- Click on **mmi15|mux2b** and place it to the right of the **mmi18|nand2b** that we just placed. View the internals (hotkey: **i**) and zoom to fit (hotkey: **v**).

Your layout should now look similar to Figure 129. If you look at the layout in 3D view (hotkey: **Alt-z**), you should see each of the cells on a different wafer level.

Figure 129: Cells Placed on all Three Wafer Levels



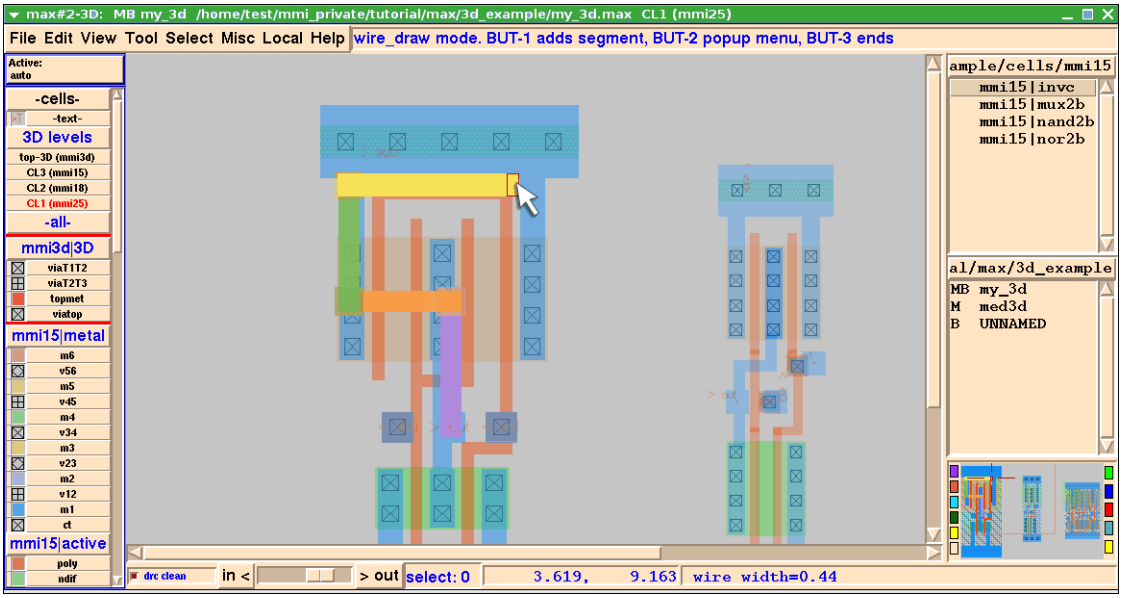
Wiring Between Wafers

Now let's wire our **CL1 nor2b** to our **CL2 nand2b**.

Step 12

- To start wiring in the bottom wafer, we need to first **select CL1** in the palette by clicking on it with **Button-1**.

Figure 130: Drawing a Wire



Step 13

- Move your mouse over the "out" pad on the left **mmi25** cell as shown in Figure 130 (above) and start a wire (hotkey: **w**). Click on the "out" pad to start the wire.

Step 14

- You'll need to immediately drop a via up to m2 so we don't create any shorts. Type **d** to drop a via and anchor it in place (hotkey: **a**).

Step 15

- Move the mouse up a little and drop another via (hotkey: **d**) up to m3, move to the left and drop a via (hotkey: **d**) to m4, move up again and drop a via (hotkey: **d**) up to m5, similar to what's shown in Figure 131.

- If we try to drop another regular via up, you'll get the warning:

  Warning: can't add via above mmi25 | m5. No more layers

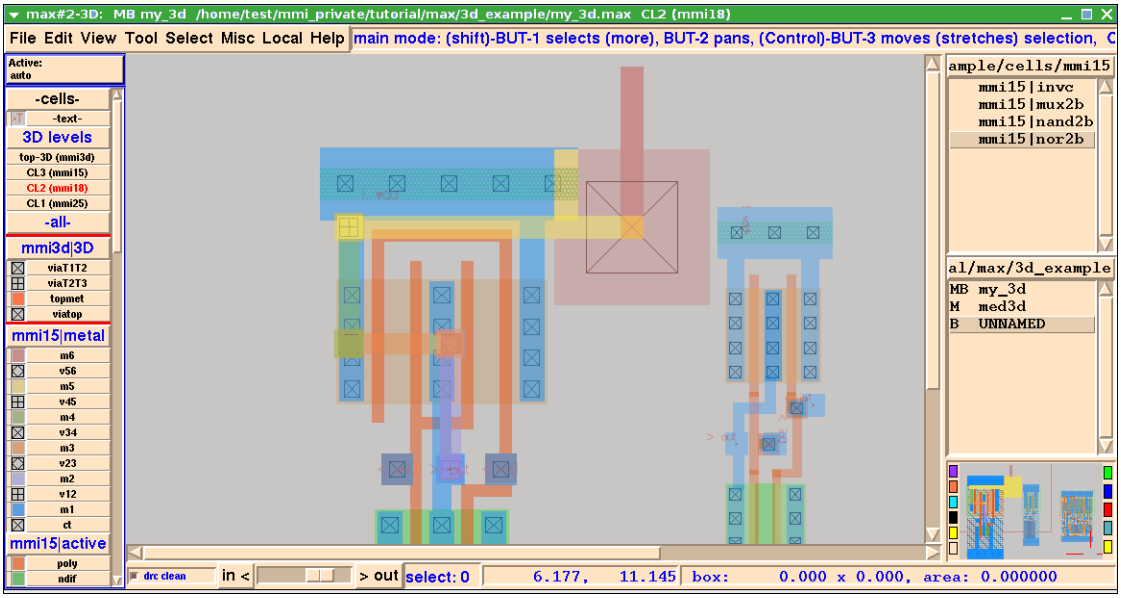
  If this occurs, simply close the warning popup.

Step 16

- While still in wire mode, hold down the **middle mouse button** (or type **Space**) to see available options. Notice the hotkey **t** does a "**drop 3Dvia up**". Select it from the menu, or type **t**. Drag the mouse up and end the wire (**Button-3**).

You should now see something similar to Figure 131.

Figure 131: First Part of Wire Finished



Take a look at the palette and notice that **CL2(mmi18)** is not red (active).

— When you added the 3D via up MAX-3D automatically switched the selected chip level.

- Scroll down in the palette until you see the **mmi18|metal** layers.
- Now move over the piece of red wire with which you ended your wire. Notice that the red box to the left of m6 under the **mmi18|metal** layers. This means when you dropped the 3D via up it went from **CL1** m5 to **CL2** m6.

  Remember that the middle wafer level is flipped so that m6 is on the bottom. So, now when we drop vias to get to the in1 input on our nand2b, we'll be dropping vias down.

Step 17

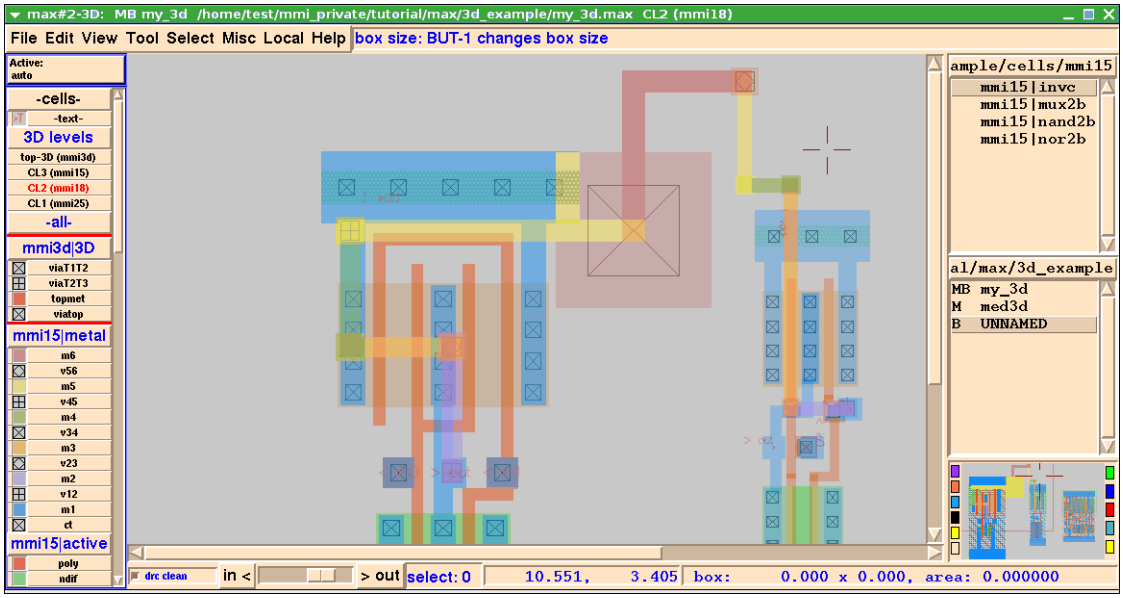
- Move over the piece of m6 where you ended the wire. Start a wire (hotkey: **w**) and click with **Button-1** on the piece of m6.

Step 18

- Move the mouse to the right, drop a via down (**shift-d**) to m5, move the mouse down, drop a via down (**shift-d**) to m4, move the mouse to the right, drop a via down (**shift-d**) to m3, move the mouse down, drop a via down (**shift-d**) to m2, move the mouse over to the in1 input of the nand2b gate, drop a via down (**shift-d**) to m1, and end the wire (**Button-3**).

You should now see something similar to Figure 132. Notice the DRC status box at the bottom of the MAX window. In this example there is one DRC error. You may not have any DRC errors, but if you do let's fix them.

