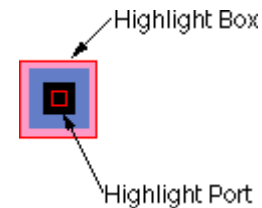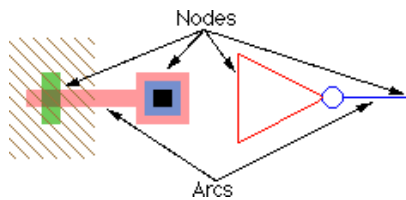# Sample Use of ELECTRIC

- Definitions (from 1.6)
    - **Nodes**: electrical components such as transistors, contacts, and logic gates.
    - **Arcs**: wires that connect two components.
    - **Ports**: connection sites on nodes where the wires connect


    - **Cell**: collection of Nodes and Arcs that form a circuit.
    - Cells may have different **Views**: schematic, layout, icon, etc
        - Each view may have different **versions** reflecting design history.
    - **Library**: collection of cells
- Layout involves selecting nodes and wiring with arcs.
- Electric is **connectivity** based, not geometry. Thus material of the same type that appear to be touching MAY NOT BE. (You must explicitly wire)
- Electric is hierarchical (instances of one cell may be used within another)
- User Manual: Available from the "Help" tab
    - Online: https://www.staticfreesoft.com/jmanual
    - pdf: https://www.staticfreesoft.com/jmanual/ElectricManual-9.07.pdf
- Left panel of display has 3 tabs
    - **Components**: gives available nodes (in blue border) & arcs (in red border)
        - Pure: add "pure" material of some layer
        - Misc: Miscellaneous combinations
        - Cell: complete multi-layer nodes
        - As you run cursor over entries, bottom **Status Area** gives more detail
    - **Explorer**: gives hierarchy of design files, including error reports
    - **Layers**: controls which "layers" of the design are visible
- **Messages window** between edit panel and Status provides text messages
- Manual Section 1-8 and 1-9 give mouse & keyboard shortcuts

Sample Use of ELECTRIC

- Download the most recent Java .jar version from https://www.staticfreesoft.com/productsFree.html and place in a directory (say "Electric")

- Go to https://www.staticfreesoft.com/jmanual/mchap01-12-01.html to start the tutorial,. For now ignore looking for the "mipscells" library

- Click on the "electricBinary-9.07.jar" code. This should bring up Electric Window.
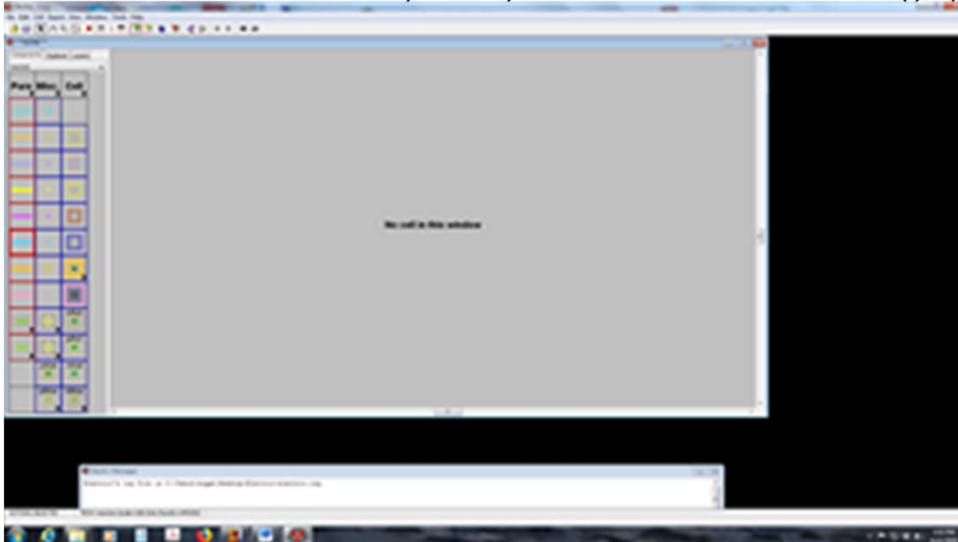
- Click on the "File" menu and select "New Library." Enter the name "Tutorial"

