類比電路佈局合成自動化
Automatic Layout Synthesis for Analog Circuits

單元一
類比電路佈局合成自動化介紹與設計流程建置

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THE EDA LAB
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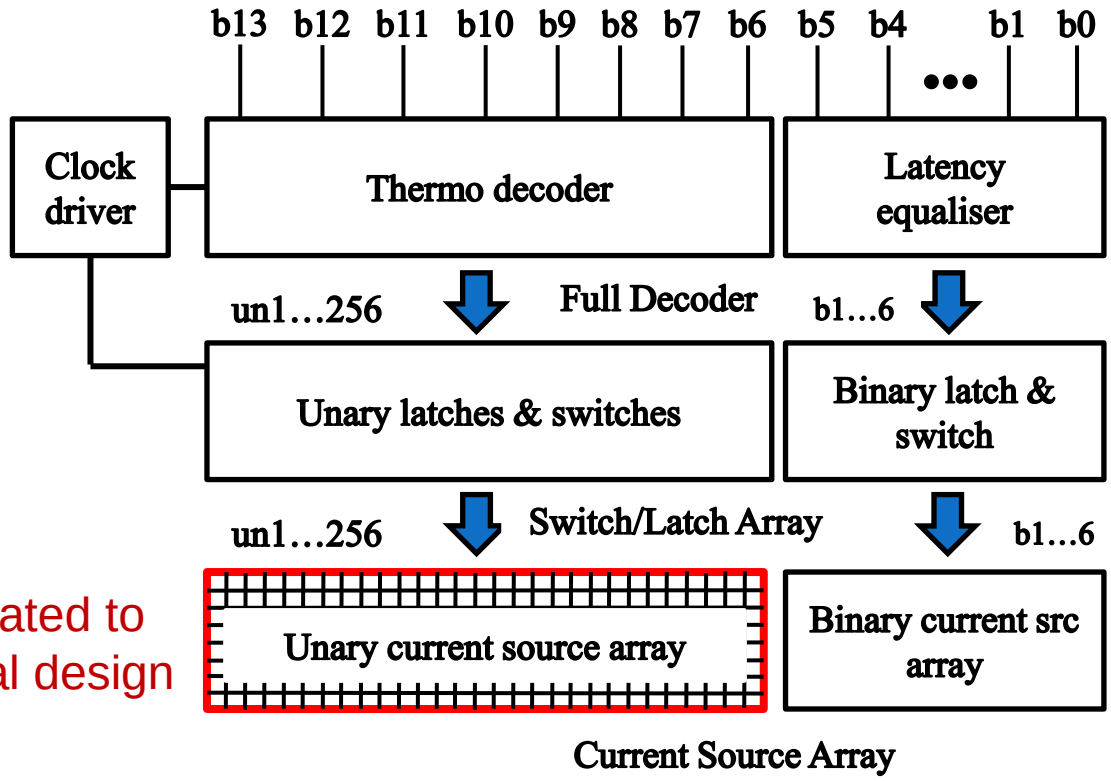
A Large-Scale Analog Circuit

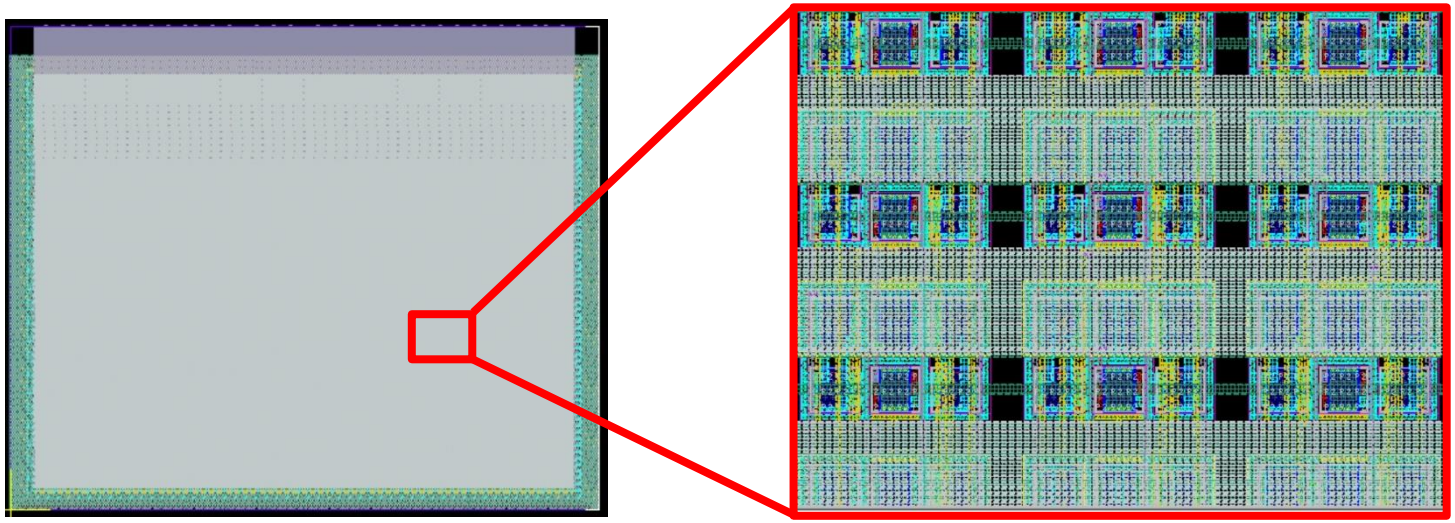
- **A 14-bit current-steering digital-to-analog converter (DAC)**
  - The 8 MSBs are decoded from a thermometer decoder that steers a unary-weighted current source array
  - The 6 LSBs steer the binary weighted current source array