Figure 132: CL1 and CL2 Wired Together



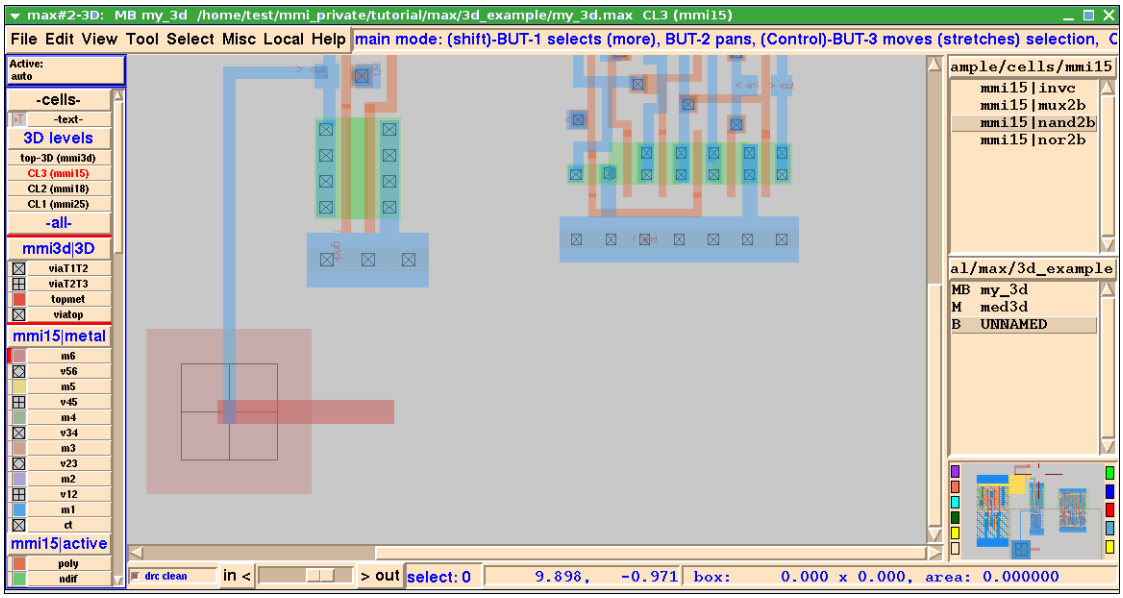
Step 19

- Fix any DRC errors you may have if you want to. It's not required for the rest of the tutorial, but it's alwbays good practice. Remember to look at the DRC status area for the number of DRC errors. If you can't see any error, the hotkey **Shift-n** will zoom you in to the next DRC error.

Finally we're going to wire **CL2** and **CL3** together. Since both levels are flipped we'll be going from **CL2** m1 up to **CL3** m6. When you do this for a real wafer, you will have left adequate space to place the **viaT2T3** without shorting out the other m1 in your chip. To get around this for our case, we'll bring the output of the nand2b down below the cells away from the standard cell.

Check the palette to make sure CL2 is red and therefore the selected level. ***Start a wire*** (**w**) and click on the out pad of the nand2b. Move to the left and add a corner (**left mouse button**). Drag the mouse down below the standard cells as shown in Figure 133.

Figure 133: Beginning of Wire Between CL2 and CL3



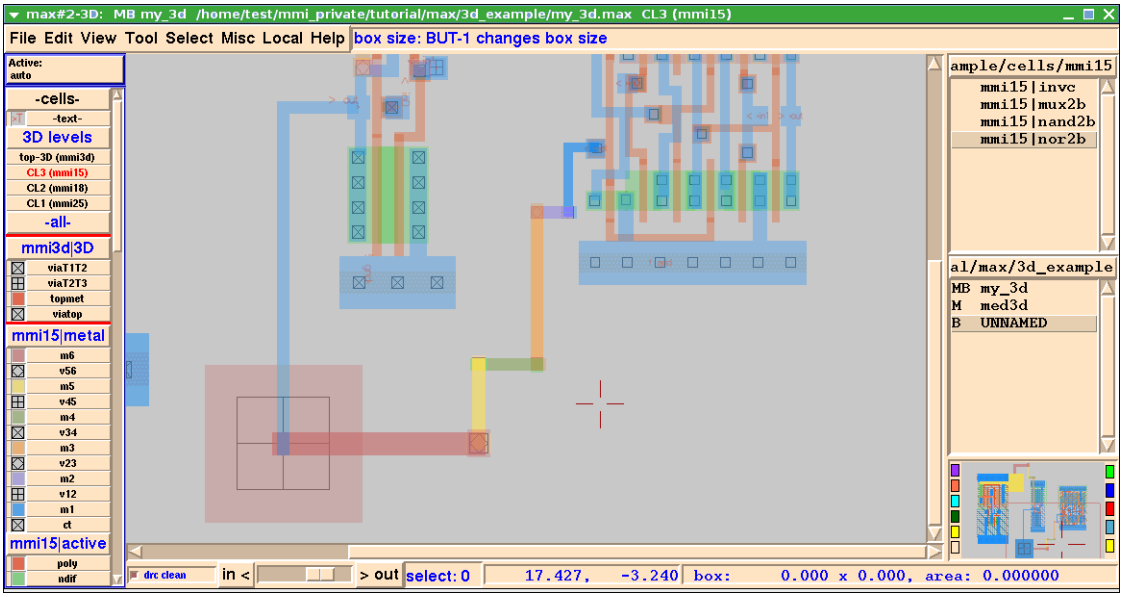
Step 20

- Now drop a 3D via up (hotkey: **t**) and move your mouse to the right as shown in the figure above.

Step 21

- Drop vias down (**Shift-d**) until you get to m1 and end the wire (**Button-3**) on the sel routing pad, as shown in Figure 134.

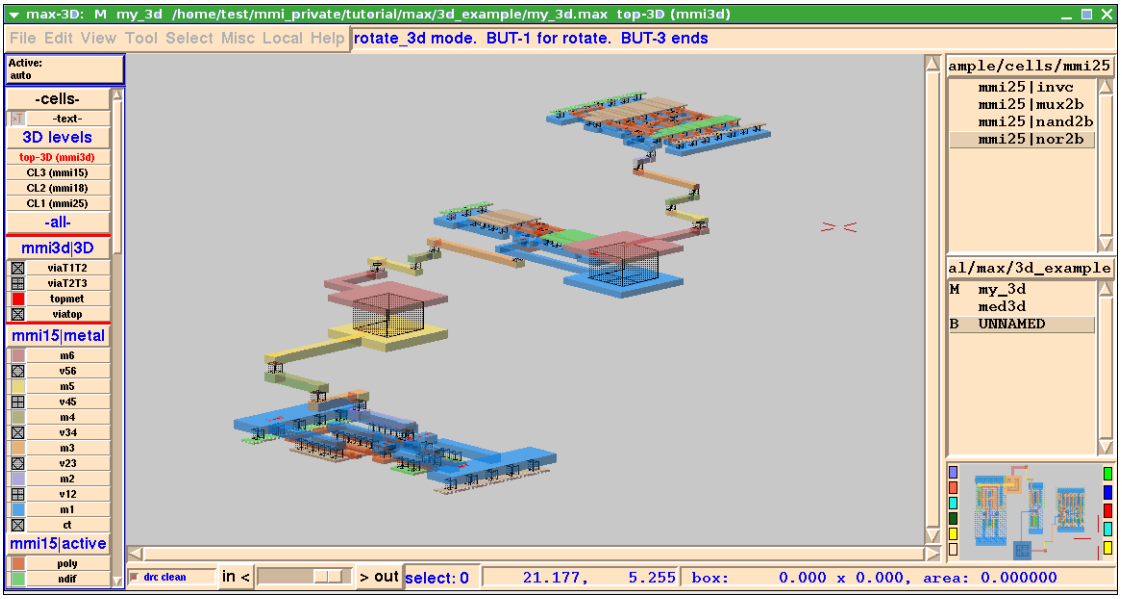
Figure 134: Wire Between CL2and CL3Completed



You can now view your layout in 3D to confirm that everything is correct.

Step 22 ■ Type the **Alt-z** hotkey and you should now see something similar to Figure 135.

Figure 135: Finished Layout in 3D View



As you are doing wiring in MAX-3D, it's a good idea to check your progress using the 3D view. If you have the wrong level selected when you start your wire, the the wire will not be at that level and 3D view shows you the problem.

— From earlier in the MAX tutorial, we talked about the **Active layer** at the top of the palette. If it is set to **auto** (the default), the wire tool starts on the routable layer under the cursor. If no layer is under the cursor, it starts in m1. This means that MAX will look for a routable layer under the cursor on the currently selected wafer/chip level

Notice that the rectangles making up the wire in **CL3** are slightly darker than the rest of the layout. This is another way you can see which chip level is selected, meaning that any layout in **CL3** at the top level of hierarchy will be darker.

Flattening Cells in 3D

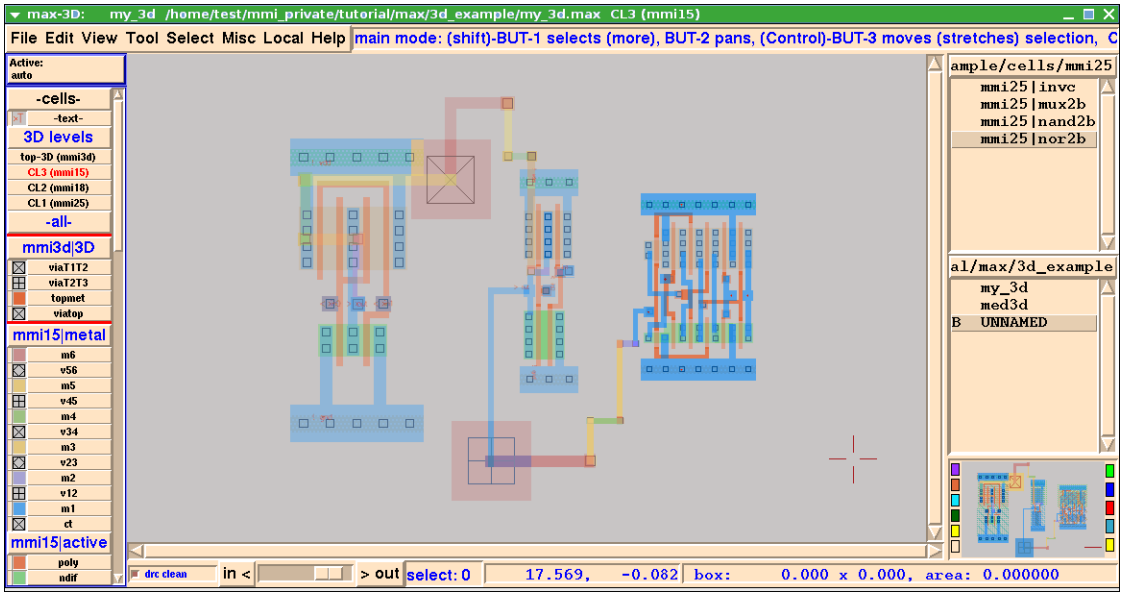
In our example, the standard cells are one level of hierarchy, so they are not brighter. Let's flatten one of the standard cells so this becomes more clear.