- Open the Cell menu, and click on New Cell. Enter "nand2" as cell name, select the "schematic" view. Note that the upper left now says you are editing Turorial:nand2(sch).
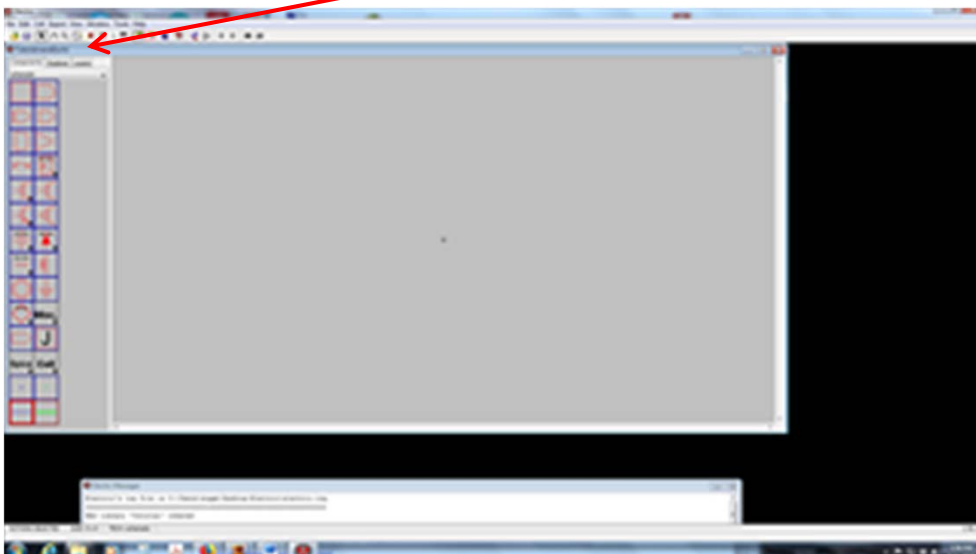
- Label your cell by selecting Components tab on left, click on "Misc", select "Annotation Text". Move the cursor into the working space where you want a label, and click (you get a small odd-looking symbol).
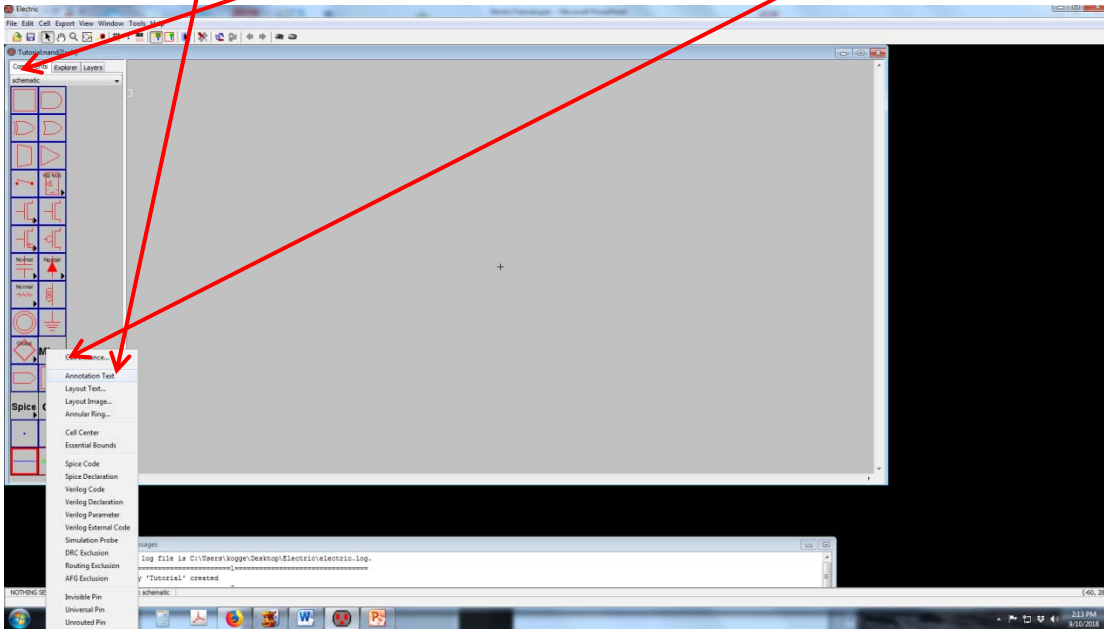

