Schematic Design and Simulation (IC Design Flow)

Dr. Ahmed Reda Mohamed[1,2]

[1]IRC for Communication Systems and Sensing, King Fahd University of Petroleum & Minerals, Dhahran 31261, Saudi Arabia

[2]PhD, The MoE Key Laboratory of Artificial Intelligence & Bio-Circuits and Systems Laboratory (*BiCASL*), Department of Micro-Nano Electronics, Shanghai Jiao Tong University, Shanghai, China.

Outlines

- ❑ Objective
- ❑ CMOS Inverter
- ❑ Schematic Editor
- ❑ Create Symbol
- ❑ Testbench
- ❑ Cadence Hot Keys
- ❑ Discussion

Outlines

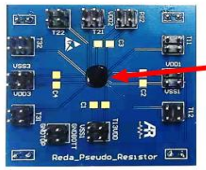
- ❑ Objective
- ❑ CMOS Inverter
- ❑ Schematic Editor
- ❑ Create Symbol
- ❑ Testbench
- ❑ Cadence Hot Keys
- ❑ Discussion

Objective (1/2)

- Objective
  - Create a schematic and symbol for a CMOS inverter in Cadence Virtuoso.
  - Perform simulations for the inverter

Discrete Element

Bread Board

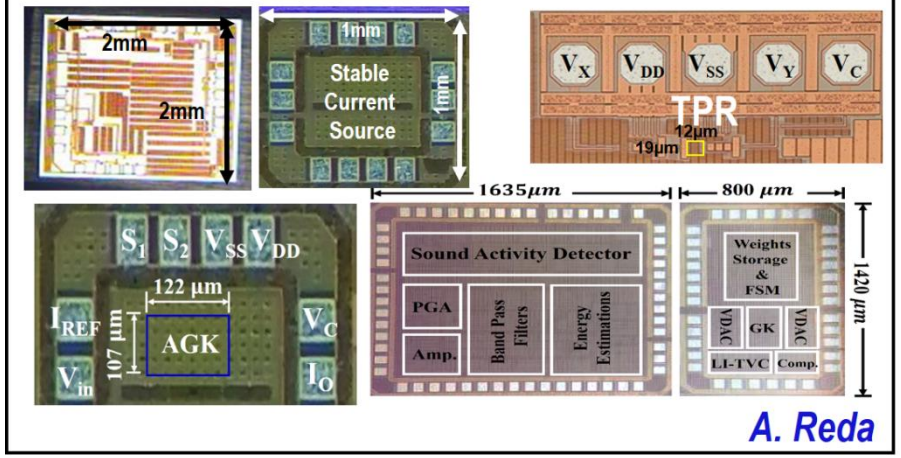


Chip-On-Board (COB)

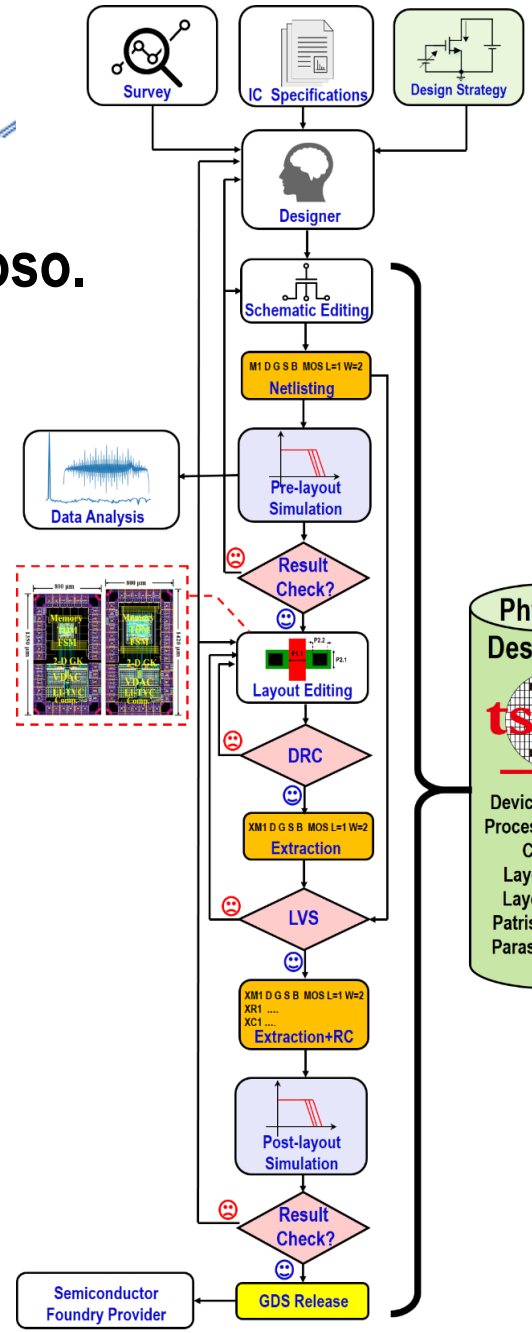
Printed Circuit Board (PCB)

- Through-hole
- Surface mount

Vey large Scale Integrated Circuit



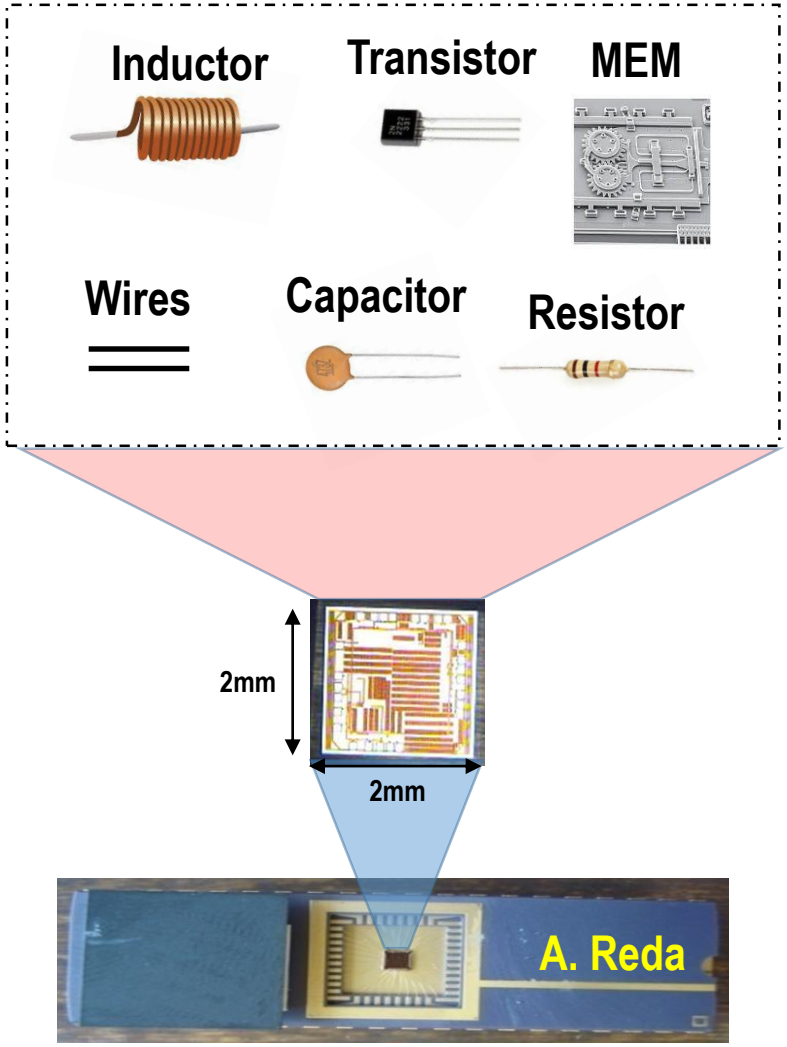
Item	Discrete Element	Very large scale Integrated Circuit
Area	Large	Small
Configuration	Easy	Complex
Price	Cheap	Expensive
Applications	Small production	Mass production
Power consumption	High	Low