Too complicated to adopt manual design

Why EDA is Required

- **Electronic design automation (EDA)**
  - A category of software tools for designing electronic systems such as digital/**analog** integrated circuits (ICs)
- **The 8-bit unary current source array**
  - 256 current sources, each consists of 16 units
  - 4096 current source units arranged in a 64x64 array

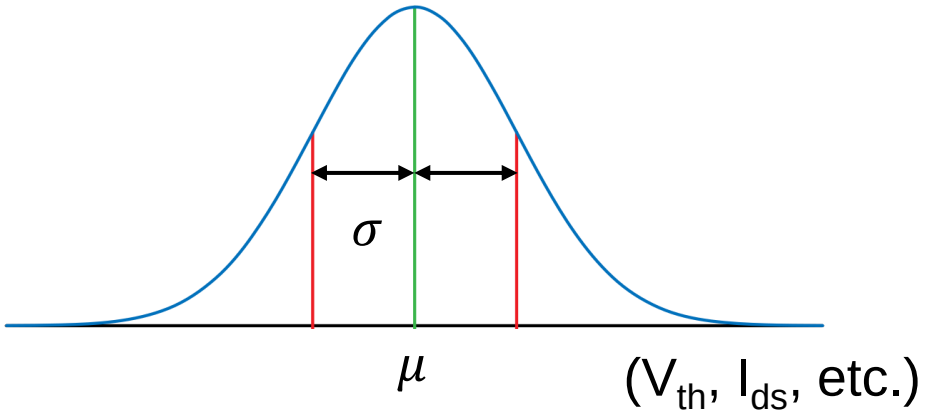


Manually laid out: > 1 month

EDA: < **1 second**

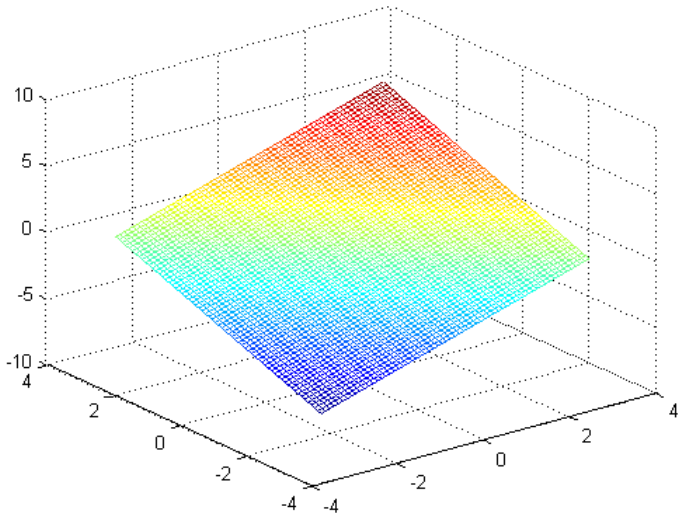
Causes of Mismatches

- **The performance of an analog circuit is usually dominated by mismatches among devices that should be identical**
- **Random variations**
  - Caused by random fluctuations in pattern dimension, doping, oxide thickness, etc.
  - Usually modeled as a Gaussian distribution
  - Mitigation approaches
    - Increase device area
    - Decompose a device into units and distribute in a layout

