

MASSACHUSETTS INSTITUTE OF TECHNOLOGY  
Department of Electrical Engineering and Computer Science

6.374: Analysis and Design of Digital Integrated Circuits  
Using MAGIC

Fall 2003

Issued: 9/04/00


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## Basic Usage of Magic

### The Basics

#### 1. Changing tools

There are 4 types of tools you can select in magic by pressing the *space bar*. The one that is used most often is the **box tool**, which the mouse cursor looks like a cross hair. You should be using box tool when you are designing basic transistor cells.

 : Box Tool

## 2. Commands

Commands can be invoked in Magic in three ways: 1) by pressing buttons on the mouse; 2) by typing single key-strokes on the key board (called macros); 3) typing longer commands on the keyboard (called long commands).

When you're giving commands, make sure that the mouse cursor is on the cell window, not on the command window. Long commands are invoked by typing a colon(:). After you type the colon or semi-colon, the ">" prompt on the command window will be replaced by ":". ( When you're giving macro or mouse commands, the cursor on the command window should be ">" )

Most of the commands that we will be using are the default macros. In general, commands are sent to MAGIC using the format ":[keyword] [arguments]". To see a list of commands or to get help on a particular, use the ":[help [key word]]" command.

## 3. Viewing

The first thing you should do is show the grid. *Typing "g" will turn the grid on/off.* (or ":[grid 1" (1 lambda per division) or ":[grid 2" (2 lambda per division)).

Here are some ways to view the cell.

macro command	long command	description
v	:view	View the entire cell.
z		Zooms in to the area specified by rectangle
Z	:zoom 2	Zooms out by a scale factor of 2
,		Centers screen about mouse cursor, keeping zoom factor constant

### Painting Layers / Design Rules

You will need to draw rectangles a lot. To draw them, use the left mouse button to set one of the corners, and the right mouse button to set the other. If you already have a rectangle drawn, clicking the left mouse button moves the rectangle and with its origin (the lower left corner) at the cursor location. Clicking the right mouse button will change the position of the other corner of the rectangle, while keeping the origin at the same point. This is useful for resizing box sizes. Practice this a little. The middle mouse button copies all the layers under the mouse cursor location to the currently drawn box. (more on this later.)

Now you're ready to draw the transistors. In general, it's best to save drawing the wells (pwell and nwell) for last. Specify a box about 5 lambda tall and 1 lambda wide. Now, type ":[paint poly]". Note that the box is now red, which is poly. Note also that white dots have appeared next to it. This means that you have violated a design rule. To find out exactly what design rule you have violated, draw a box containing some white dots and press "y". Some information regarding the drc (design rule check) violation(s) will be displayed in the text window.

Once you have drawn a piece of poly, you no longer need to type ":[paint poly]". All you need to do to draw another box of poly (or any other layer) is to specify a new box, then move your mouse pointer to the layer(s) to be copied into the box and press the middle mouse button. Remember, however that all the layers will be copied; a common mistake is to copy multiple layers by accident.

^D is the converse of the middle mouse button; pressing ^D will delete all the layers under the mouse cursor from the currently specified box.

Here are some of the more common paint layers:

#### Single layers

p or poly or polysilicon or red	Polysilicon
blue or m1 or metal1	Metal 1
m2 or metal2 or purple	Metal 2
cyan or m3 or metal3	Metal 3

green or ndiff or ndiffusion  
brown or pdiff or pdiffusion  
pw or pwell  
nw or nwell

n-type diffusion (for use w/ NMOS)  
p-type diffusion (for use w/ PMOS)  
p-well (for use w/ NMOS)  
n-well (for use w/ PMOS)

### Complex layers

nfet or ntransistor  
pfet or ptransistor

Poly over ndiffusion (NMOS)  
Poly over pdiffusion (PMOS)

### Contacts

pc or pcontact or polycontact or polycut  
m2c or m2contact or m2cut or v or via  
m3c or m3contact or m3cut or v2 or via2  
ndc or ndcontact or ndiffcut  
pdc or pdcontact or pdiffcut  
pwc or pwcontact  
nwc or pwcontact

Poly to Metal1  
Metal1 to Metal2  
Metal2 to Metal3  
n-diffusion to Metal1  
p-diffusion to Metal2  
p-well to Metal1 (for well contacts, usually)  
n-well to Metal1 (for well contacts, usually)