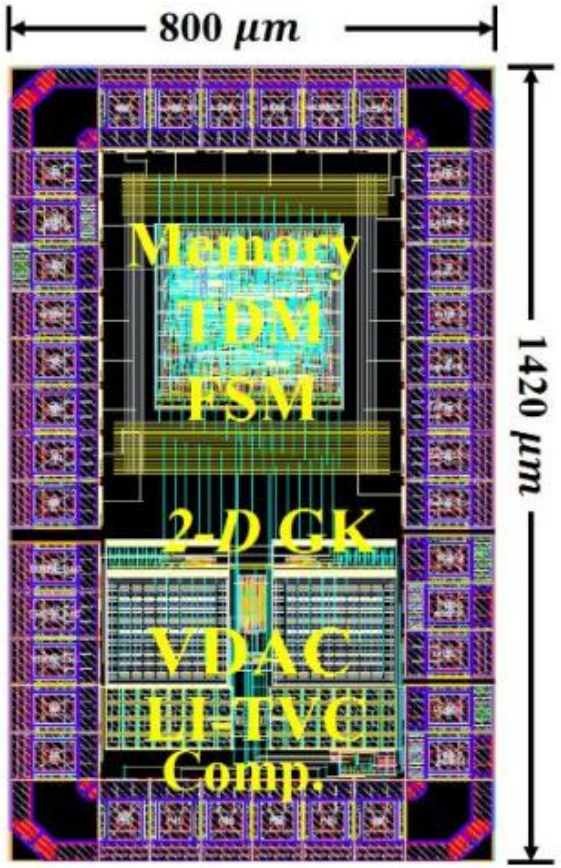


Analog IC design flow (Cadence tools)

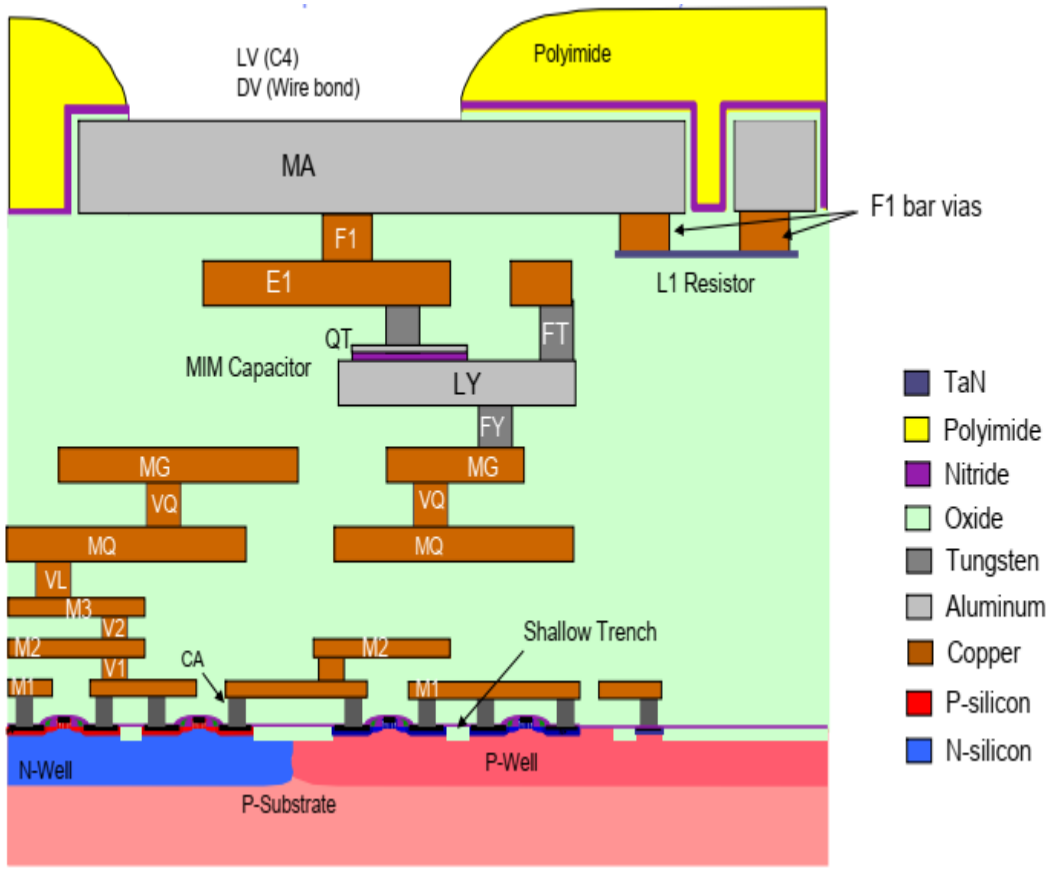
Objective (2/2)

- An **integrated circuit** (IC) is a set of electronic circuits on one small flat piece (or "chip") of semiconductor material, usually silicon.





Layout using CAD tool



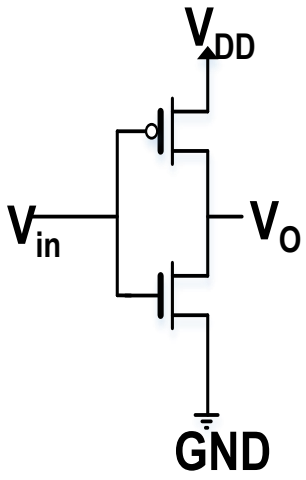
Process Cross-Section

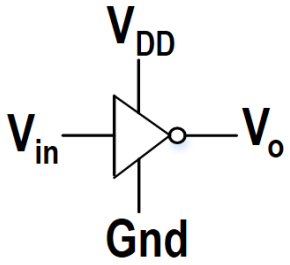
8 layers

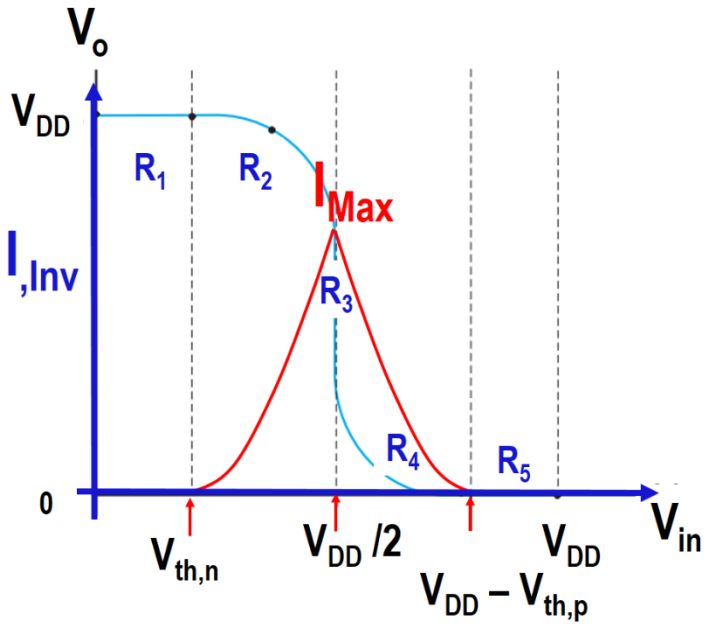
Outlines

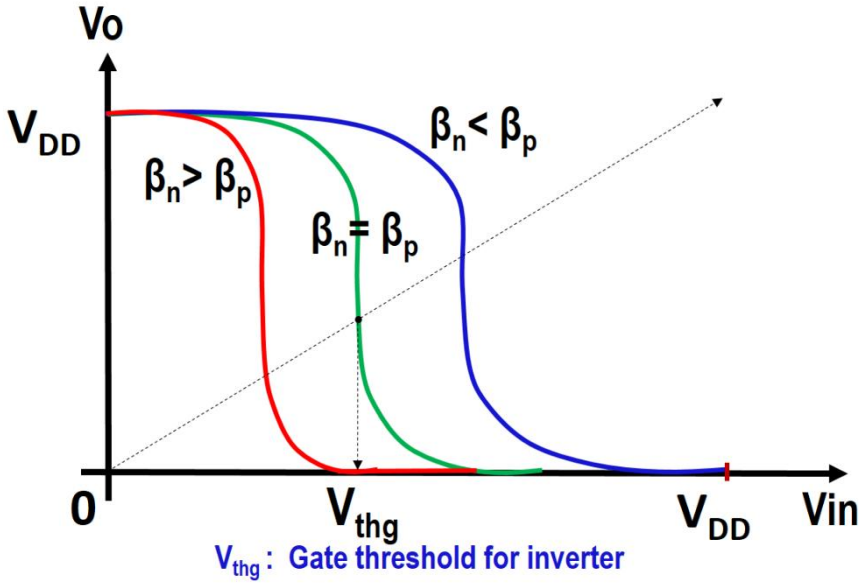
- ❑ Objective
- ❑ CMOS Inverter
- ❑ Schematic Editor
- ❑ Create Symbol
- ❑ Testbench
- ❑ Cadence Hot Keys
- ❑ Discussion