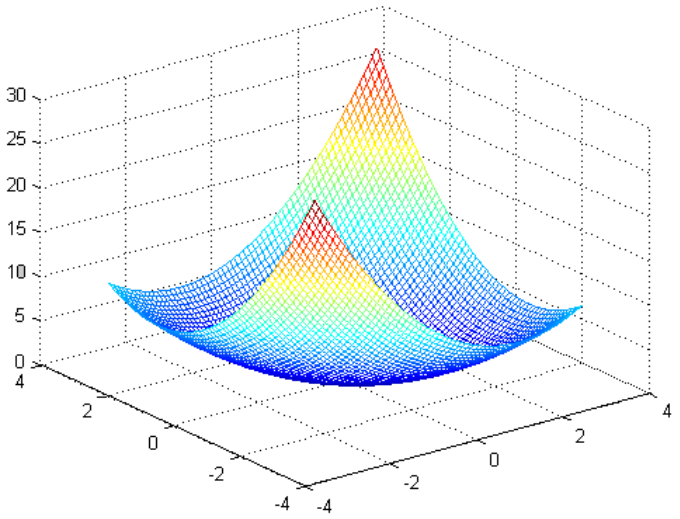


Causes of Mismatches (cont'd)

- **Systematic variations**
  - Caused by process variation, thermal distribution, uneven mechanical stress from other circuit layers, etc.
  - Show up as spatial gradients in device parameters



First-order gradient



Second-order gradient

Common-Centroid Constraint

- **Systematic mismatch can be compensated by careful layout design**
- **The common-centroid constraint**
  - The centroids of the multiple units of all devices are at the same position patterns
  - Used to eliminate linear gradient errors
  - Nonlinear gradient error mitigation will be introduced later

a_1	b_1	c_1	d_1
a_2	b_2	c_2	d_2
d_3	c_3	b_3	a_3
d_4	c_4	b_4	a_4

- Four devices
- Four units for each device
- Common-centroid

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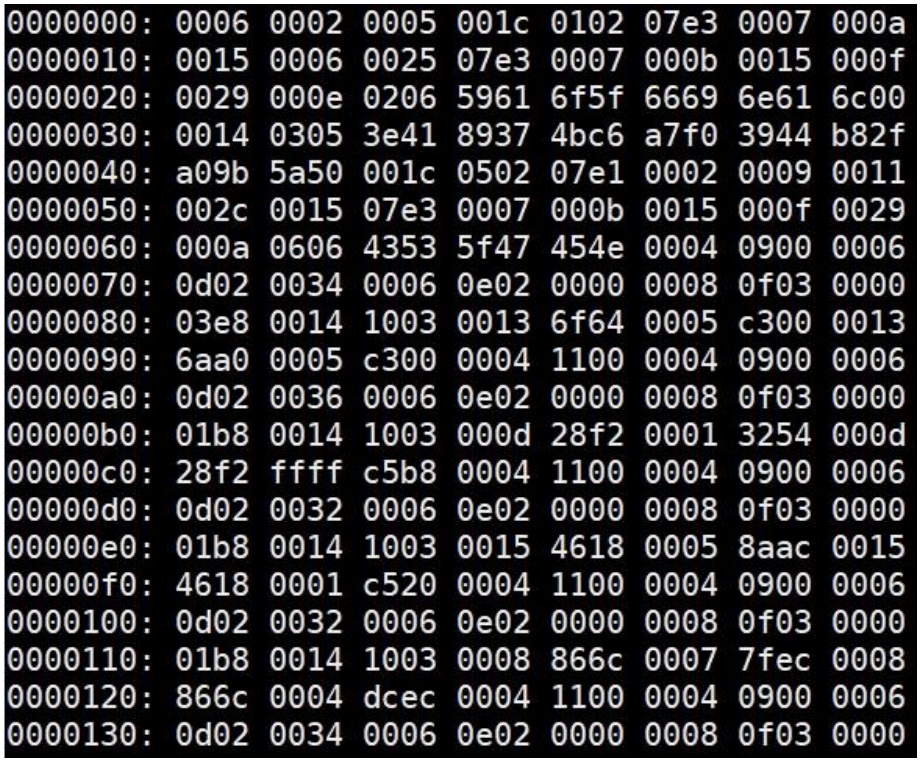
Design Flow Construction

GDSII Introduction

- **GDSII is a binary file format representing planar geometric shapes, text labels**

- **GDSII includes**
  - Standard cells
  - Metals
  - Vias
  - Polys
  - Diffusions
  - etc



DEF Introduction

- **Design Exchange Format (DEF)**
  - An open specification for representing physical layout of an IC

