

Magic Advanced Reference Guide

Advanced Features of Magic

The previous tutorial gave only the basic preliminaries for creating simple layouts in magic. For real production work, you will need to know several other things such as how to create hierarchical designs, how to move, copy, array, and rotate objects, how to extract your circuit for simulation, and how to write CIF or GDS files to send to MOSIS for fabrication. This guide covers these topics, as well as a summary list of commonly used commands.

Hierarchy

Any design larger than a few transistors should employ hierarchy to help minimize errors and maximize productivity. When you create a layout (such as an inverter) and save it under a name, you have created a 'cell' that can be used in other designs.

To use a previously created cell in a layout, enter the command

```
:getcell <cell name>
```

This will place the cell at position defined by the lower left corner of the box.

The cell will be displayed in outline form. To see it fully, place the cursor in it, hit the 'f' key (or issue the ':select cell' command), and hit the 'x' key (or issue the ':expand' command). Note that you cannot edit the cell, but you can see it (in slightly less vivid colors than layers drawn directly in the design you are editing). To unexpand it, hit 'f' and then 'X'.

Moving and Copying

Moving and copying operations can be done on selected object(s) with the commands

```
:move [up|down|left|right] <n>  
:copy [up|down|left|right] <n>
```

where <n> is the number of lambda units to move/copy in the specified direction.

You cannot move or copy cells that have been expanded. For cells, first select the cell (using 'f'), and then unexpand it (using 'X').

NOTE: Do not copy any complex layout that could be made a cell and then get-celle'd multiple times into a higher level of a design hierarchy. If you do, you will be sorry when it comes time to make a change in the thing you copied!!! If you make it a cell and get-cell it in a higher level design multiple times (or copy the cell at the higher level while it is unexpanded), then a change made to the cell will take effect in all copies of the cell!

Editing a Cell In-Place

It is probably best to edit a lower level cell by leaving magic and re-invoking it on the cell. However, it is possible (albeit tricky and potentially dangerous in some ways) to edit a cell in-place. To do so, put the cursor in the cell (with it expanded), hit 'f' to 'find' the cell, and then enter the command ':edit'.

After editing the cell, use ':save' to save it, then hit 'f' multiple times till you get back to the enclosing cell you started from, and enter the ':edit' command to return to that cell. Do not forget to do this !!! If you do, you will be painting things in the cell that you think are being painted in the enclosing layout !

Rotating and Flipping

You can rotate selected layers (or cells) in a design using the command

```
:clockwise
```

or flip it side-to-side or top-to-bottom using

```
:sideways
```

```
:upsidedown
```

The What Command

Complex designs with many layers on top of each other are often difficult to interpret. To see what layers exist in a certain area of a layout, place the box over the area, enter the 'a' command to select all layers in the area, and then enter the command

```
:what
```

Measuring Things

To see how big something (e.g. a collection of cells) is, place the box around it, and type 'b'.

Making Connections

Drawing long, thin metal lines can be tedious. A better way is to use magic's wiring mode. To use it, hit the space bar once, place the cursor over the starting point (e.g. the end of a metal trace), click the left key, move the mouse to the end point, and click the right key. You can continue moving and clicking the right key to make corners, etc. When done, hit the spacebar three times to return to the normal 'box' mode.

Checking Connections

Checking connections in a large design is an important part of verifying your layout. Magic is good at this. To see what is connected to a trace, etc., place the cursor over the trace and hit the 's' key multiple times.

Extracting Circuits for Simulation

A mandatory check before submitting a design to fabrication is to extract the circuit and simulate it. This section covers only the extraction process. See the tutorial on spice3 for information on simulating.

To extract a circuit, first setup the extraction style using

```
:extract style <style name>
```

You can see the available style names by issuing just ':extract style' without an argument. After setting the style, do

```
:extract all
```

The extracted circuit will be saved under <cell name>.ext. After you leave magic, you will need to run the program 'ext2spice' or 'ext2sim' to map it into the appropriate circuit 'netlist' format for the simulator you will use (spice3 or irsim).

Writing CIF Files

To send a file out for fabrication, or to exchange it with a layout editor other than magic, you will need to export the design in CIF (CalTech Intermediate Format), or GDSII format. CIF is most useful for learning since it is an ASCII format that is readable.

To write out a design in CIF format, do

```
:cif ostyle <style>
```

where you can see the styles available using ':cif ostyle' without any arguments. See your instructor and the MOSIS web site for information on correct style, etc. Then issue the command

```
:cif write <file name>
```

The suffix .cif will be automagically appended.

Reading CIF

It is very wise to check a CIF file prior to fabrication by reading it back into magic and looking at the design carefully to be sure there are no surprises. To read, do

```
:cif istyle <style>  
:cif read <file name>
```

Reading and Writing Calma (GDSII) Files

GDSII (also called Calma) format is preferred in industry since it is a binary format that uses less disk space for large designs. If you ever need to use this format, issue the :cif istyle (or ostyle) command, and then use

```
:calma read <file name>  
:calma write <file name>
```

in place of :cif read/write.

For More Information

For lots of additional information, see the magic 'man' page by typing

```
man magic
```

from any Xterm, or look at magic's detailed on-line tutorials in directory

```
/usr/local/cad/doc
```

using Linux's postscript viewer 'ghostview' on the .ps files.

Layer Names

Layer names available are defined by the technology file. Commonly used layers in CMOS tech files include

- nwell
- pwell
- ndiffusion
- pdiffusion
- poly
- pcontact (poly contact)
- ndcontact (ndiffusion contact)
- pdcontact (pdiffusion contact)
- nwcontact (nwell contact)
- psc (p substrate contact)
- metal1
- metal2
- metal3 (if supported in process)
- via (contact between metal1 and metal2)
- via2 (contact between metal2 and metal3)
- glass (for making probe contact openings)
- pad (for bonding pads)

```
macro v "view"
macro z "findbox zoom"
macro Z "zoom 2"
macro b "box"
macro B "findbox"
macro , "center"
macro y "drc why"
macro ' ' "redraw"
macro Y "drc why"
macro ? "help"
macro o "openwindow"
macro O "closewindow"
```

Commands

Here is a list of the keystroke macros defined in .magic. For detailed information on the commands that the keystroke commands alias to, see the magic tutorial.

```
macro s "select"
macro S "select more"
macro a "select area"
macro A "select more area"
macro f "select cell"
macro C "select clear"
macro d "delete"
macro ' ' "erase $"
macro t "move"
macro T "stretch"
macro c "copy"
macro ' ' "expand toggle"
macro x "expand"
macro X "unexpand"
macro q "move left 1"
macro w "move down 1"
macro e "move up 1"
macro r "move right 1"
macro Q "stretch left 1"
macro W "stretch down 1"
macro E "stretch up 1"
macro R "stretch right 1"
macro g "grid"
macro G "grid 2"
macro u "undo"
macro U "redo"
```