CMOS Inverter (1/2)









$$B_n = \mu_n C_{ox} \frac{W_n}{L_n}$$

B_n :Gain process factor of n-MOSFET
μ_n: Mobility of Electron
C_{ox}: Gate Oxide Capacitor/unit area
W_n:width of transistor
L_n: length of transistor

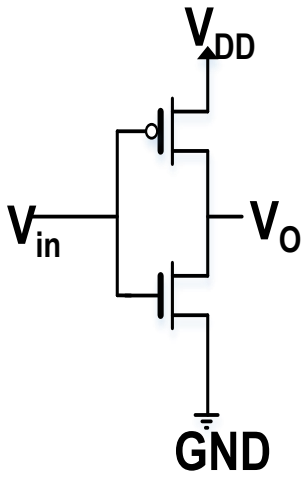
$$B_p = \mu_p C_{ox} \frac{W_p}{L_p}$$

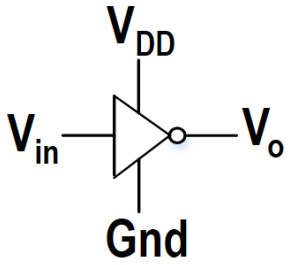
B_p :Gain process factor of p-MOSFET
μ_p: Mobility of Hole
C_{ox}: Gate Oxide Capacitor/unit area
W_p: width of transistor of p-MOSFET
L_p: length of transistor of p-MOSFET

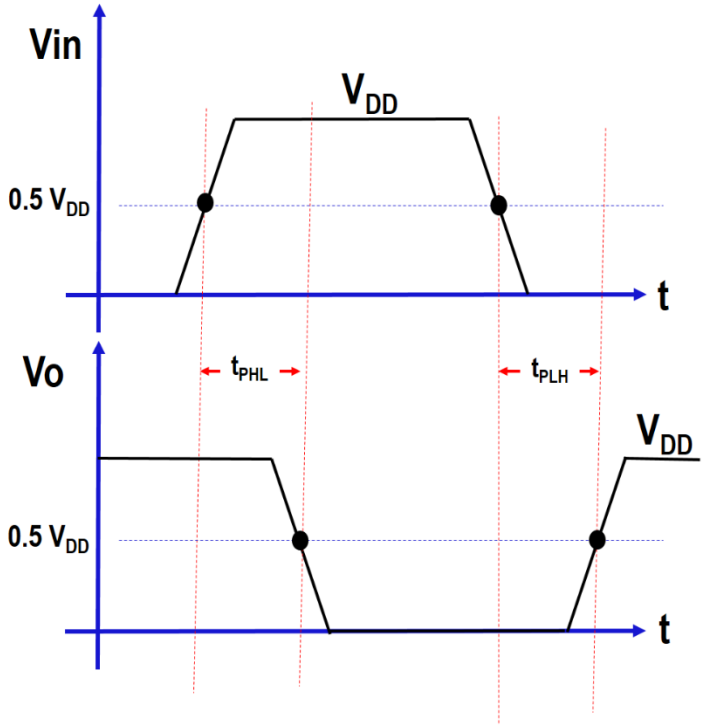
$$V_{thg} = \frac{V_{th,n} + r(V_{DD} + V_{th,p})}{1 + r}$$

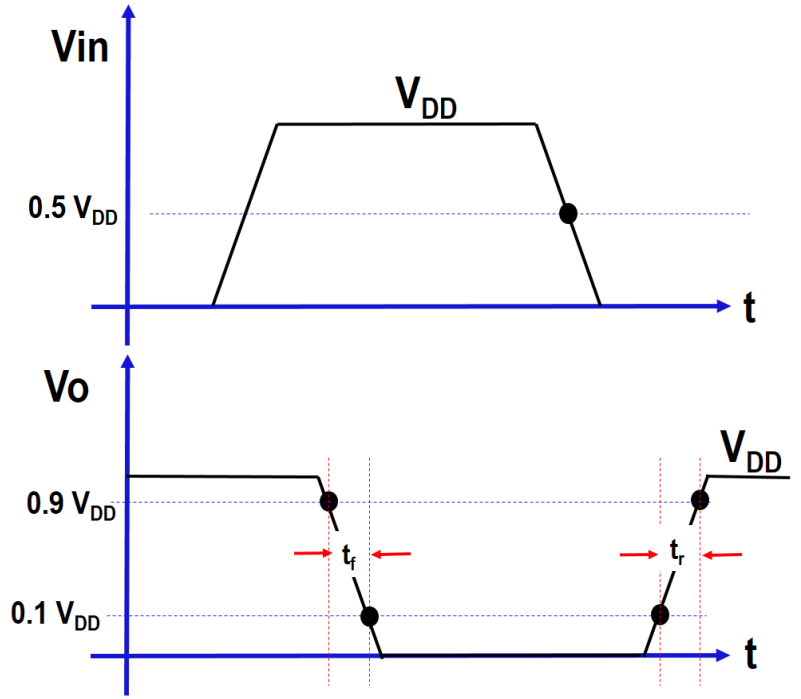
Where $r = \sqrt{\frac{\beta_p}{\beta_n}}$

CMOS Inverter (2/2)









- **Propagation time** (t_p): is the time between 50 % of the input voltage to 50 **%** of the output.

$$t_p = \frac{(t_{PHL} + t_{PLH})}{2}$$

- t_{PHL}: **is the propagation time from high to low.**
- t_{PLH}: **is the propagation time from low to high.**

- **Rise time** (tr): is the time between 10% of the output voltage to 90 **%** of the output.

- **Fall time** (tf):): is the time between 90% of the output voltage to 10**%** of the output

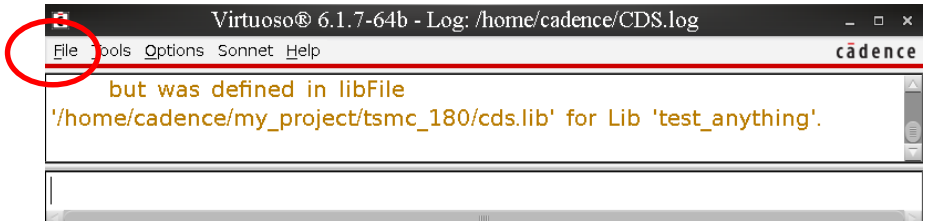
Outlines

- ❑ Objective
- ❑ CMOS Inverter
- ❑ Schematic Editor
- ❑ Create Symbol
- ❑ Testbench
- ❑ Cadence Hot Keys
- ❑ Discussion

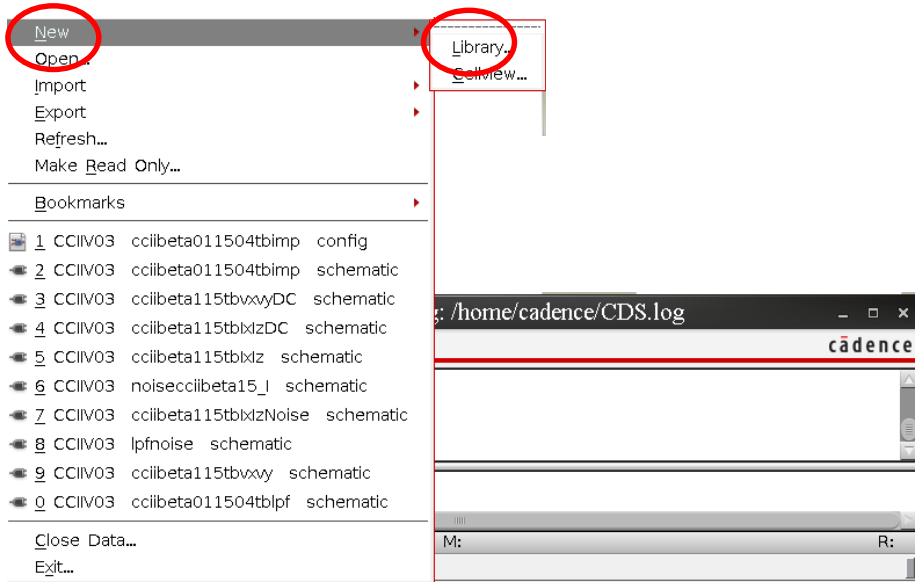
Schematic Editor (1/4)