Step 23 ■ Save your work (**Ctrl-s**).

Step 24 ■ Zoom to fit all (**v**), then select the **mux2b** cell and select **Flatten Cells...** from the **Misc** menu. Keep the default options and click on **Done**.

You should now see the entire **mux2b** is darker/brighter than the rest of the layout as shown in Figure 136.

Figure 136: "mux2b" Cell Flattened



Step 25

- Undo (hotkey: **u**) the flatten.

Selecting Objects and Nets in MAX-3D

We'll now look at selecting nets in MAX-3D. As we mentioned earlier, if you have one of the chip levels (**CL1**, **CL2**, **CL3**) selected, then MAX-3D will only select objects or nets under the cursor on that chip level. If the top level (**top-3D**) is selected, then MAX-3D will select objects or nets on any chip level. Let's select some objects.

Step 1

- Select chip level **CL3** in the palette. Now you'll only be able to select objects and nets on **CL3**.

Step 2

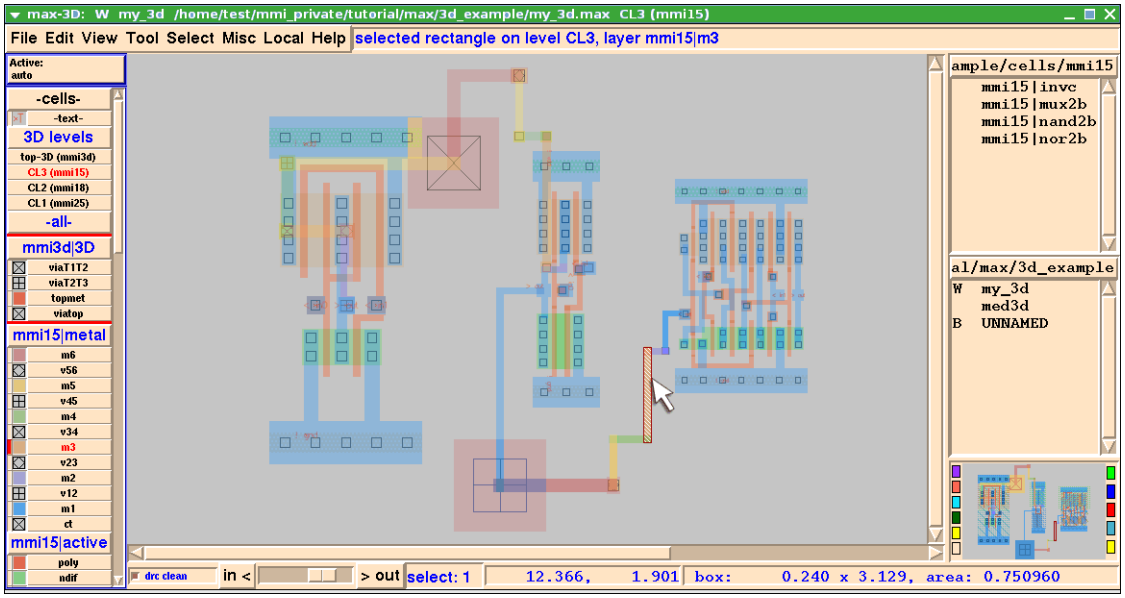
- Click with **Button-1** over the **mmi15|mux2b** from the List Box at the right. Notice that the **mux2b** cell is selected. Now click with **Button-1** over the **mmi18|nand2b** in the middle. Notice that nothing is selected because it is not on our current cell level, **CL3**.

Step 3

- Click with **Button-1** on a m3 rectangle in **CL3** as shown in Figure 137. The m3 rectangle is selected. The MAX message area (to the right of the menus) should say:

  selected rectangle on level CL3, layer mmi15|m3

Figure 137: m3 Rectangle Selected on CL3



Step 4

- Now we will select a net. With your mouse over the same m3 rectangle, type the select net command (**s**).

You should now see something similar to Figure 138. The MAX message area should now say:

Selected nets: mmi15|mux2b_0/sel CL3

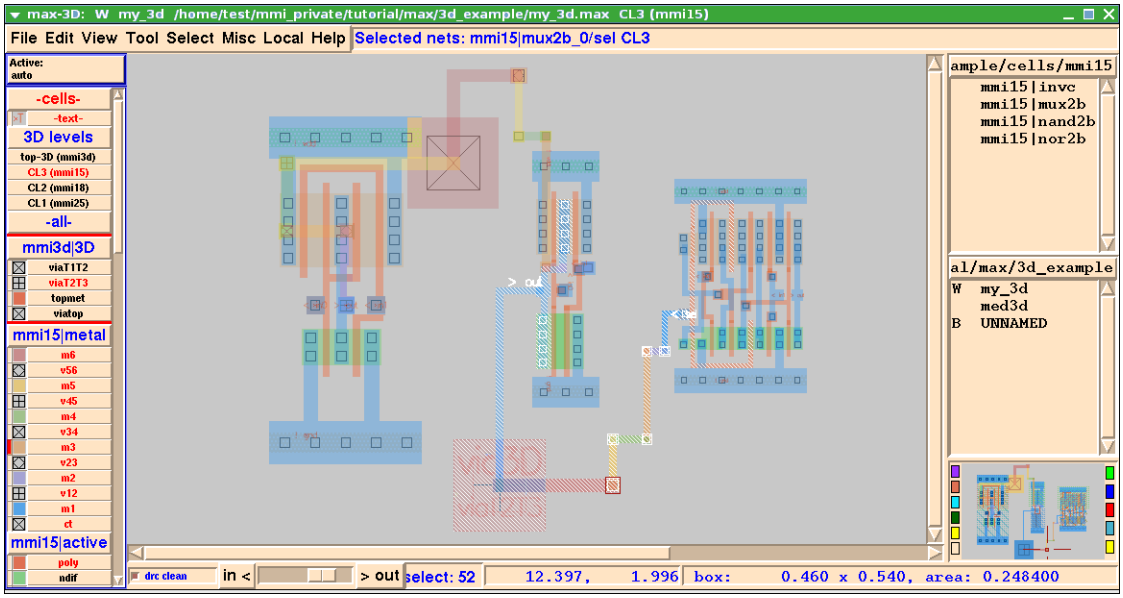
You should also see the same information printed in the MAX command window (the terminal from which you started MAX). MAX reports the net name as the path to the instance pin and the chip level. If we also had a piece of text (xyz) on the net, then the report would look like:

Selected nets: mmi15|mux2b_0/sel CL3 xyz CL3

So, MAX reports the pins and text attached to a net.

It's often helpful to arrange your windows so that at least the lower part of the command window is visible. There is often useful information printed there.

Figure 138: Net Selected on CL3



Differences in Levels Selection

Now we will look at the differences if we have the **top-3D** level selected instead of one of the three chip levels.

Step 5

- Click with the **Button-1** on **top-3D** in the palette. It should now be red text.

Step 6

- Click on the **mux2b** cell and the m3 rectangle and notice that the same information is printed in the message area. Select some of the cells and rectangles on the other chip levels. Notice that you can now select objects on any chip level.

Note: Even though you can select objects on any chip level when **top-3D** is the selected level, you can only edit objects on the **top-3D** level.

Step 7

- Now move your mouse to the same m3 rectangle and select the net (hotkey: **s**).

The same net is selected as when **CL3** was the selected level. But you should see something different reported in the MAX command window.

```
top-3D selected nets:

CL3 selected nets:
 mmi15|mux2b_0/sel
CL2 selected nets:
 mmi18|nand2b_0/out
CL1 selected nets:
```

MAX now also tells you the pin on **CL2** to which the net is connected.

Step 8

- Go ahead and try selecting different chip levels and then selecting objects and nets.

Importing GDSII Into MAX-3D and MAX-3D Tech Files

In the next section of this tutorial, we'll cover different ways of creating 2D MAX tech files. Here, we'll go over the differences when importing gdsii into MAX-3D and what's needed for the MAX-3D tech file.

Step 1

- First make sure you have **CL3** selected in the palette.

Step 2

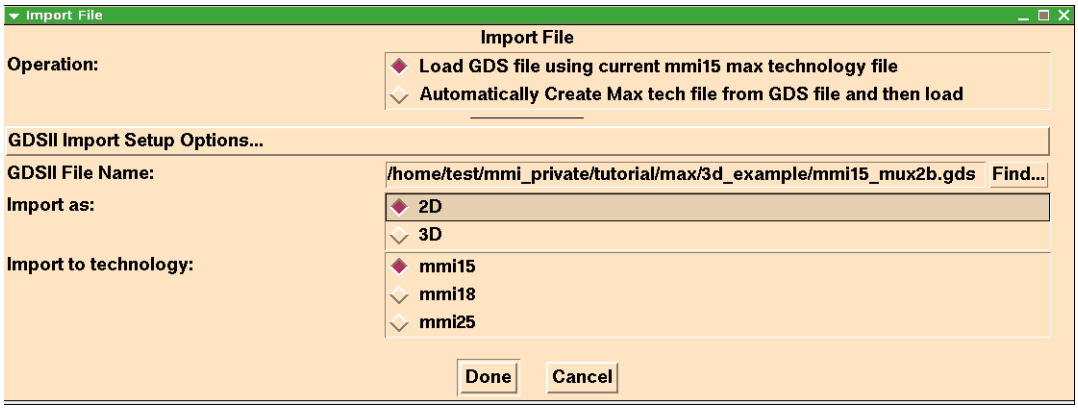
- From the **File** menu, select **Import File**. The **import gdsii popup** will appear. Click on the top option as shown in Figure 139.