- **DEF includes**
  - Die area
  - Components
  - Special nets

```
SPECIALNETS 6144 ;
- W4622
  + ROUTED ME4 1000 ( 1273700 377600 ) ( 1272480 * ) ;
- W2328
  + ROUTED ME5 440 ( 862450 78420 ) ( * -14920 )
    NEW ME3 440 ( 1394200 363180 ) ( * 116000 ) ;
- W1517
  + ROUTED ME3 440 ( 558700 491500 ) ( * 318700 )
    NEW ME4 1000 ( 512730 191100 ) ( 505260 * ) ;
- W3811
  + ROUTED ME5 440 ( 1418950 491500 ) ( * 361970 )
    NEW ME3 440 ( 462700 318420 ) ( * 160760 ) ;
- W761
  + ROUTED ME3 440 ( 275200 491500 ) ( * 397780 )
    NEW ME5 440 ( 103450 431820 ) ( * 168220 ) ;
```

```
VERSION 5.6 ;
DIVIDERCHAR "/" ;
BUSBITCHARS "[]" ;
DESIGN CS_GEN ;

UNITS DISTANCE MICRONS 1000 ;

PROPERTYDEFINITIONS
  COMPONENTPIN text STRING ;
END PROPERTYDEFINITIONS

DIEAREA ( 0 0 ) ( 1535670 576790 ) ;


COMPONENTS 10496 ;
- via5922 Via34
  + PLACED ( 345480 -370 ) N ;
- via5923 Via34
  + PLACED ( 405480 -370 ) N ;
- via5926 Via34
  + PLACED ( 1101480 -370 ) N ;
- via5927 Via34
  + PLACED ( 1185480 -370 ) N ;
```

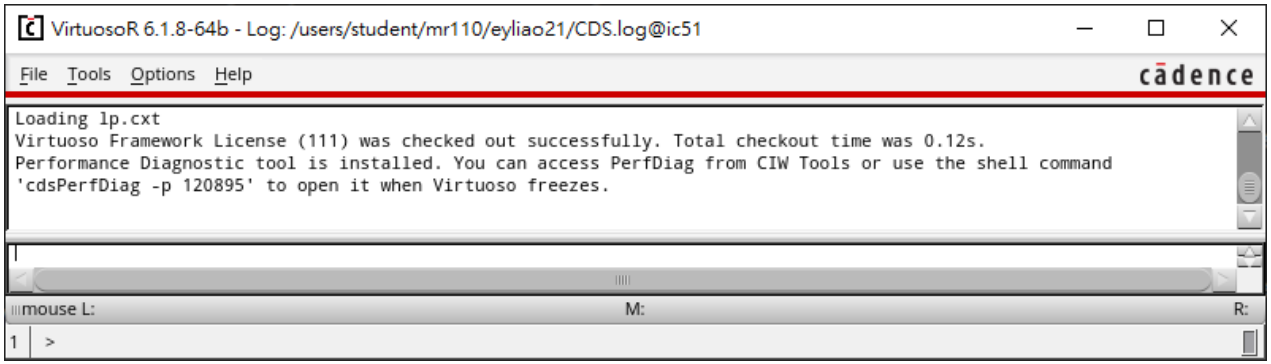
Open Virtuoso

- **Open Virtuoso**

```
$ cd HW5_visual/
$ setenv OA_HOME /usr/cad/cadence/IC/cur/oa_v22.60.074
$ virtuoso &
```