- Open a terminal and write “virtuoso &”

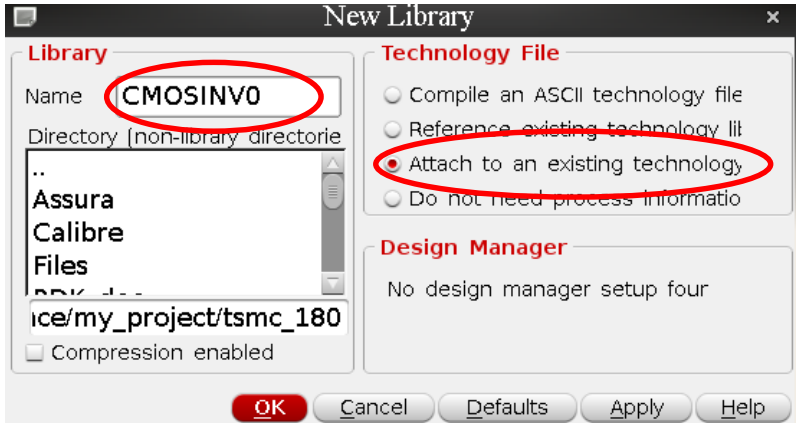
- Select “File”



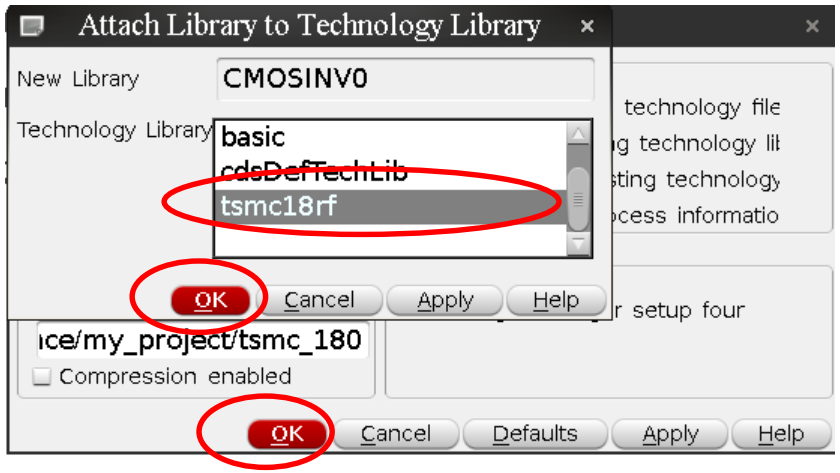
- From new →library



- Write library’s name and select “attach to an existing technology”

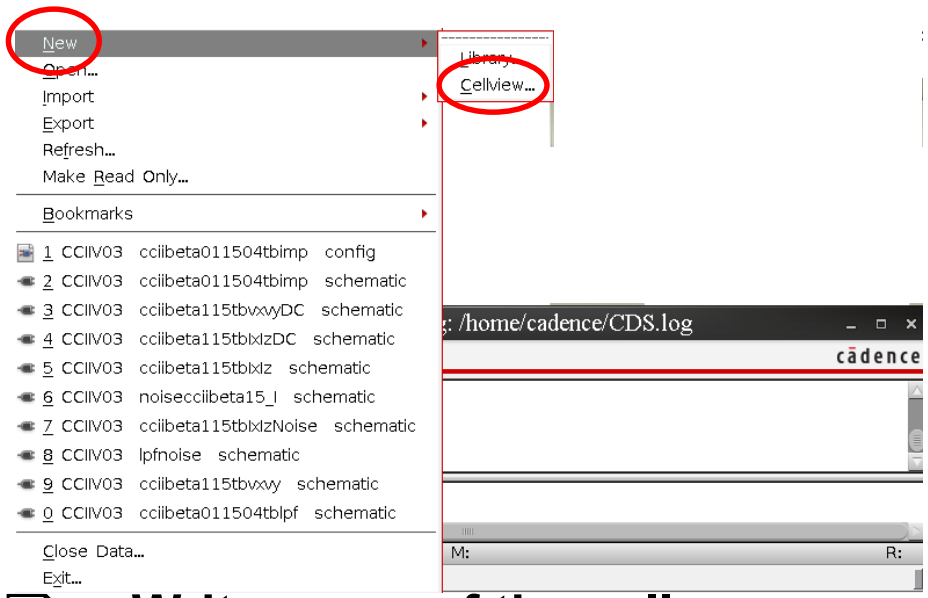


- Then, select technology library “tsmc18rf”, and press “OK”

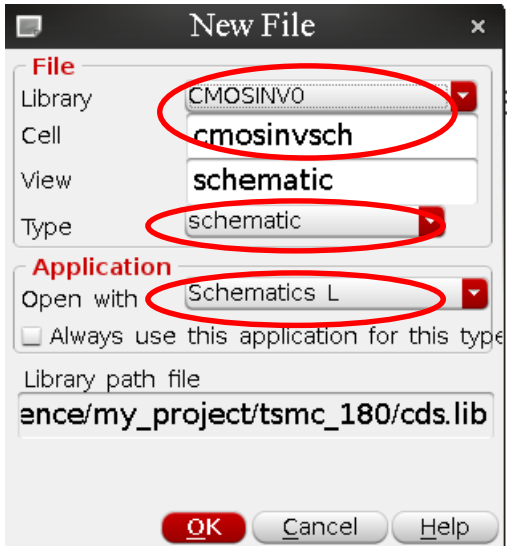


Schematic Editor (2/4)