Since we have **CL3** as the selected level, the top Operation says:

> Load GDS file using the current mmi15 max technology file

Generally you will have already created your 2D technology files using one of the methods described in the next section of this tutorial, so you'll want this option selected. Notice that you have an **Import as** option where you can select either 2D or 3D. If you select 2D, then the popup changes as shown in Figure 139. So it doesn't matter which chip level you have selected in the palette. You can import GDSII in any of the technologies.

Figure 139: Import File Popup in MAX-3D



Loading GDSII Files

In this section of the tutorial, all of the cells were in MAX format, not GDSII. Let's load one of the cells from GDSII.

Step 3

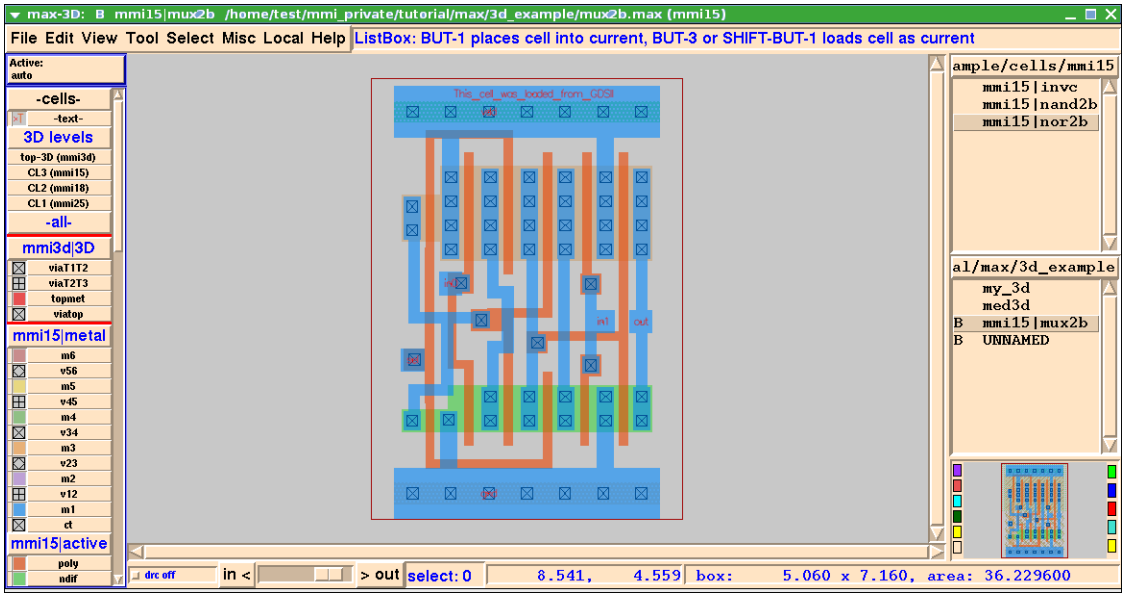
- Select "**Load GDS file using current mmi15 max technology file**", select **2D** to "**Import as:**" and **mmi15** as "**Import to technology:**" as shown in Figure 139 (above).

Step 4

- To the right of **GDSII File Name**, click on **Find**, select **mmi15_mux2b.gds**, click on **OK**, and then click **Done**.

You should now see something similar to Figure 140. If your top cell list is not already looking at **.../cells/mmi15**, select that directory. Notice that **mmi15|mux2b** is no longer listed here. Because we loaded this cell from GDSII, the new cell is what is used by MAX-3D. Notice the text "**`This_cell_was_loaded_from_GDSII`**" at the top of the cell. This makes it easier to tell which cell has been used. When multiple copies of the same cell (in the same technology) are loaded, MAX always uses the last one which was loaded.

Figure 140: "mmi15|mux2b" Cell Loaded From GDSII



Let's go back to our **my_3d** cell.

Step 5

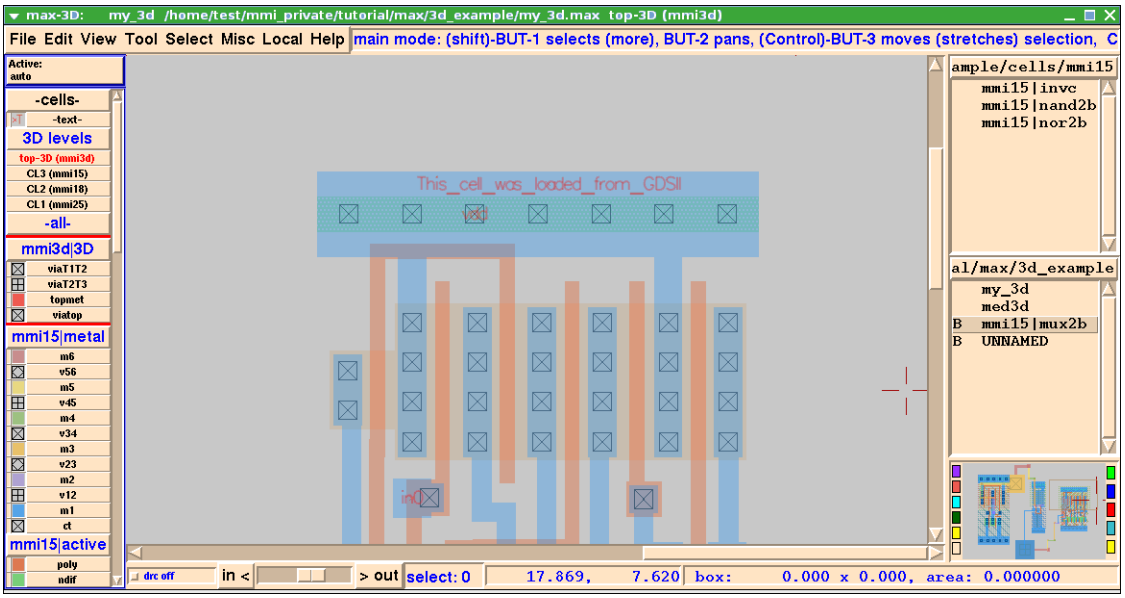
- In the bottom cell list, click with the **RIGHT mouse button** on **my_2d** to open this cell.

Step 6

- Zoom in on the upper right portion of this cell and you should see something similar to Figure 141.

Notice the text. We know the the **mmi15|mux2b** cell loaded from GDSII is being used.

Figure 141: New "mmi15|mux2b" Cell Used



For more information on importing and exporting GDSII files to/from MAX-3D, refer to the *MAX User's Manual*.

If you already have your MAX-3D technology file, you can skip this next section describing the MAX-3D tech file.

MAX-3D Technology Files

In order to use MAX-3D, some technology files are needed. You need MAX technology files for each chip level. They can be different technologies, as in this tutorial, or the same technology. The next section discusses how to create/convert 2D MAX technology files. In addition to the 2D technology files, you need a very simple 3D tech file. Refer to the following file for an example: **`$MMI_TOOLS/max/tech/mmi3d/mmi3d.source`**. We'll discuss each section.

- The first section specifies the 3D layers: these are the thru-silicon vias, and any metal layers or other vias used between chip levels or on top.
- As with regular 2D tech files, you specify the GDSII layer and datatype and the text layer and datatype, if any. The type for all of these layers is 3D.
- In order to use the wire tool, MAX needs to know the width and spacing rules for each layer.
- Finally, you can specify the color and fill type.

```
#Sample 3d tech file combining mmi25, mmi18, and mmi15

#layergds:dttxt:dttypewidthspacecolor
#=========== ============================
viaT1T215-3D1.751.45x:black
viaT2T317-3D1.751.45+:black
topmet41-3D 0.350.35solid:red
viatop27-3D 1.751.45x:black
```

The next section defines each of the chip levels and the technology for each chip level. MAX-3D will look for the technology files for each of the technologies listed. It's best to list the chip levels from top to bottom as shown here.

```
3d_level CL3 mmi15
3d_level CL2 mmi18
3d_level CL1 mmi25
```

The **`3d_top`** statement tells MAX-3D which chip level is the top when viewed in 3D. This statement is not necessarily needed as MAX-3D figures this out on it's own.

```
3d_top topmet
```

Next we have all of the connect statements. These are needed for the **wire tool** and for **select net**. The first connect is a regular connect statement as both viatop and topmet are at the same level.

```
connect viatop topmet
```

The rest of the statements are **`3d_connect`** as they describe connections between chip levels.

Let's look at the first line. It says the **viatop,** which is one of the 3D layers we defined, connects to m1 on chip level 3 (**CL3**). If you think about this, it tells MAX-3D that m1 is the top level metal on **CL3**, so **CL3** is flipped.

```
3d_connect viatop CL3 m1

3d_connect viaT2T3 CL3 m6
3d_connect viaT2T3 CL2 m1

3d_connect viaT1T2 CL2 m6
3d_connect viaT1T2 CL1 m5
```

The next set of statements describe the DRC rules for each of the 3D layers and the 2D layers they connect to. These statements are needed for the wire tool. If you will only be viewing 3D layouts and using select net, then this section is not required. Refer to the *MAX User's Manual* for more details on the DRC commands.

```
drc topmet enc viatop 0.625

drc viaT1T2 area 3.0625
drc viaT2T3 area 3.0625
drc topmet area 0.1225
drc viatop area 0.2025
drc CL1 m5 3d_enc viaT1T2 0.625
drc CL2 m6 3d_enc viaT1T2 0.625

drc CL2 m1 3d_enc viaT2T3 0.625
drc CL3 m6 3d_enc viaT2T3 0.625

drc CL3 m1 3d_enc viatop 0.625
```

This final section specifies the thickness of each 3D layer, otherwise it defaults to 1.0 um. 2D layers thicknesses are defined in the 2D tech file and default to either the minimum width of the layer if specified or 0.2 um if minimum width is not specified. You generally don't want to specify the actual thicknesses because the 3D and 2D layers are so different that it would be hard to see anything when viewing in 3D. These statements only affect the 3D view.

```
# 3D height information
set Z_DATA(thickness,topmet) 0.6

set GRID(resolution) 0.001
set GRID(mask) 0.001
```

If you have any questions about MAX-3D technology files, please contact Micro Magic at support@micromagic.com.