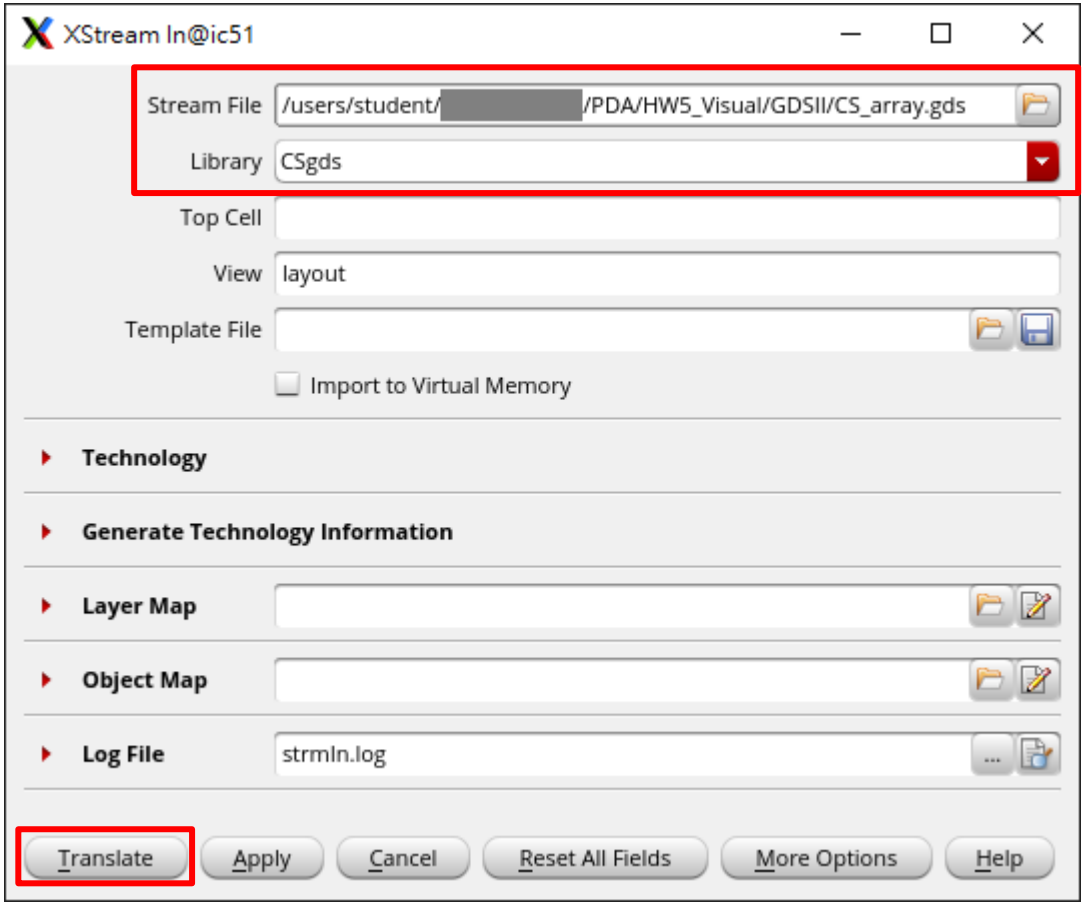
```
[      @ic51 ~/PDA]$ cd HW5_visual/
[      @ic51 HW5_visual]$ setenv OA_HOME /usr/cad/cadence/IC/cur/oa_v22.60.074
[      @ic51 HW5_visual]$ virtuoso &
[1] 236417
[      @ic51 HW5_visual]$ C: unknown locale

[      @ic51 HW5_visual]$
```