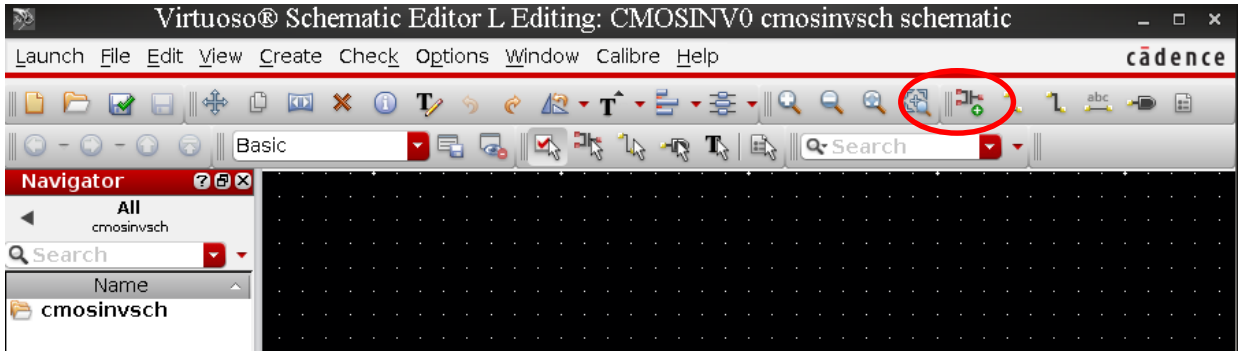
- From File→ new→ Cellview

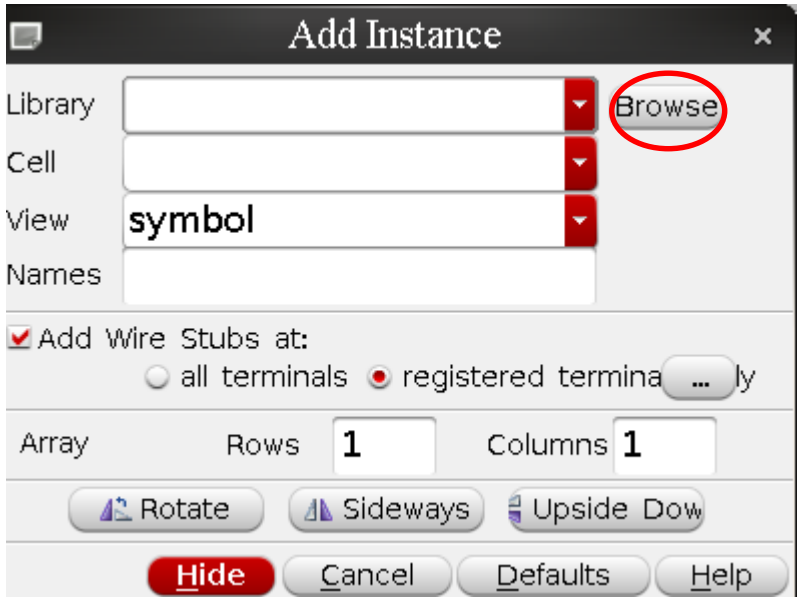


- Write name of the cell



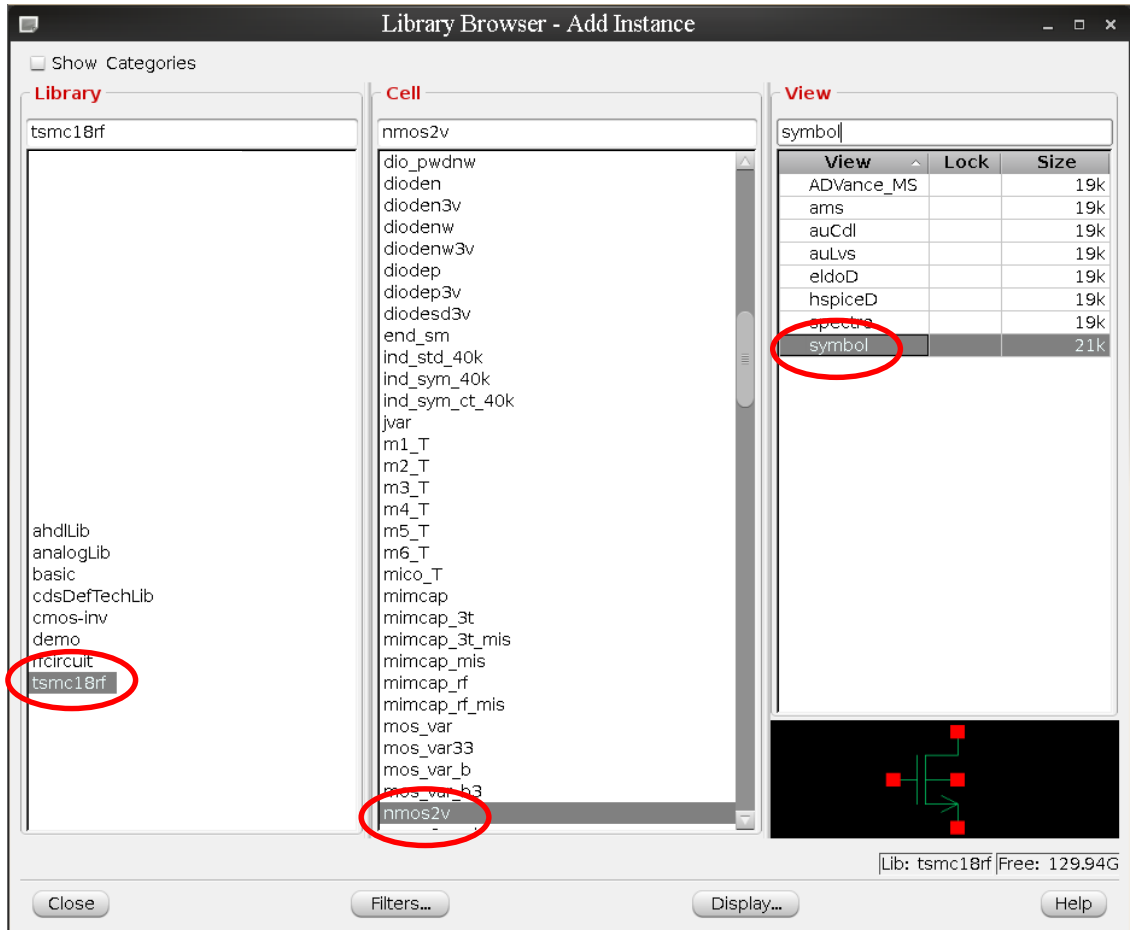
- Then, start to add the instances (MOSFET)



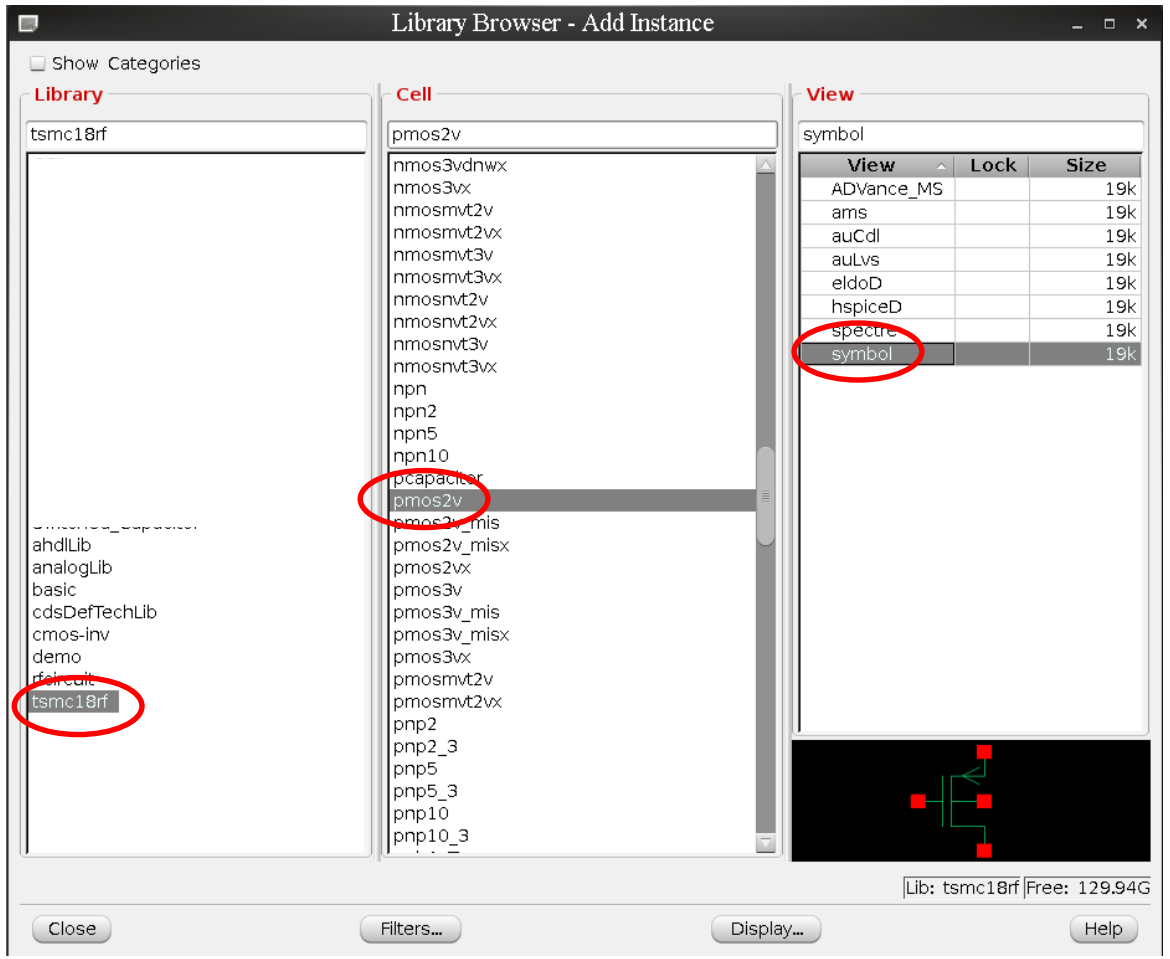


Schematic Editor (3/4)