Part 7 Importing GDSII and Customizing MAX

Reading in GDSII Files and MAX Technology Files

Each GDSII or MAX layout file needs an associated **technology file** to describe the layer names, how layers connect to each other, and layer colors and fill patterns. This tech file contains the color (HSV or RGB), the transparency, and the dot/stipple pattern and/or outline settings, DRC rules and other information concerning each layer. It also contains information on how to map GDSII layer numbers to layer names.

The technology file we used for **`TOP_CHIP`** near the beginning of this tutorial is a generic technology created using Micro Magic, Inc. standard layer definitions and colors. When you read in your own GDSII file, MAX will need the information for that technology. We will cover two different ways for obtaining that information.

Creating Technology Files from GDSII Files

One way to get the technology information is to let MAX figure out what the layers are. You'll need to have a list showing you which GDSII layer numbers map to which layer names. This is used to verify that MAX picked the layers correctly. MAX generally figures out metal, via, and poly layers correctly for digital CMOS processes.

MAX will default to the Micro Magic layer color and fill patterns. You can modify these settings as needed, and as often as needed. Black background options are available for MAX technology files by adding the "**`-bb`**" modifier (example: **`-tech mmi18-bb`**).

IMPORTING GDSII FILES

For the purposes of this tutorial, we will be using an example GDS file included in the tutorial installation.

Step 1

- If MAX is still running, quit MAX (**Ctrl-d**).
- If you did the MAX-3D portion of this tutorial, you need to **`cd`** to the main tutorial directory: "**`cd ..`**"

If you do a "**`pwd`**" you should see the directory: **`~/mmi_private/tutorial/max`**.

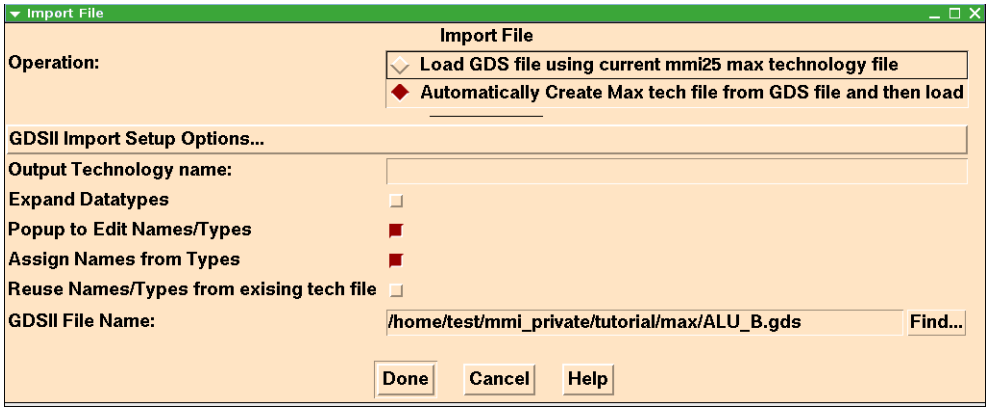
Step 2

- Start MAX by typing "**`max`**" on the command line.

Step 3

- Select **Import File...** under the **File** menu. You should see a pop-up like Figure 142.

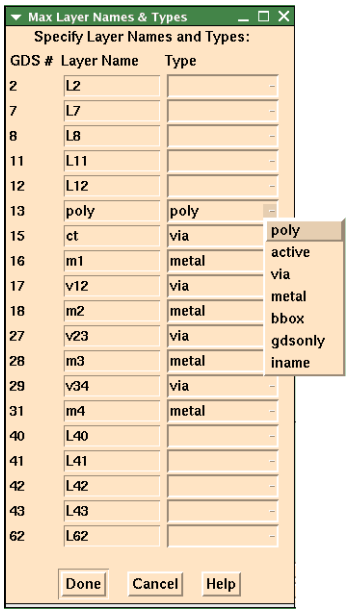
Figure 142: Import GDSII File



Step 4

- Click on "**Automatically Create MAX tech file from GDS file and then load.**"
- Click on the **Expand Datatypes** toggle button so that it is turned **off** as shown in the above figure.
- Click on **Find...** (at the lower right) and select **`ALU_B.gds`**.
- Click on **Done** from the **Import File** pop-up. You should now see the **Layer Names** pop-up as shown in Figure 143.

Figure 143: Layer Names and Type Pop-up

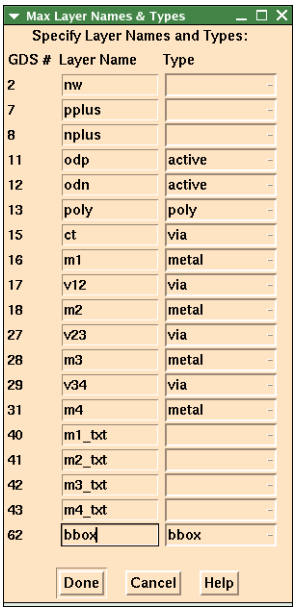


If the layer is not metal, via or poly, then the **Layer Name** is simply a generic name. We will change some of these names to make more sense.

The **Type** is a category MAX uses to determine how layers are connected.

To simply have a quick look at the layout, you don't need to specify any of the layer names or types. The layers for poly, metal, and vias need to be defined as the correct type in order for **Select Net** to work. In order to create fet and via gcells, MAX need to have the active layer specified as well as some of the DRC rules. How to specify DRC rules is covered in the *MAX User Manual*.

Figure 144: Changed Layer Names

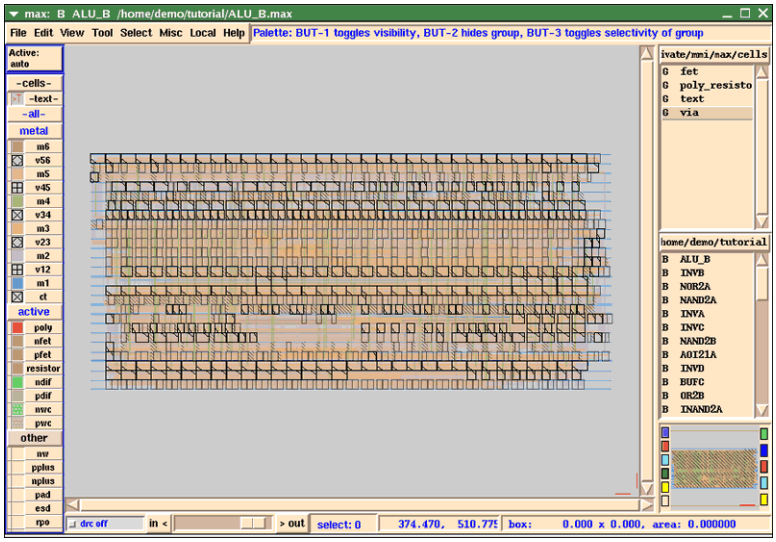


Step 5

- When prompted, click on **Restart Max Automatically Now with File**.

You should now see something like Figure 145.

Figure 145: Results of Changing Layer Name(s) - “other” layers now turned OFF



Step 6

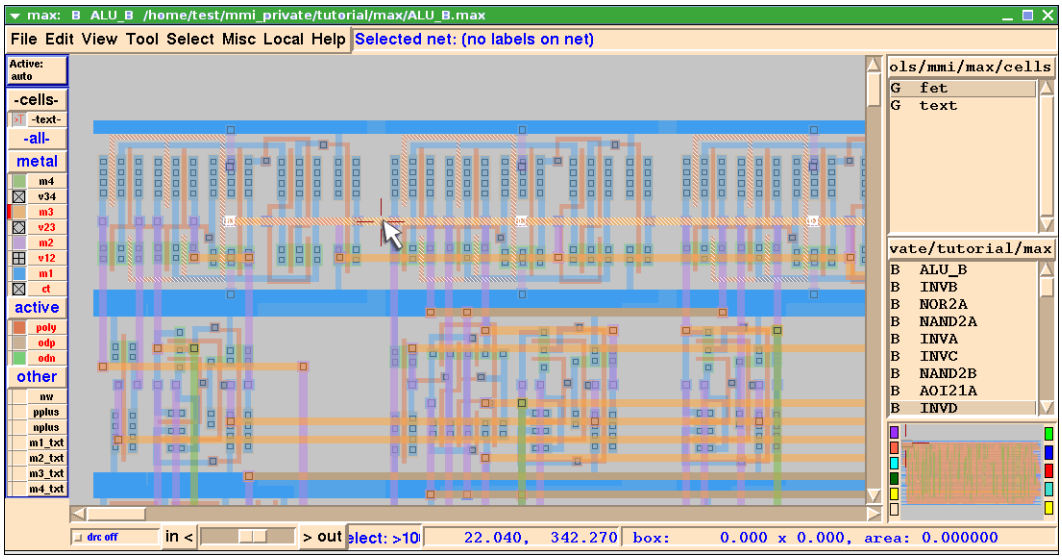
- Zoom in on the upper left corner of the layout, and type the hotkey **i** for **Internals, View All** to display internals for the layout.

  (Note that the “**other**” layers in the palette have been turned off for greater clarity in this tutorial.)

Step 7

- Select a net. Type the hotkey **s** (for **Select Net**, in the **Select** menu) to see layer connectivity tracing working. In Figure 146 the net attached to the **m3** layer has been selected.

Figure 146: Tracing Net Connectivity



- To view the extent of the selected net, use the hotkey **Shift-v**, or click on **Zoom to Fit Selected** from the **View** menu. The display will zoom out enough to show the entirety of the selected net.