- Double click on the symbol, type in a name of the cell ("NAND2"),, and when done move the cursor away and click to exit the text editing. This leaves NAD2 with an "X" thru it. Either Ctrl-I or Edit/Properties/Object Properties, and then set Text Size to 20, and units to "Points". Apply and hit OK.
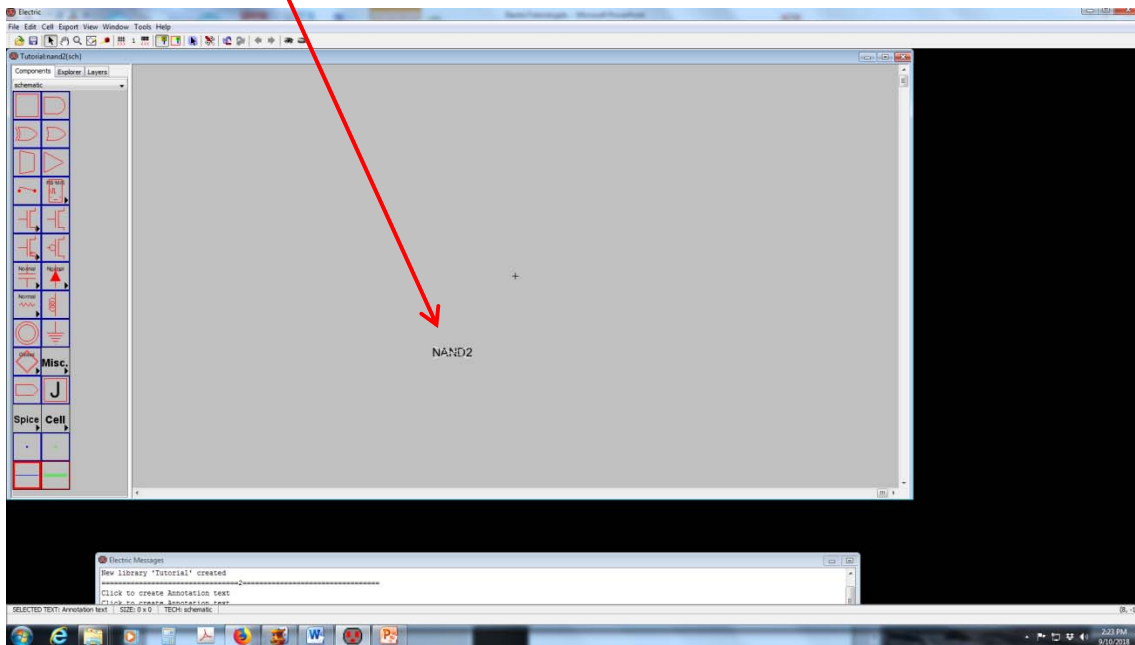
- In menu Window "Toggle Grid" to bring up. grid.
- Now use the component tab on left to click on a nMOS transistor. Click in the workspace where you want to position the transistor. Repeat with another nMOS, two pMOS, Power, and Ground.
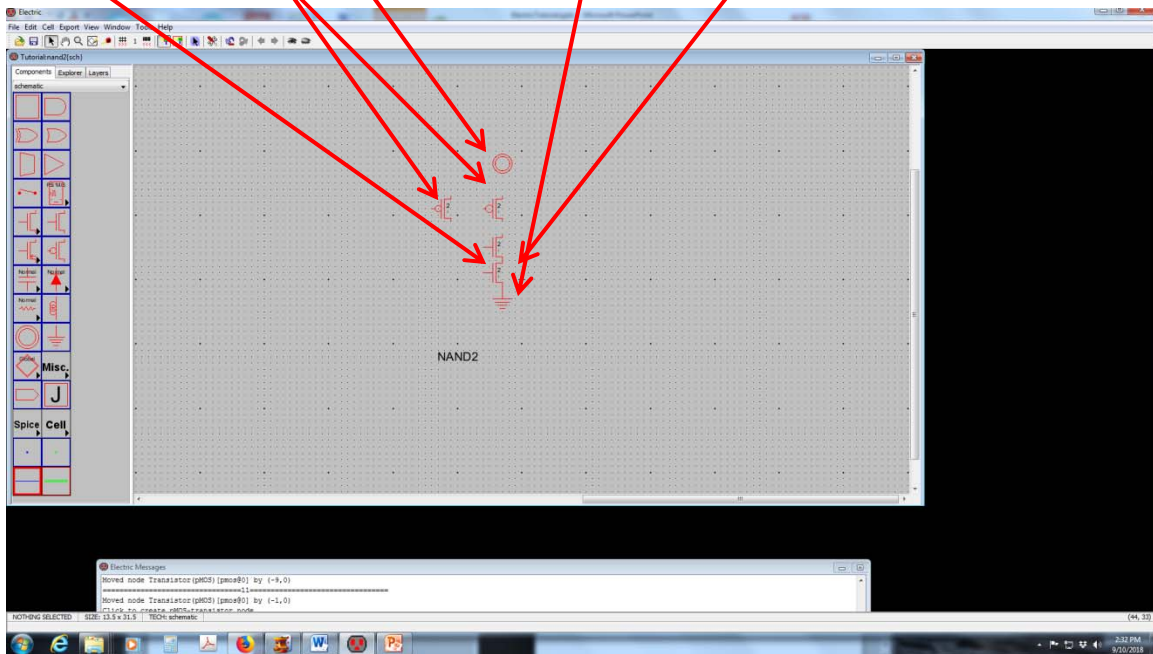
- The numbers in each transistor are the width in λ. Lengths are always 2λ. Double click on each transistor and change to "12" (We'll discuss choice later).