- Select tsmc18rf→nmos2v→symbol

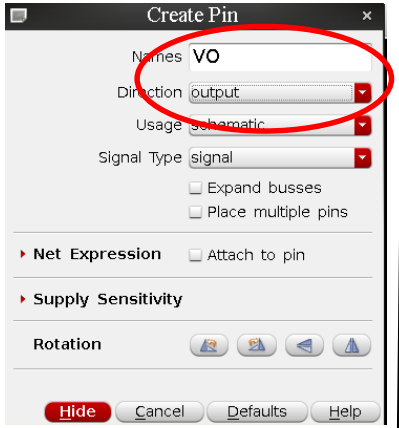


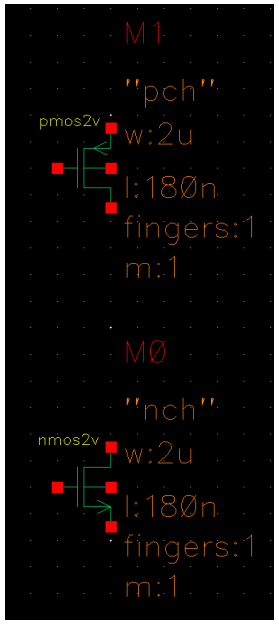
- Select tsmc18rf→pmos2v→symbol

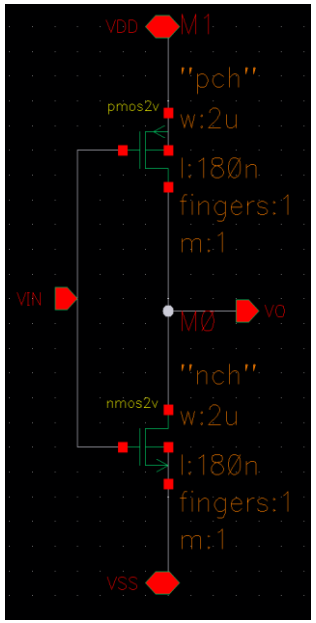


Schematic Editor (4/4)

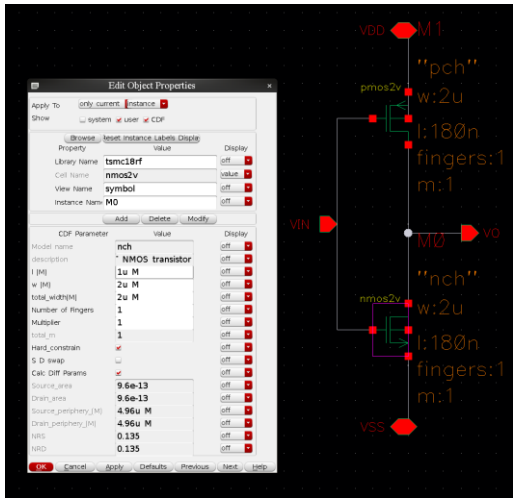
- Start to wire the instances using key “w” and add pins by using “p”

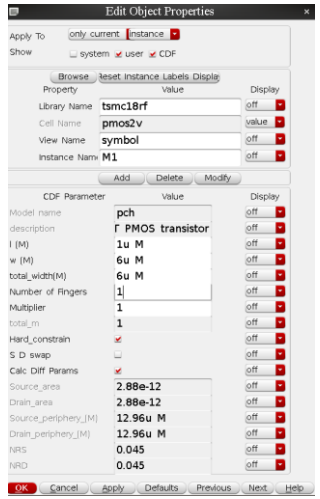






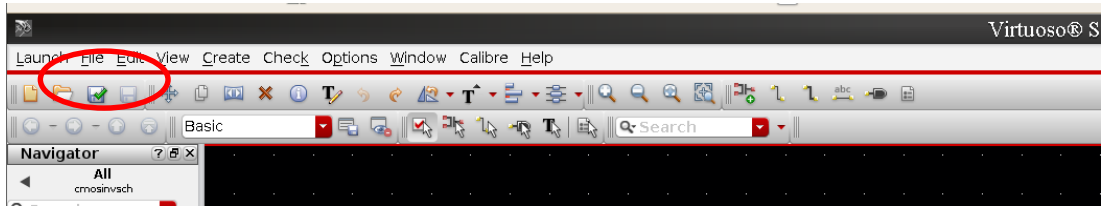
- Change the L and W of the MOSFETs by selecting the instance and press “q”. Do this step for NMOS and PMOS sing the following table.





	L (µm)	W (µm)
M0	1	2
M1	1	6

- Check and save

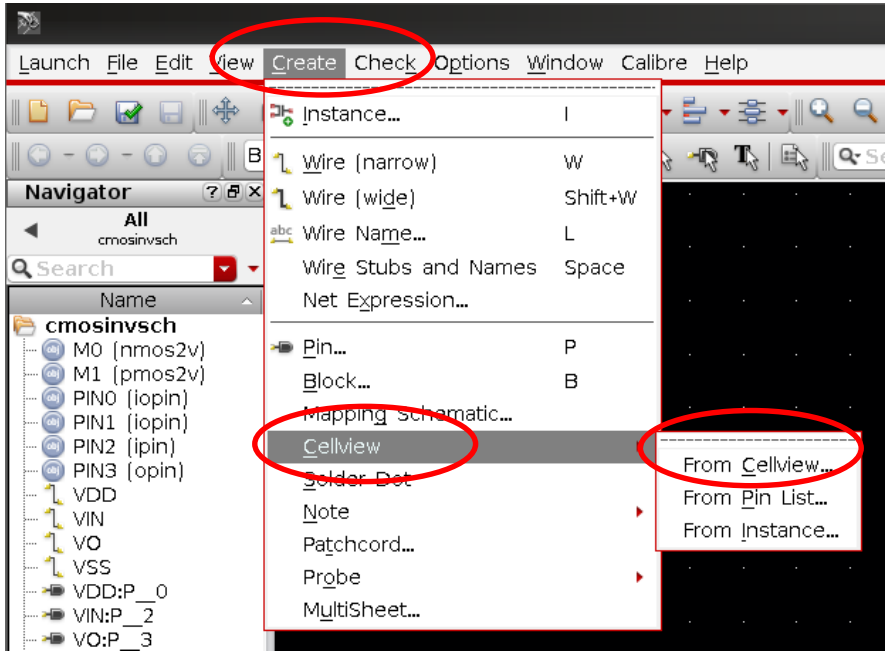


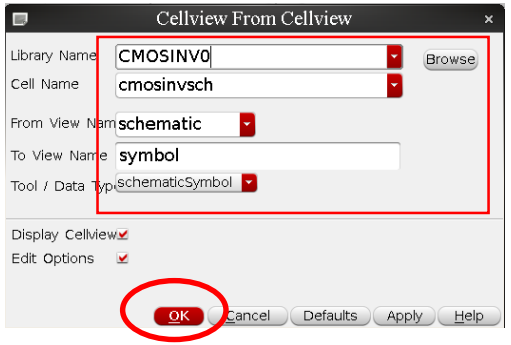
Outlines

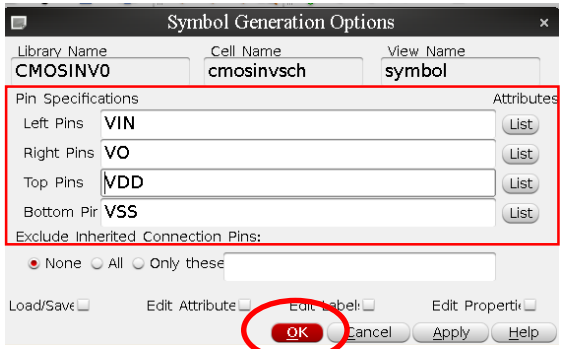
- ❑ Objective
- ❑ CMOS Inverter
- ❑ Schematic Editor
- ❑ Create Symbol
- ❑ Testbench
- ❑ Cadence Hot Keys
- ❑ Discussion