Because this layout was read in from GDSII and the technology file was created from this GDSII, there are no DRC rules in this particular technology file. Those rules can be added manually, as described in the MAX Technology Files chapter of the *MAX User Manual*.

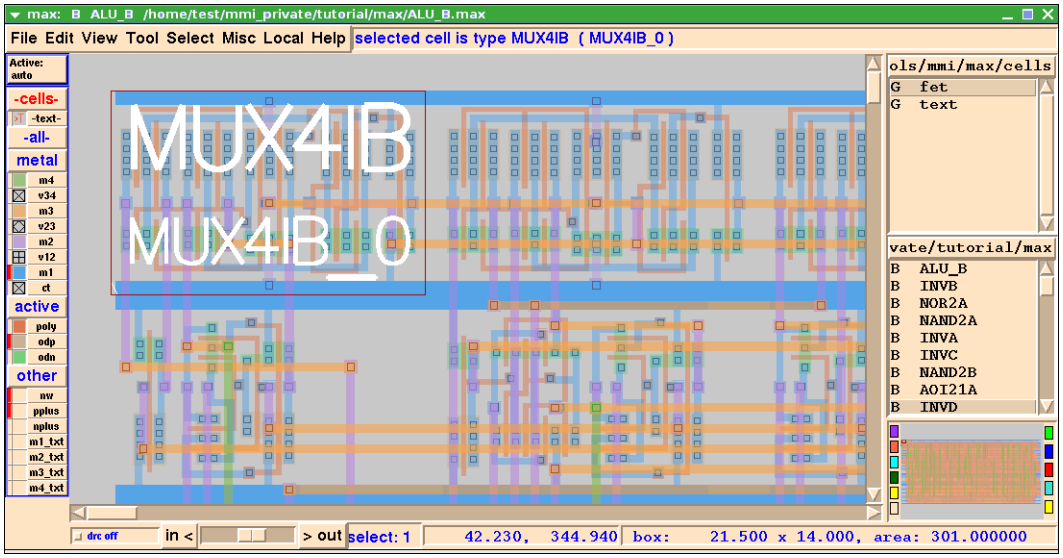
Modifying Palette/Layer Styles within MAX

Let's change some of the layer colors and stipple patterns for the cell **ALU_B**.

Step 1

- Zoom in on the very upper left corner of **ALU_B**. Click on the corner cell with the **Button-1** or use the select cell command (hotkey: **f**). You should now see **MUX41B_0** selected as shown in Figure 147

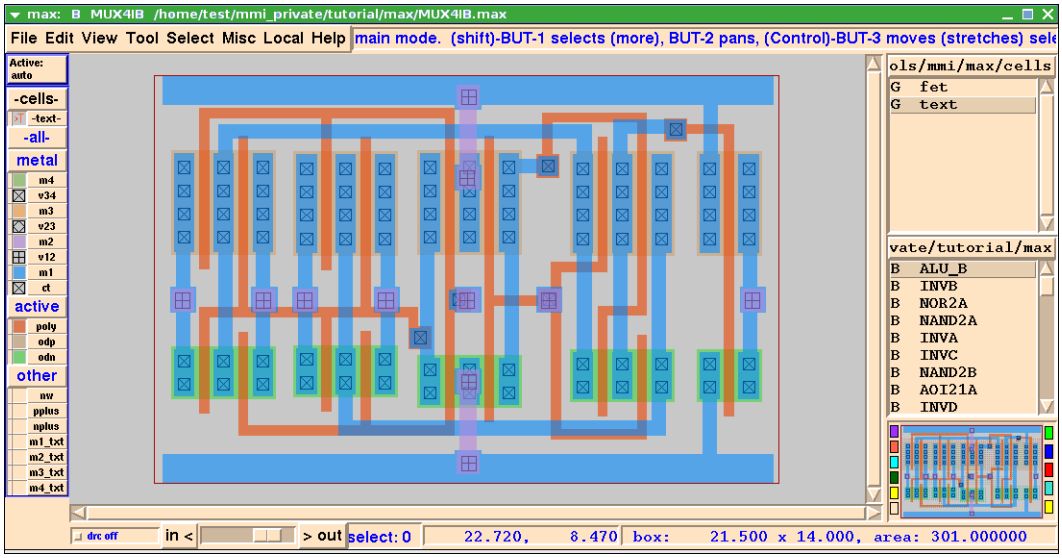
Figure 147: Cell MUX41B Selected in Upper Left Corner of ALU_B



Step 2

- ***Push into the cell*** **MUX41B** using the **e** hotkey, as shown in Figure 148. This will make any changes to layer colors in the palette much easier to see.

Figure 148: Editing MUX41B Cell



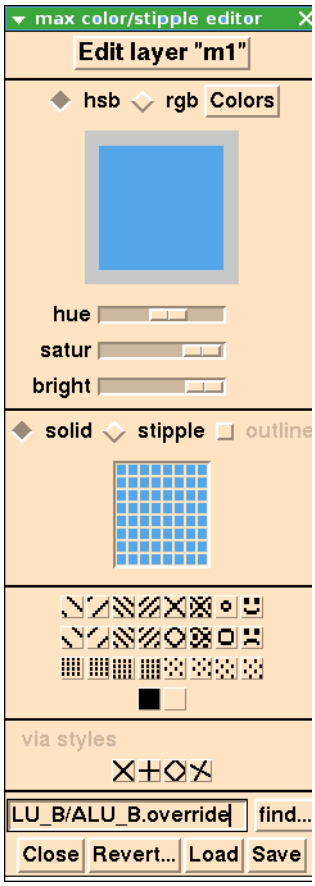
Changing Layer Color

First, we need to open the **Color/Stipple Editor**.

Step 1

- Click with the **MIDDLE mouse button** (**Button-2**) on **m1** in the palette or, from the **File** menu, select **User Prefs** and then **Color Editor**. Figure 149 shows the **Color/Stipple Editor** and its features.

Figure 149: Color/Stipple Editor



Layer Selection pull-down menu - Click and hold to select layer to edit.

Select HSB or RGB values, or choose from a list of pre-set colors.

This box displays the solid fill color.

HSB (or RGB) slider bars. Move these left or right to change the color.

Fill pattern buttons: Solid for solid fill; Stipple for patterned fill; Outline draws an outline around that fill.

Stipple edit area

Pre-set Stipple patterns. Use as-is, or modify further as needed.

Solid fill or "nothing/empty" fill buttons.

Pre-set via styles.

Find... palette file button

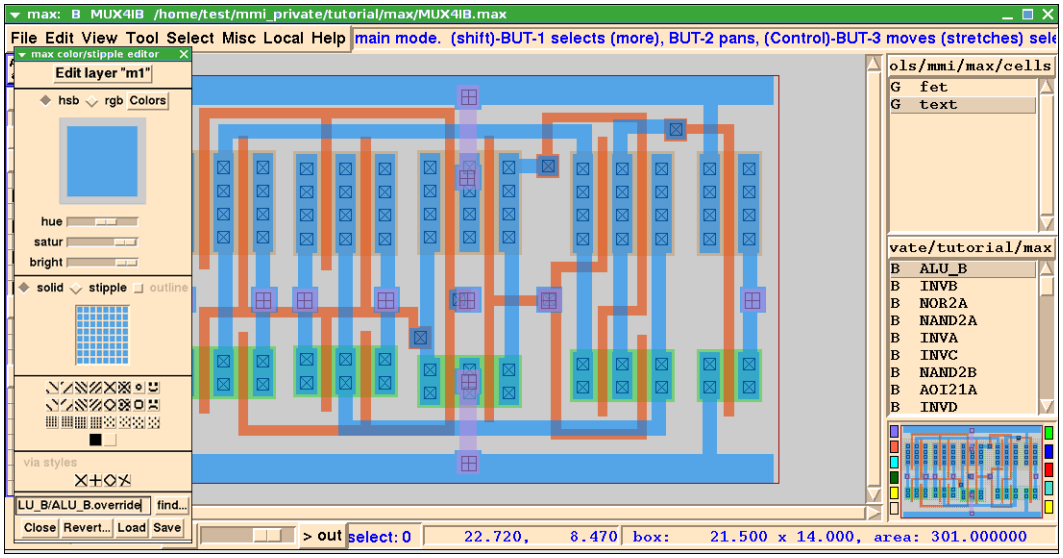
Buttons for: Close color/stipple editor (without saving), Revert... (to last saved version), Load (palette file) Save (this palette as a new file)

Step 2

- Select the layer you want to edit from the pull-down menu at the top.

  In this example we'll be editing layer "`m1`". If you brought up the **Color/Stipple Editor** using the **MIDDLE mouse button** on the palette, then `m1` is already the edit layer. Otherwise, select `m1` from the list.

Figure 150: Selecting Layer "m1" to Modify



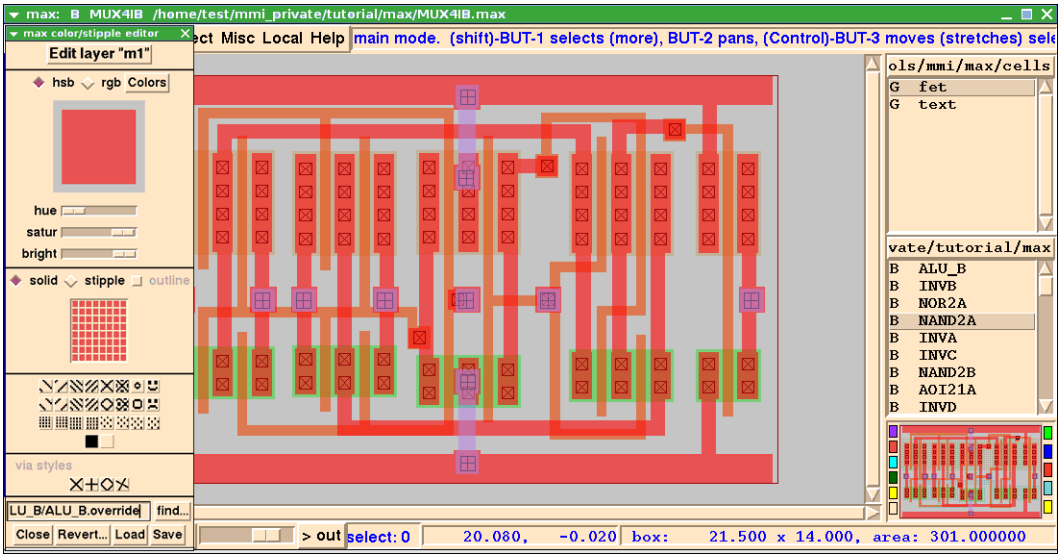
Step 3

- Now that you've chosen the layer to edit ("**m1**"), it's time to choose the color and fill pattern. Click on the radio buttons at the top to work in either HSV or RGB values, and then modify the color itself using the slider bars underneath.