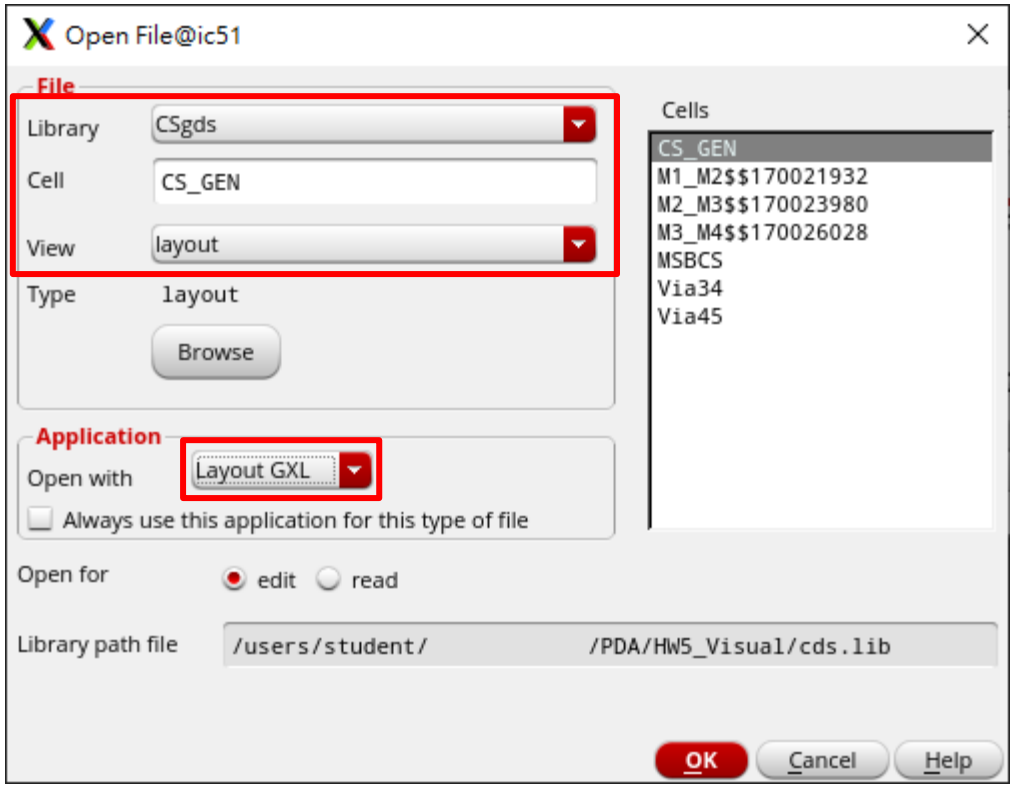
Import GDSII

- **Import “CS_array.gds” and specify a new library “CS_gen”**
  - Left click: File → Import → Stream…
  - Stream File: GDSII/CS_array.gds
  - Library: CSgds
  - Left click: Translate
- **Technology file can be loaded if one is available**

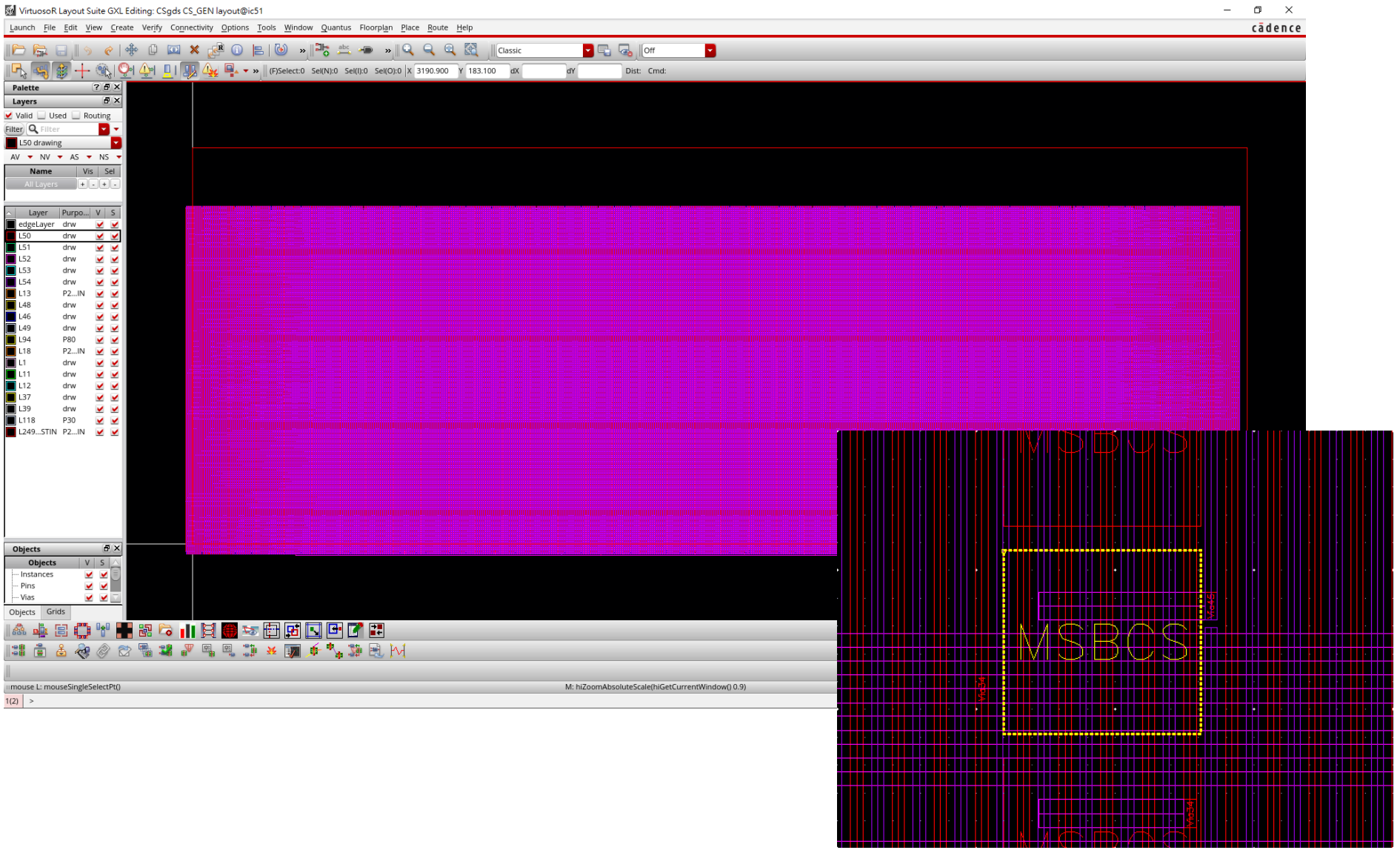


Import GDSII (cont'd)