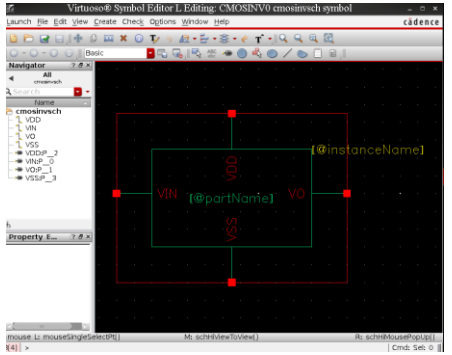
Create Symbol

- To create a symbol create → cellview→ from cellview



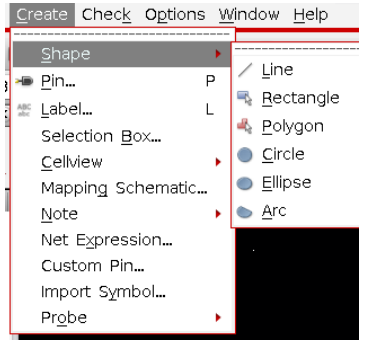


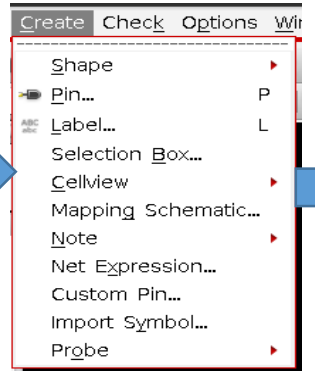


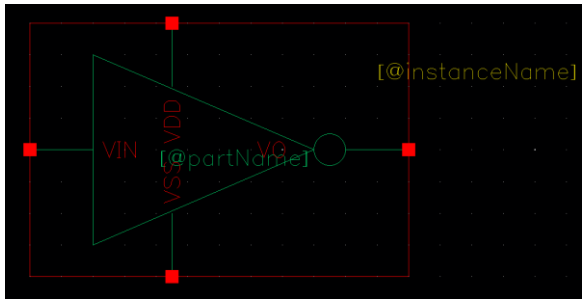


Remove the red box and green box

- Shape of the symbol can be adjusted using create → line/circle







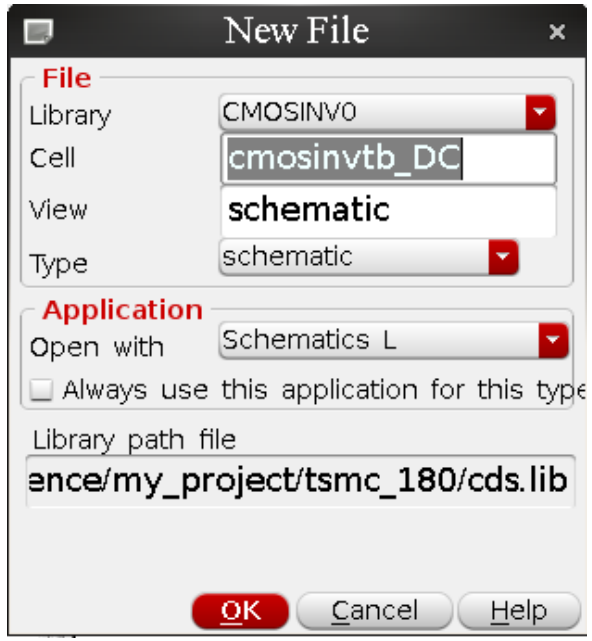
Outlines

- ❑ Objective
- ❑ CMOS Inverter
- ❑ Schematic Editor
- ❑ Create Symbol
- ❑ Testbench
- ❑ Cadence Hot Keys
- ❑ Discussion

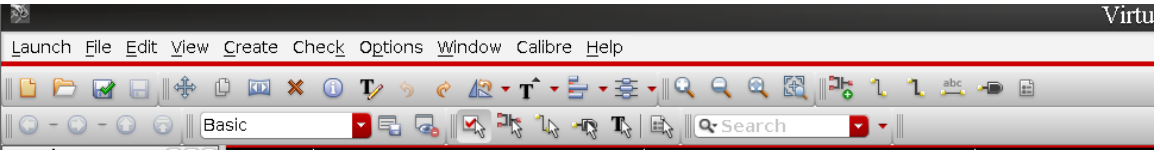
Testbench (1/3)

- Create a testbench for DC sweep

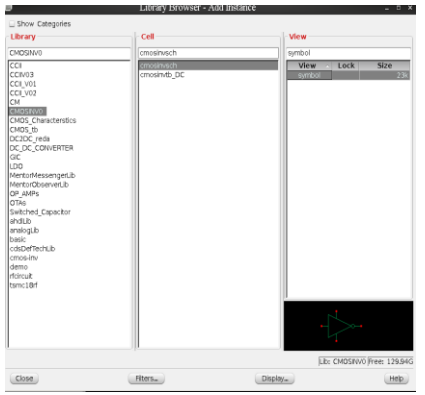
File→ new→ cellview

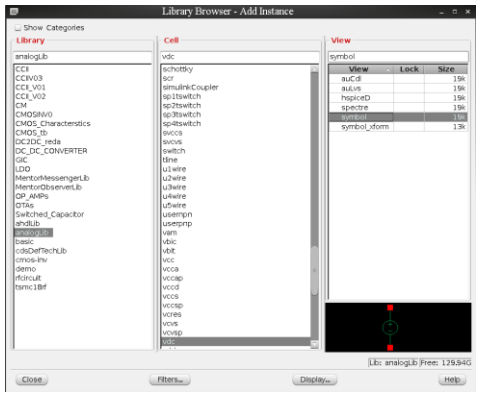


- Add you symbol

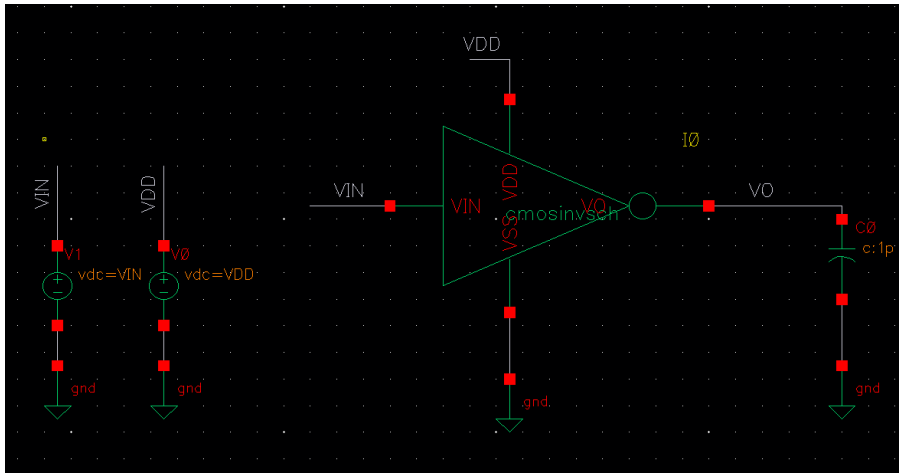


- Select your symbol lib, cell, and cell view
- Add DC power supply, gnd, and Cap from analog lib



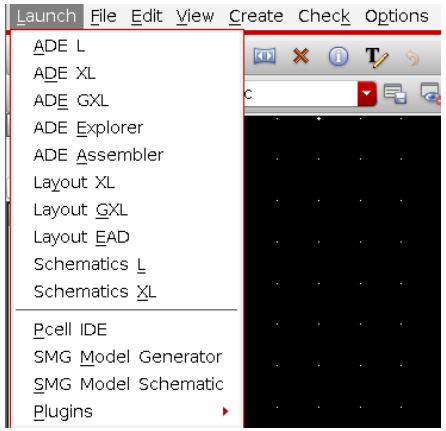


- Then, wire and add wire's labels using "l"

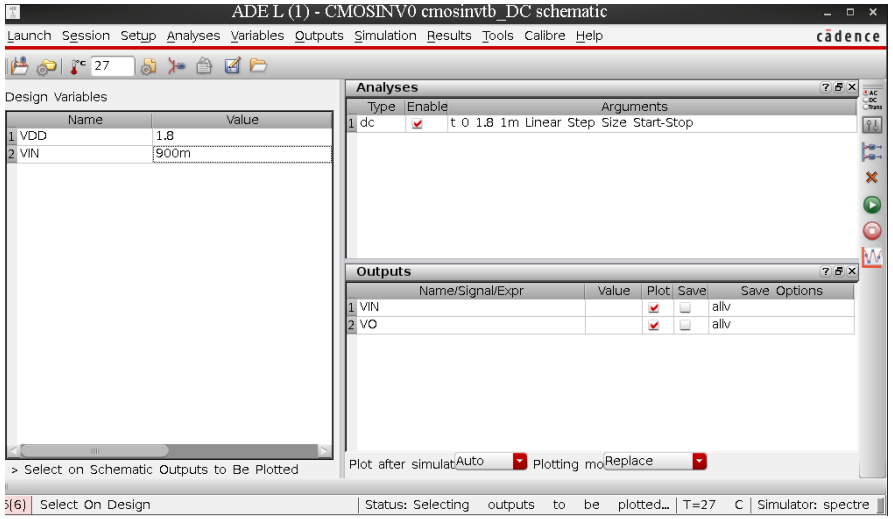


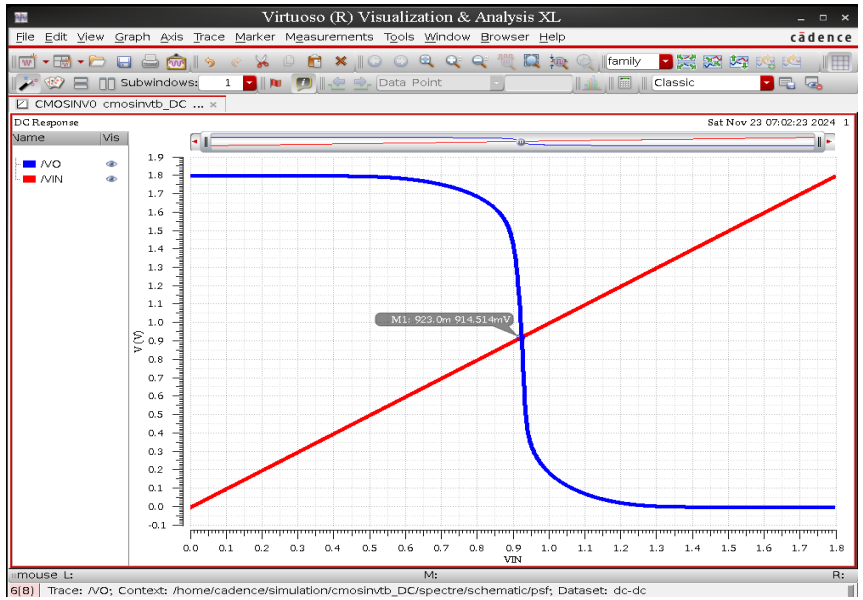
Testbench (2/3)