  Colors will change dynamically as you work.

- In this next illustration (Figure 151), the bright blue color has been changed to bright red by sliding the HSV bars. The H S and V bars were pushed all the way right. You can see an immediate difference in the layout.

Figure 151: Color Changed to Bright Red in Editor and Layout



- If you prefer, select a pre-set color from the list available by clicking the **Colors** button. This list presents both color names and their RGB triplets.

Changing Stipple Pattern

Step 4

- Click on the **stipple** toggle button. Now experiment with stipple patterns by clicking on the grid of squares in the stipple-pattern area to toggle the color on/off.

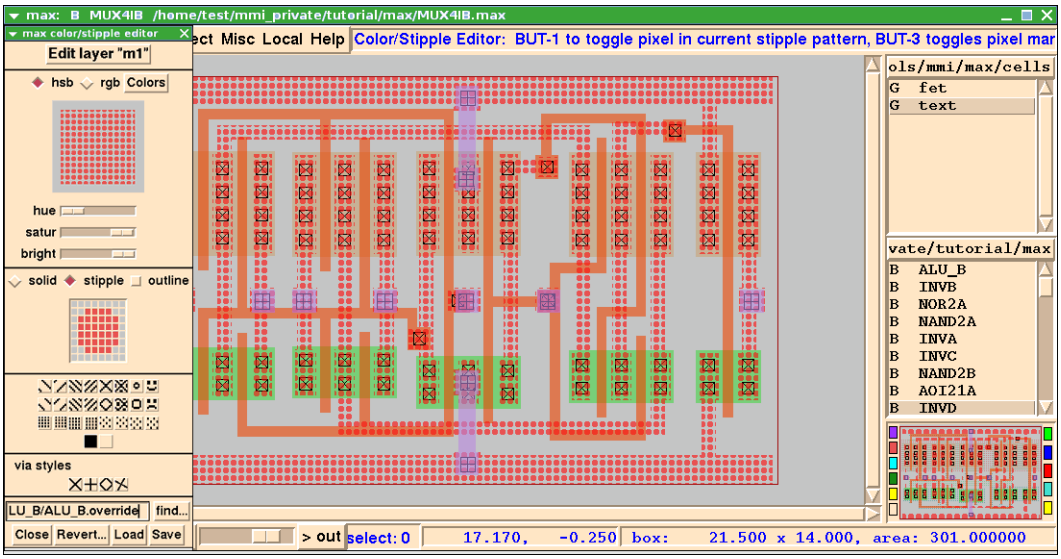
  As you make changes, these are reflected immediately in the display window. Figure 152 shows effects of this stipple pattern on the layout.

- For speedier editing, you can select the '**solid**' square button under the stipple patterns and remove colors for a heavy stipple such as this example. And the reverse is also true — select the '**empty**' square button and click on squares to set up a light stipple, or to clear a pattern and start fresh.

- With the immediate feedback on the layout view, it's very easy to see when a stipple pattern is "right".

In this fashion, you can generate stipple/fill patterns to mimic those from any other layout editor.

Figure 152: Large Dot Stipple Pattern in Editor and Layout



Step 5

- Clear the edits you've just made by clicking on the **Revert...** button at the bottom of the color/stipple editor. Then click on **Done** to revert to the **Start-up Defaults**. This reverts the palette settings to the last saved version.

- If you would prefer to save the changes you've made to the palette, click on **Save**. The default location for the palette override file is:
  `~/mmi_private/max/tech/ALU_B/ALU_B.override`.

Since we didn't specify a technology name we we read in the GDSII, the technology name defaulted to the name of the GDSII file. When the technology file was created from the GDSII, MAX automatically made an **`ALU_B.palette`** file with the default colors. The **`ALU_B.override`** is read in after the **`ALU_B.palette`** file when MAX is started up with this technology, and therefore overrides the layer color and fill patterns.

- A pop-up will open, asking if you'd like to override the default palette file. You can type in a new palette name in the field to create a new palette file, or override the current palette file.

Step 6

- Exit MAX by either typing the hotkey **Ctrl-d** or selecting **Exit** from the **File** menu.

Using a Black Background

If you prefer working with a black background, MAX has a pre-assigned palette already set up.

Step 7

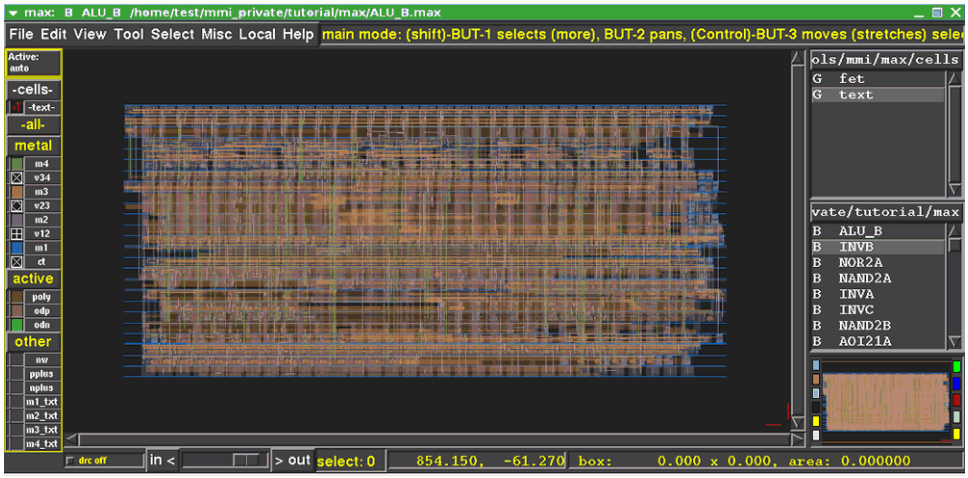
- Let's try this with our technology. On the command line, type:

```
max -tech ALU_B-bb ALU_B.gds
```

Step 8

- View the internals (hotkey: **i**).
- You should now see something similar to FICGC>C

Figure 153: ALU_B Technology with Black Background



Step 9

- Exit MAX (hotkey: **Ctrl-d**).

Importing Layers and Palette Styles from Another Program

In addition to GDS and ASCII file formats, MAX can also handle industry-standard formats, including **.DRF** and **OpenAccess**.

Importing Technology Information From A PDK

IMPORTING A "DISPLAY.DRF" FILE

The foundry generally provides you with a Physical Design Kit (PDK) which should contain an ASCII tech file and sometimes a separate GDS layer map file. If you have layer colors and fill patterns specified for Cadenc's *Virtuoso* layout editor, MAX can also read in that information from the ***.drf*** (display reference file) file.

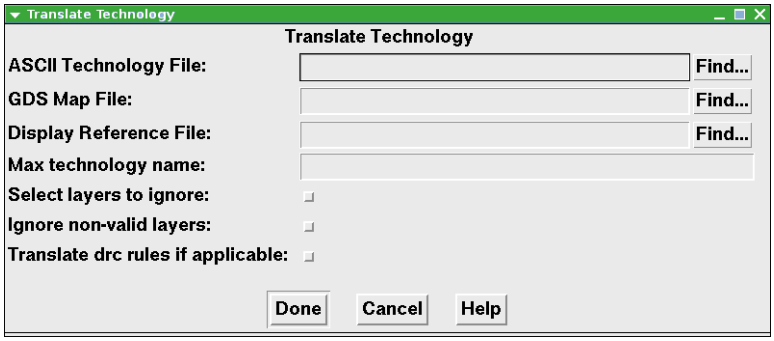
Step 1

- From the command line (shell window) type:

  `cds_convert`

  This opens the **Technology Translation Menu**, as shown in Figure 154.

Figure 154: Technology Translation Menu for "cds_convert" to Import "display.drf" files



Step 2

- Click on the **Find...** button to select the desired **ASCII Technology File**. This file usually has an extension of **`.tf`**, **`.asc`**, or **`.tech`**. It includes the layer names and usually the GDSII layer number mapping information, as well as some basic DRC rules.

If the ASCII technology file does not contain the mapping information from GDSII layer number to layer name, then it will be in a separate file (usually with a **`.map`** extension). Specify it as the **GDS Map File**.

- The **Display Reference File** (**`.drf`**) is optional and is where layer colors and stipple patterns are defined. If not specified, **`cds_convert`** uses MAX default colors and stipple patterns.

The MAX default colors use **layer transparency** which can make it easier to see multiple layers on top of each other. Each layer can have a transparency value from 0 to 100 (completely see-through to completely opaque). We suggest that you first do the conversion without the **`.drf`** file to see how MAX transparent layers look on your designs. You can always change the colors as shown in the above section. If you are used to using stipple patterns for transparency, you may find true transparency easier on the eyes.

- Type the name of the technology in the **Max technology name** text area. If no technology name is specified, **cds_convert** will use the rootname of the ASCII technology file.

- To use this technology file, on the command line, type:

```
maxview -tech <tech_name>
```

The technology file gets put in **~/mmi_private/max/tech/<technology name>**. To make the technology accessible to all users, put the technology files in **$MMI_TOOLS/../mmi_local/max/tech**. MAX automatically looks in **$MMI_TOOLS/../mmi_local/max/tech** and then in ...**~/mmi_private/max/tech** for technology files.