### Editing / Moving Rectangles

To edit or move objects, you must specify them. This is how:

s select the largest box containing all the layers under the mouse cursor.  
S keep the current selection and add another box containing all the layers under the current cursor position.  
a select everything under the specified box.

d delete selected object  
c copy selected object (distance from origin of box to cursor position specifies where copy is placed)  
m move selected object (distance from origin of box to cursor position specifies where object is placed)

e  
q r direction to move a selected object by 1 lambda  
w

E  
Q R direction to stretch a selected object by 1 lambda  
W

Magic has a large undo/redo buffer. Paint, move and experiment with these options:

u undo  
U redo

Finally, don't forget to save your work:

:save mylayout

The filename will be called "mylayout.mag".

There are still many topics not covered; only the very basics were covered. Reading the magic tutorials is highly recommended.

### Step 3.

Layout an inverter following the attached layout. Once your layout is done, we need to extract the circuit for simulation. If you used the technology file option when you started magic, the extraction style should default to the standard for 6.374. Simply type the following:

```
:extract
```

This will create a "filename.ext" file that can be used by ext2spice and ext2sim.

#### Step 4.

To simulate a circuit in HSPICE, run ext2spice on the .ext file:

The

```
% ls
inverter.ext      inverter.mag
```

```
% ext2spice inverter
```

```
% ls
inverter.ext      inverter.mag      inverter.spice
```

The .spice file will only have transistor information (parasitic R and C are included); voltage sources, .model statements, .sweep and .tran statements must all be added.

The macros are listed below for your convenience:

```
Macro `^D' contains "erase $" (erase layer(s) under cursor from sel. region)
Macro `^L' contains "redraw"
Macro `^N' contains "iroute route -dSelection"
Macro `^R' contains "iroute route -dBox"
Macro `^X' contains "expand toggle"
Macro ` ` contains "tool"
Macro `,' contains "center"
Macro `.' contains "macro" (repeat last command)
Macro `?' contains "help"
Macro `A' contains "select more area"
Macro `B' contains "findbox"
Macro `C' contains "select clear"
Macro `E' contains "stretch up 1"
Macro `G' contains "grid 2"
Macro `O' contains "closewindow"
Macro `Q' contains "stretch left 1"
Macro `R' contains "stretch right 1"
Macro `S' contains "select more"
Macro `T' contains "stretch"
Macro `U' contains "redo"
Macro `W' contains "stretch down 1"
Macro `X' contains "unexpand"
Macro `Z' contains "zoom 2"
Macro `a' contains "select area"
Macro `b' contains "box"
Macro `c' contains "copy"
Macro `d' contains "delete"
```

Macro `e` contains "move up 1"  
Macro `f` contains "select cell"  
Macro `g` contains "grid"  
Macro `o` contains "openwindow"  
Macro `q` contains "move left 1"  
Macro `r` contains "move right 1"  
Macro `s` contains "select"  
Macro `t` contains "move"  
Macro `u` contains "undo"  
Macro `v` contains "view"  
Macro `w` contains "move down 1"  
Macro `x` contains "expand"  
Macro `y` contains "drc why"  
Macro `z` contains "findbox zoom"

## EXAMPLE

### INVERTER

athena % magic

Magic 6.4.4 - Compiled on Wed Jun 21 00:22:15 EDT 1995.

Using technology "scmos", version 8.2.6.

MOSIS Scalable CMOS Technology for Standard Rules

Unable to allocate 7 planes in default colormap; making a new one.

Black = 0            White= 1

Using new basepixel = 128  
Only 126 contiguous colors were available.

Magic news (07 Jun 1995):

Rev. 8.2.6 of the MOSIS SCMOS technology file is now installed.  
<jgealow@mtl>

If you need help using Magic, send mail to cad-problems@mtl.

```
>
:paint pdiff
:paint ndiff
:paint poly
:paint pdc
:paint ndc
:paint pc
:paint m1
:label IN left pc
:label OUT right m1
:label Vdd! center m1
:label GND! center m1
Selected cell is inv (Topmost cell in the window)
:save inverter
:extract style SCNE12(ORB)
Extraction style is now "SCNE12(ORB)"
:extract all
Extracting inverter into inverter.ext:
:quit

athena %
```