- To start the simulation



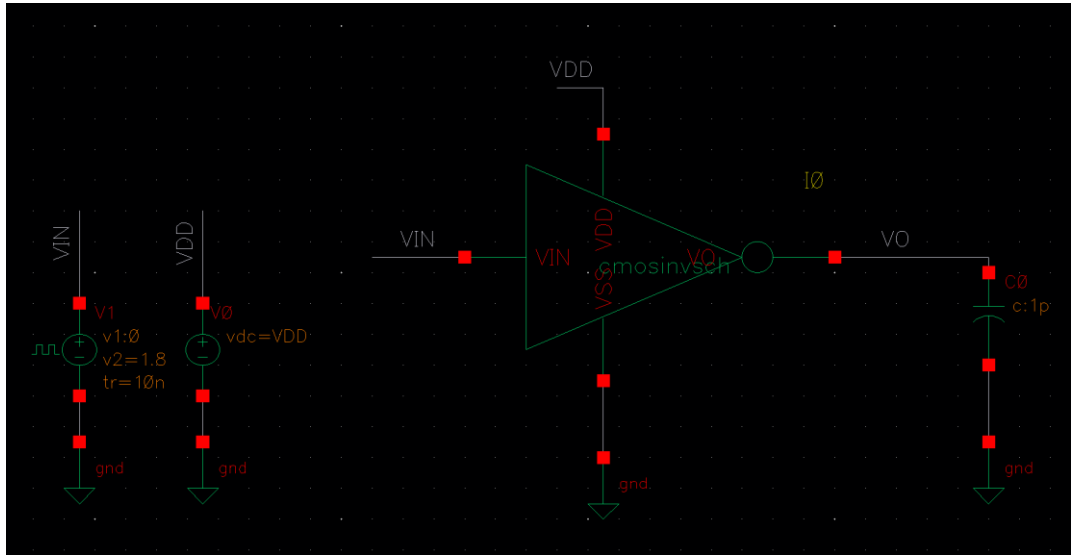
- Adjust the ADE as following and run



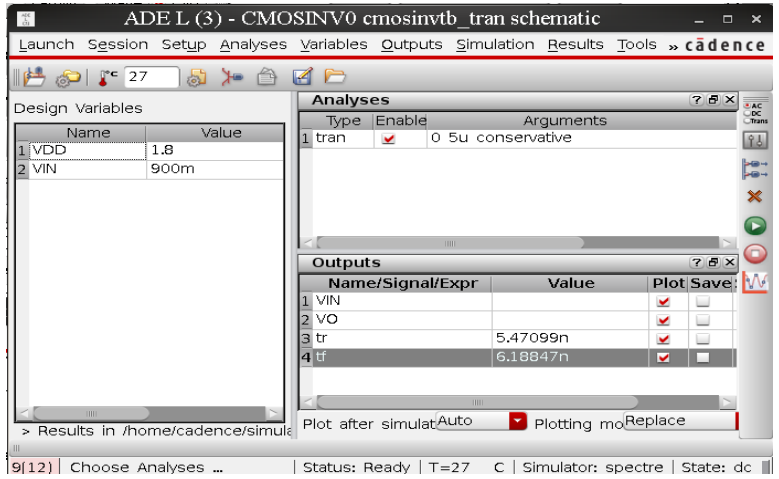


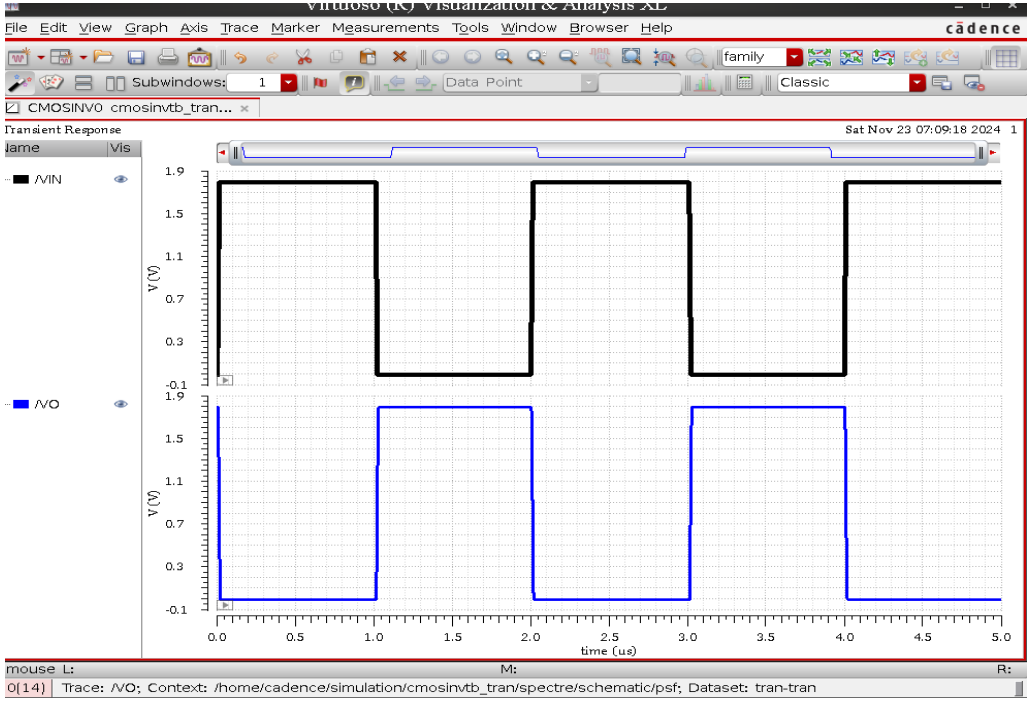
Testbench (3/3)

- To start the transient simulation



- Adjust the ADE as following and run






```
tr= cross(v("/VO" ?result "tran") 1.62 1 "rising" nil nil  )-
cross(v("/VO" ?result "tran") 0.18 1 "rising" nil nil  )

tf=(cross(v("/VO" ?result "tran") 0.18 1 "falling" nil nil) -
cross(v("/VO" ?result "tran") 1.62 1 "falling" nil nil))
```

Outlines

- ❑ Objective
- ❑ CMOS Inverter
- ❑ Schematic Editor
- ❑ Create Symbol
- ❑ Testbench
- ❑ Cadence Hot Keys
- ❑ Discussion

Cadence Hot Keys

Frequently used for schematic editor

w	add a wire
i	add an instance
p	Add a pin
l	Label to a wire
e	display options like, grid size, snap size etc
q	select an object and press q to open the property dialogue box
shift-z	zoom-out by 2×
ctrl-z	zoom-in by 2×
c	copy
m	move: if you move an object, none of the wires connected to it move to maintain connectivity
S	stretch: if you stretch an object all connections to it also extend to maintain connectivity
u /shift-U	Undo/ redo
f	*fit*: fits the entire schematic in the window
shift-X	descend to edit by one
b /shift-b	to go one level up / to return to top

Outlines

- ❑ Objective
- ❑ CMOS Inverter
- ❑ Schematic Editor
- ❑ Create Symbol
- ❑ Testbench
- ❑ Cadence Hot Keys
- ❑ Discussion

Discussion

Thanks!