- Click on the top nMOS, and then right-click to start the wiring tool. Drag to the bottom of the pMOS, and release. A wire is drawn in black. Finish the wiring to complete the cell.
- Select 3 "Off Page" symbols (rectangles with a point on right, 2 for input and one for output. Wire them in also. For the two inputs, do a "Ctrl E" (or Export/Create Export), give them names, and for Characteristic select "input". Do same for output but select "output". Feel free to move the title.
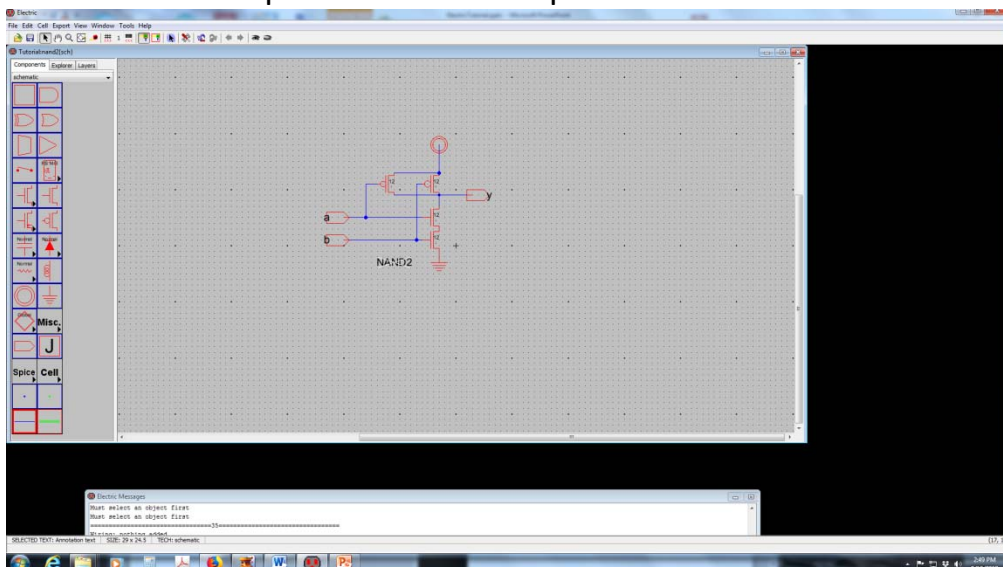
- Now Menu/New Cell. Enter "nand2" as cell name, and "layout" as view. Note that the name changes to "Tutorial:nand2(lay)". Click on File/Preferences/Technology /Technology to see the list of technology design rules., and that its currently set to "mocmos" This is changeable, but look at options, such as number of levels of metal (6 is default). Section 7-4-2 in the manual describes these options.