- **Open the layout**
  - Left click: File → Open…
  - Library: CSgds
  - Cell: CS_GEN
  - View: layout
  - Application: Layout GXL
  - Left click:OK

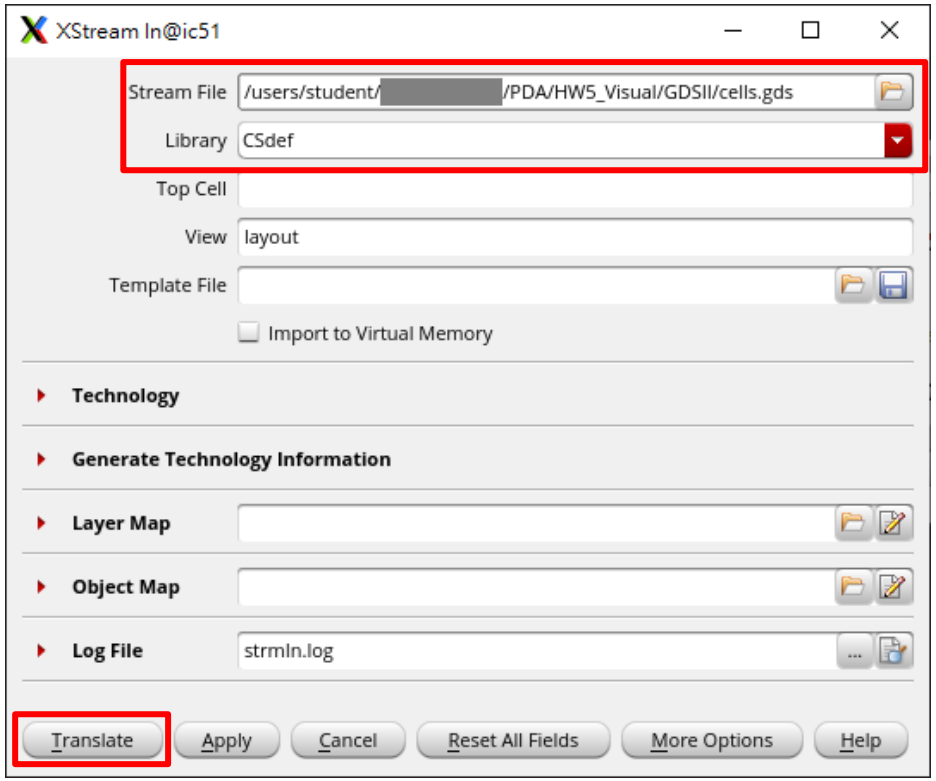


Import GDSII (cont'd)