Step 3

- Since this tutorial does not contain a PDK, click on **Cancel**.

Importing OpenAccess Database Files

Micro Magic, Inc. tools support the OpenAccess database. MAX can read the technology information from the OA database and create a MAX technology file automatically. For information on this format, please refer to ***www.si2.org***.

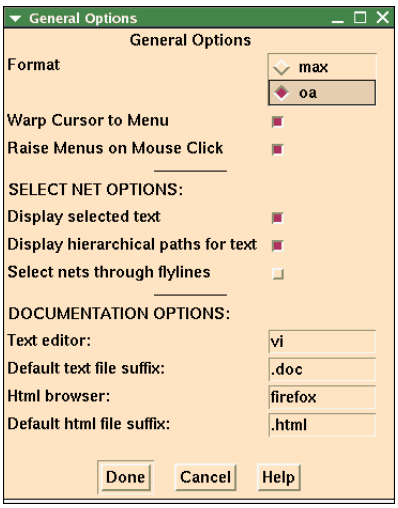
IMPORTING AN OPENACCESS FILE

To read in OA databases, the format of the layout files needs to be set ***oa***.

Step 1

- From the **File** menu, select **User Preferences**, and then select **General Setup...**. The following pop-up menu will appear.

Figure 155: General Options Pop-up Menu: Selecting OpenAccess Format



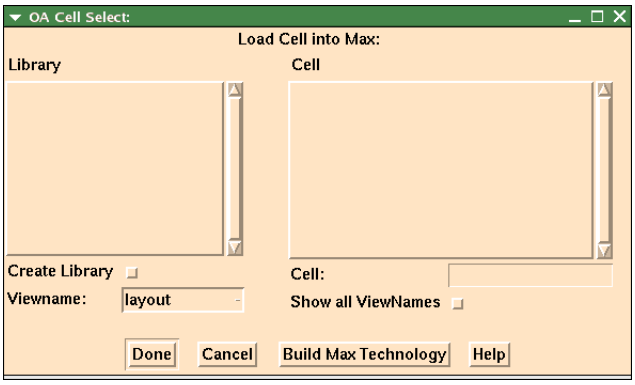
Step 2

- Click on the "**oa**" radio button to select OpenAccess format, then click **Done**. You are now in OpenAccess mode.

Step 3

- From the **File** menu select **Open**, and you will see the following pop-up. From this menu, you may access your OpenAccess library and cells.

Figure 156: OA Cell Selection Menu for OpenAccess Format Files



- If you click on **Build Max Technology**, MAX will get the layer names and other technology information from the OA database file. Note that you can change these assignments afterwards as necessary.
- To have MAX **automatically** start up on OA mode, add the following line to your **`max.rc`** file:

```
set FILE_MODE oa
```

- Once you have created the technology file from the OA database, start up MAX with:

```
max -tech <tech_name>
```

and MAX will launch using the correct technology and in OA mode.

Changing Hotkeys

With MAX, the user can change the definitions of hotkeys. Not all menu commands have hotkeys, so if you find that you are using a command often that does not have a hotkey, you might want to create one.

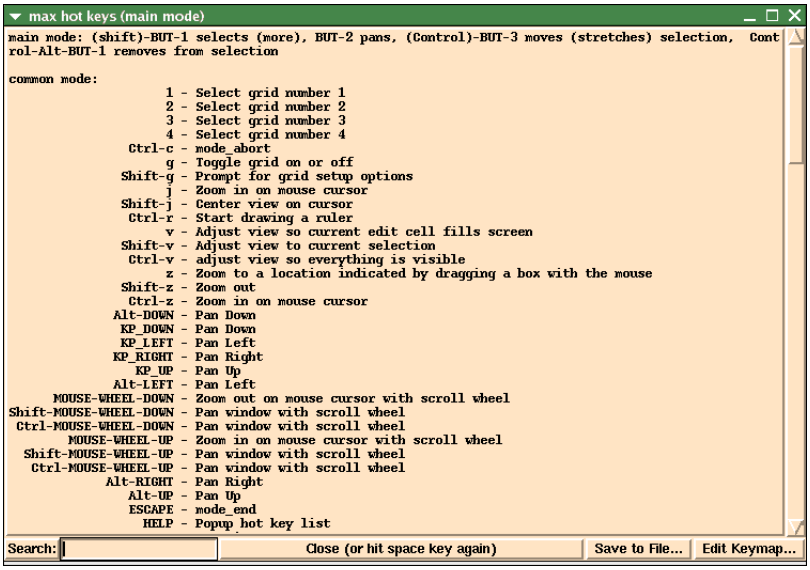
Listing Hotkeys By Command

- If MAX is not currently up, start it by typing "**`max`**" in a terminal window.

Step 1

- To bring up the current list of hotkeys, type **SPACE** or select **Current Hot Keys...** from the **Help** menu. You should see the form shown in Figure 157.

Figure 157: Current Hot Keys Pop-up Menu



This pop-up form is useful if you want to find the hotkey assigned to a command. Most of the hotkeys are also found in the menus, to the right of the menu command. If you want to change or add a hotkey, you need to edit this list.

Step 2

- Click on **Edit Keymap...** in lower right of pop-up. You should now see a pop-up like Figure 158.

Figure 158: Edit Keymap Pop-up Menu

By default, the hotkeys are ordered by their menu appearance. If you want to edit the hotkey of a specific menu command, this makes it easy to find.

Listing Hotkeys Alphabetically

If you want to find out which hotkeys have already been assigned, you want them listed in alphabetical order.

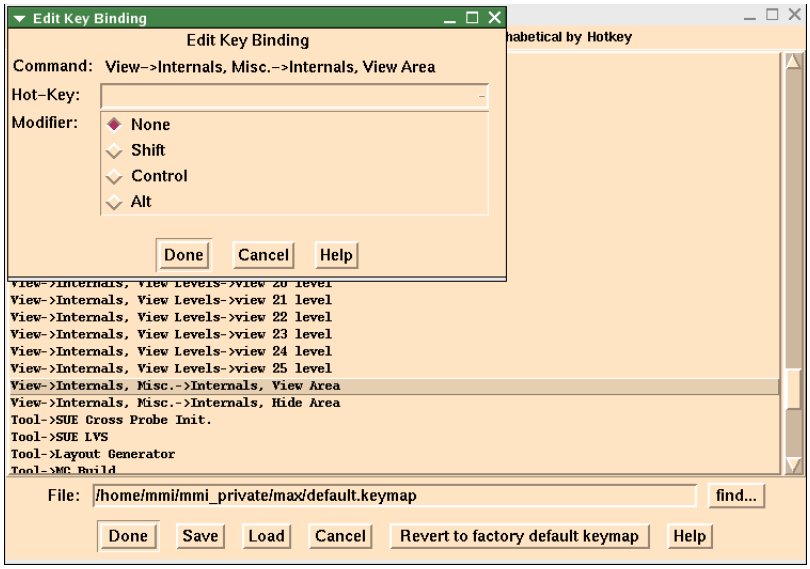
Step 3

- Click on the **Alphabetical by Hotkey** toggle button at the top of the pop-up form. Notice that the **Shift-k** hotkey is not currently used.

Step 4

- Scroll down the list to the bottom and locate **View-> Internals, Misc.-> Internals, View Area**. Click here with the **LEFT mouse button** (**Button-1**) to open the menu shown in Figure 159.

Figure 159: Edit Key Binding Pop-up Menu

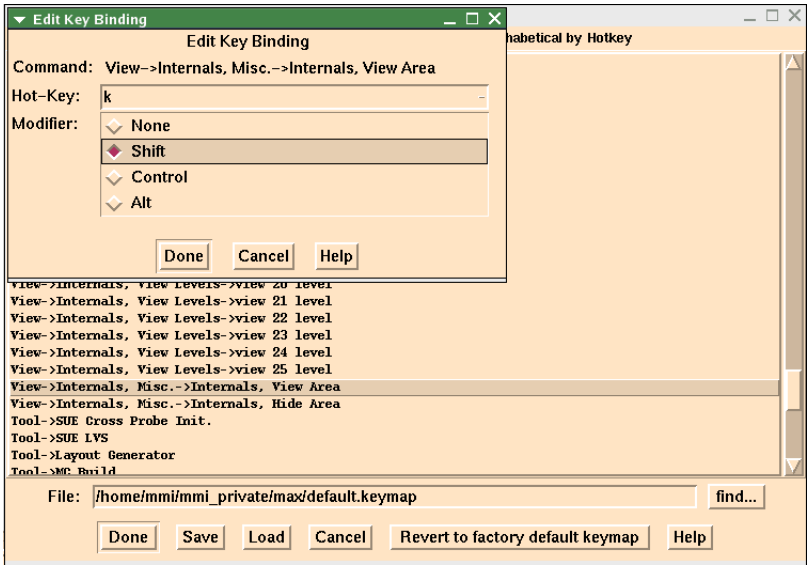


Re-mapping a Hotkey Binding

Step 5

- Type the letter "**k**" in the **Hot-Key** field. Click on the **Shift** toggle button as shown in Figure 160. This means that the hotkey for this command is now **Shift-k**. Click on **Done**.

Figure 160: Changing Hotkey Binding



You should now see the **Shift-k** hotkey highlighted in the **Edit Keymap** pop-up.

- If you wanted to save this information, you would click on the **Save** button so that this hotkey binding will be set the next time you start MAX.

- You can always return to the original hotkey definitions by clicking on **Revert to factory default keymap.** If you want to test it out or just use it for this session of MAX, click on the **Done** button.

Step 6

- Click on **Done**. Go to the **View** menu and select **Internals, Misc**. Notice that **Internals, View Area** command now has the hotkey **Shift-k** listed.

You can probably see by now that after loading your GDSII files, the ability to customize the display and hotkeys makes using MAX pleasant and easy. We at Micro Magic, Inc. hope that MAX makes loading, viewing, editing, and creating your layout as simple, fast, and painless as possible.