- From the Component menu on the left, click on an "nMOS" transistor near bottom. Rotate it 90 degrees by either "Ctrl J" or Edit/Rotate/90 Degress Counterclockwise. Double click (or "Ctrl I") and change the width to 12.

- Select the transistor itself and copy and paste (or Edit/Duplicate or "Ctrl M"). You will see a white box as you move the cursor. Drag the copy along side the other so they are not quite touching. Click the diffusion (green) of one and then right click the other transistor's diffusion. When you release, the green is contiguous.

- Noticing that each grid cell is λxλ (and the poly is thus 2λ) drag the poly of one transistor until its 3 units from the other (the two transistors are in series and the design rule says min spacing is 3). Note if you form a box around an object then the arrow keys move the object.

- At any time if you TOOLS/DRC/Check Hierarchically, (or F5) you get a message in the "Electric Messages" box towards the bottom. if errors you can expand in the window to see what they are.
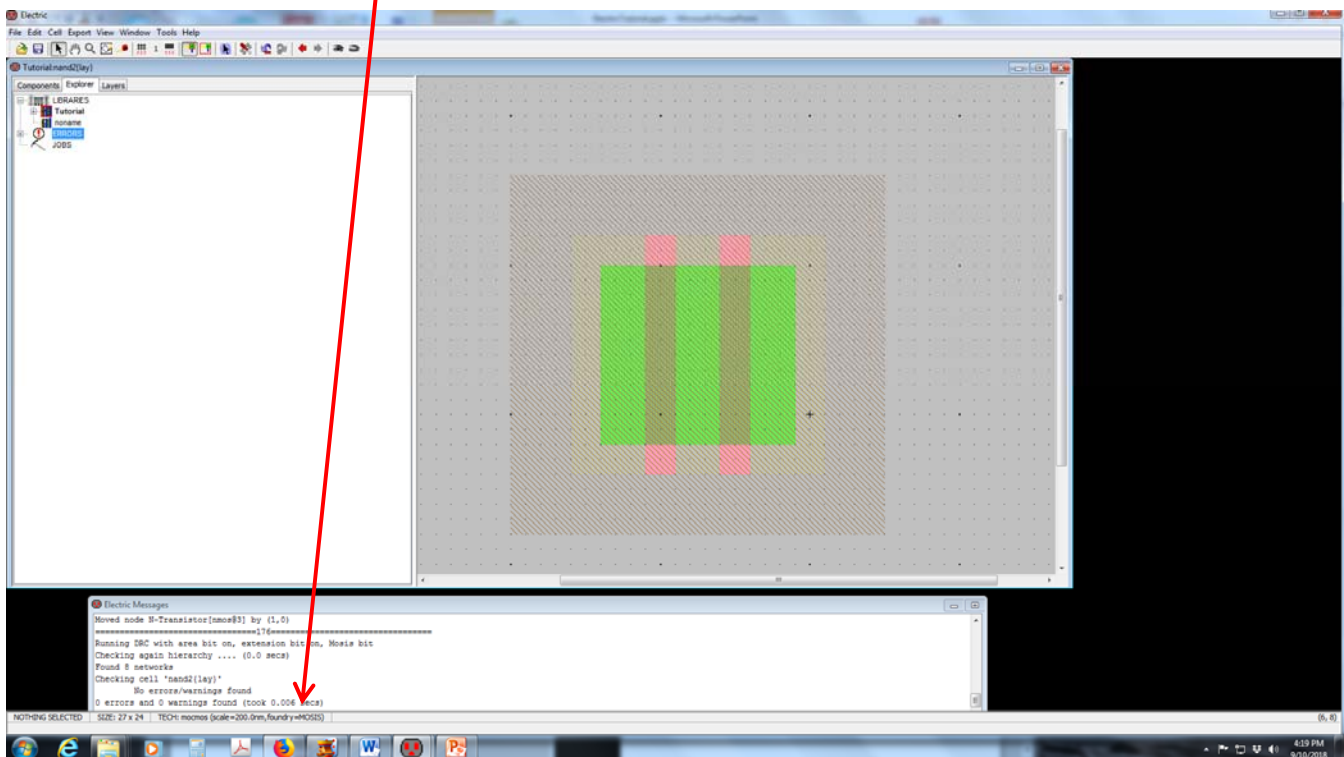

- Save frequently: File/Save Library or Ctrl-S

- Now do the same for two PMOS transistors, but you will need a separation between their gates of 5 units (we will need contacts between them as they are in parallel, not series.

- To add the contacts, choose a "Metal-1-N-active-Con" from Cell list (4th from bottom), and place near but not touching the two nMOS transistors.

- Ctrl-I and set y to 12. The contact box will expand and automatically add additional contacts and vias.

- Left click on nMOS source and right click on contact. A green wire should appear. Now you can move it properly.

- Do the same for the other side.
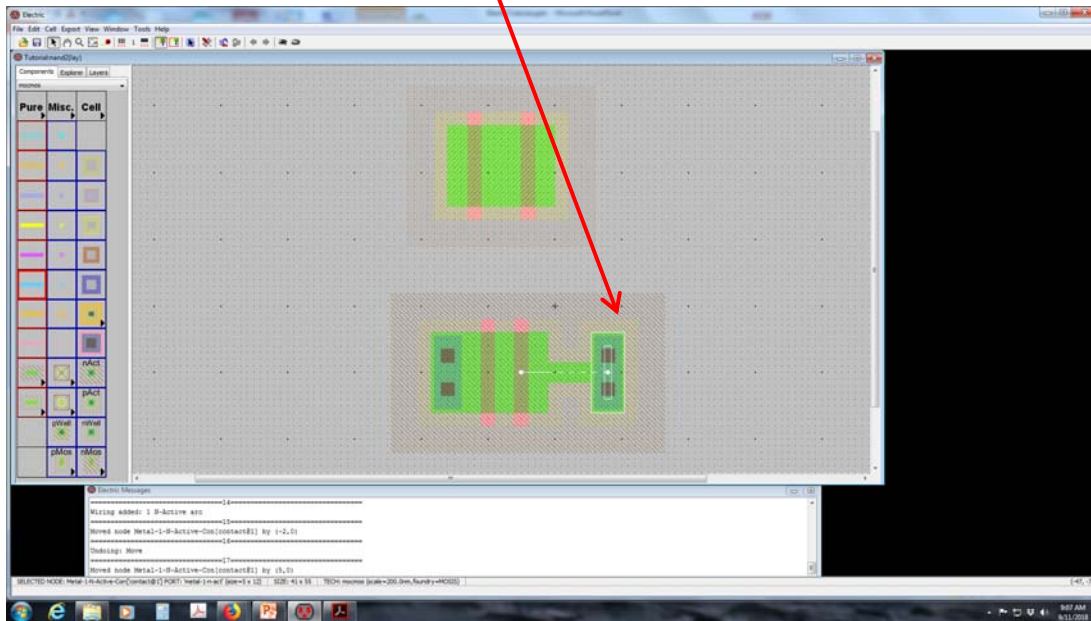
- Repeat for pMOS but place contacts between the polys also. Note: you may want to build the center row of contacts "outside" first, then wire and position. You may also want to expand the space between the two p-types to stop errors.
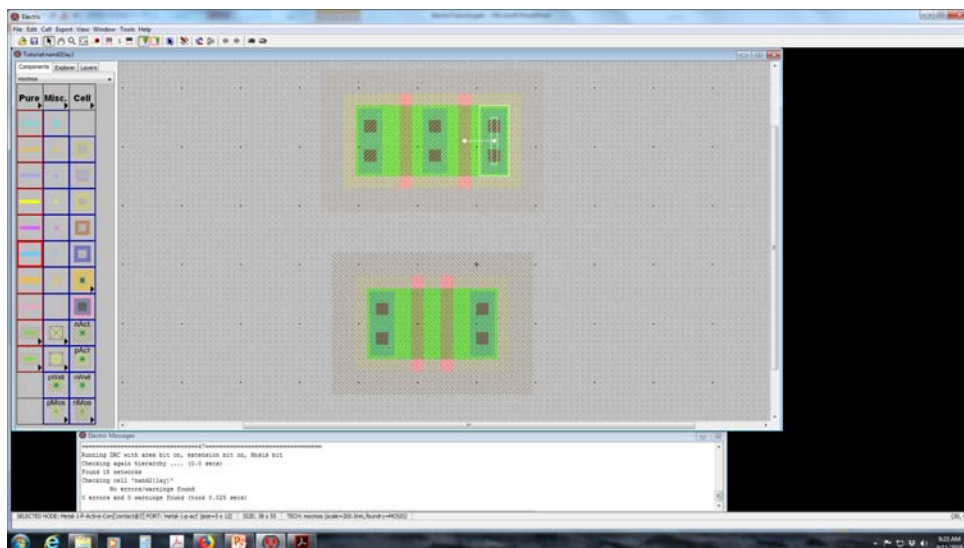
- Connect the poly lines by selecting one and then right-clicking on other
- Connect the center contacts on the pMOS with the right contacts of the nMOS by clicking on the first, moving straight down and right clicking, then right clicking on the right nMOS contacts. A blue Metal1 wire should appear.
- Add a Metal1-Poly-Con (4th from bottom under Cell), wire to left poly. Then select Metal1 from Pure column,click on the cap, and right click a bit away. Ctrl-I and rename as "a". Repeat for other poly..
- Click on the corner of the M1 wire Ctrl-I and label y
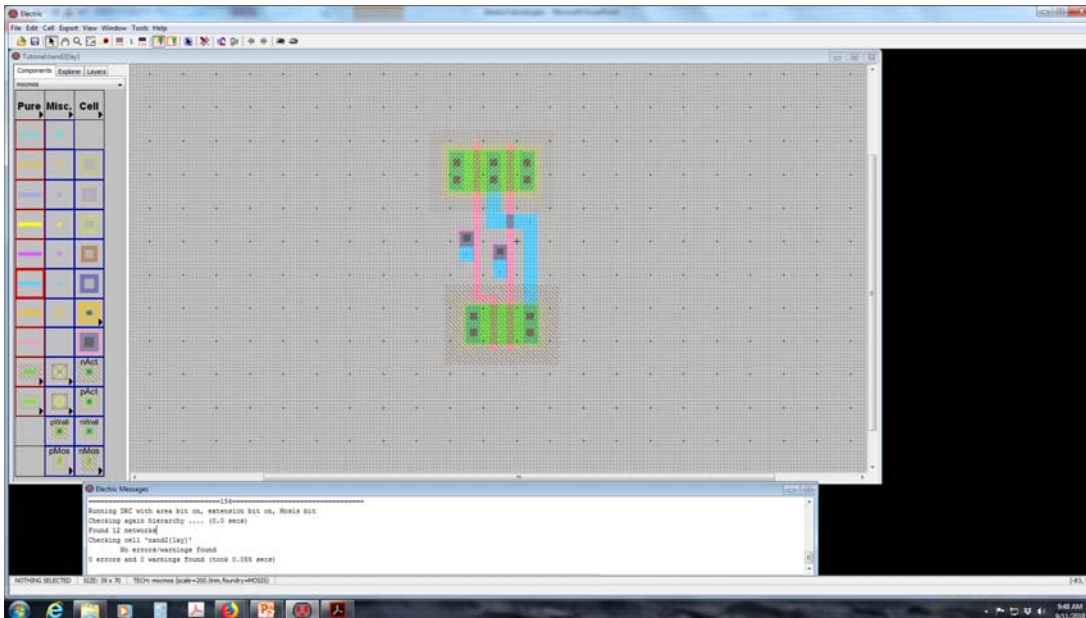
- Add Metal 2 for power (on top) and ground (at bottom)
  - Select a Meta2-Pin (5th from top in Misc), chick at start, and right click at end
  - Ctrl I and add a label
  - If you select the left contact of the nMOS, and then right click on the ground wire, a blue M1 wire will be drawn, with an M2-M1 contact automatically added.
  - Repeat for both left & right side of pMOS string to Vdd
  - Note if you select both M2 wires and Ctrl-I it will tell you how far apart they are
- Note the wells are never big enough. From Components/Pure select N-well-node and position a chuck at top. Then Ctrl-B (or Edit/Size) and drag an edge to the other side.
- Tie the Nwell to Vdd by adding a Metal-1-Nwell-Con (2nd from bottom of Cell column) to the top Nwell, and right click to Vdd
- Repeat the same for the PWell

- Now add "exports" so this cell can be reused and connected to others.
  - Select Metal-1-pin (small blue square in middle of Misccolumn)
  - Left click near the left input and then right click to the M1 to attach it
  - Right click on the metal
  - Ctrl-E opens the export box.
  - Select "input" as export type and "a" as name
- Repeat for other input "b"
- Repeat for output (anywhere on M1) with name "y" and type "output"
- Repeat for power and ground (use "vdd" and "gnd")
- Note above diagram is NOT a "as tight as possible" arrangement