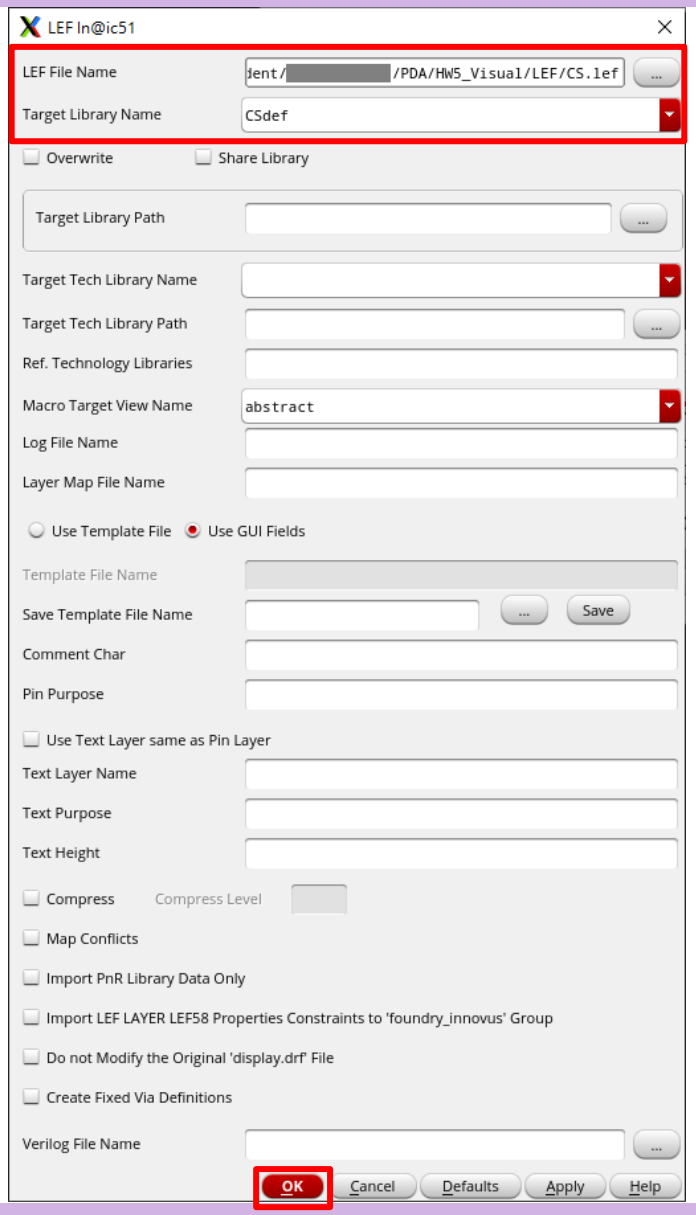
Import DEF

- **The layout automation flow requires the layouts (*.gds) of device components and then generates a DEF file specifying the placement and routing of the components**
- **Step 1: import “cells.gds” and specify a new library “CSdef”**
  - Left click: File → Import → Stream…
  - Stream File: GDSII/cells.gds
  - Library: CSdef
  - Left click: Translate



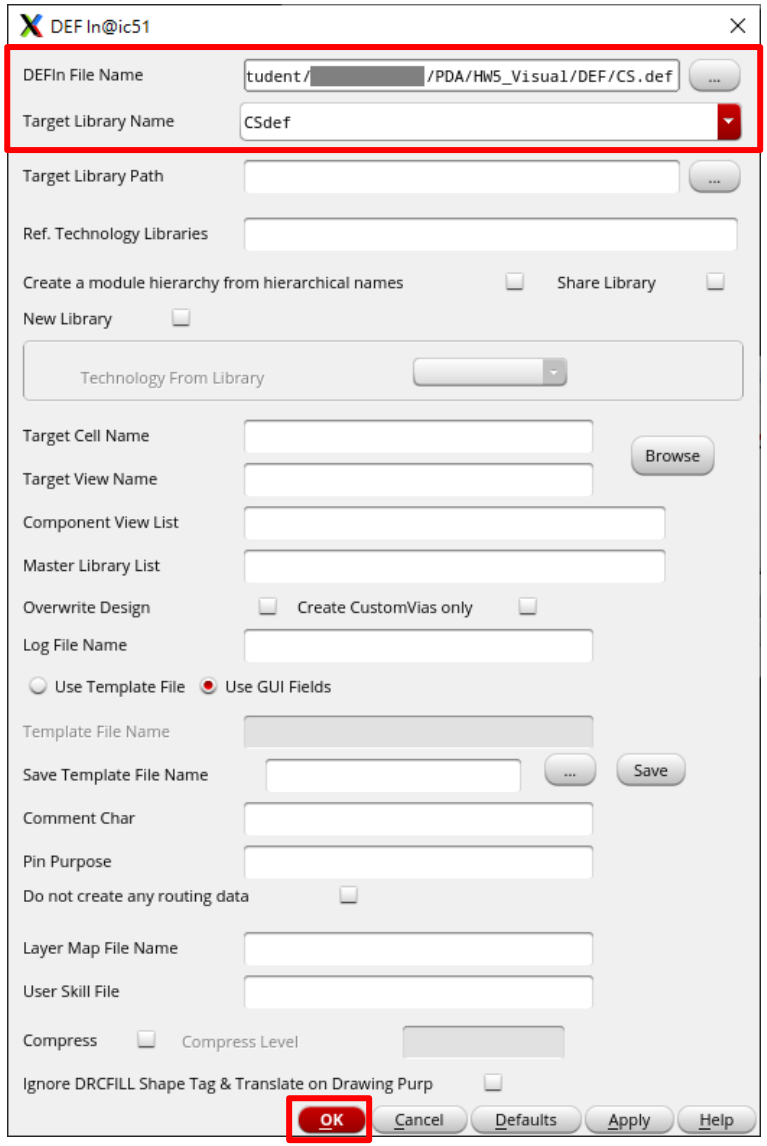
Import DEF (cont'd)

- **Step 2: import "CS.lef" to "CSdef"**
  - Left click: File → Import → LEF…
  - LEF File Name: LEF/CS.lef
  - Target Library Name: CSdef
  - Left click: OK
- **A LEF file (specifying the design rules of metal layers) is required before importing a DEF file**



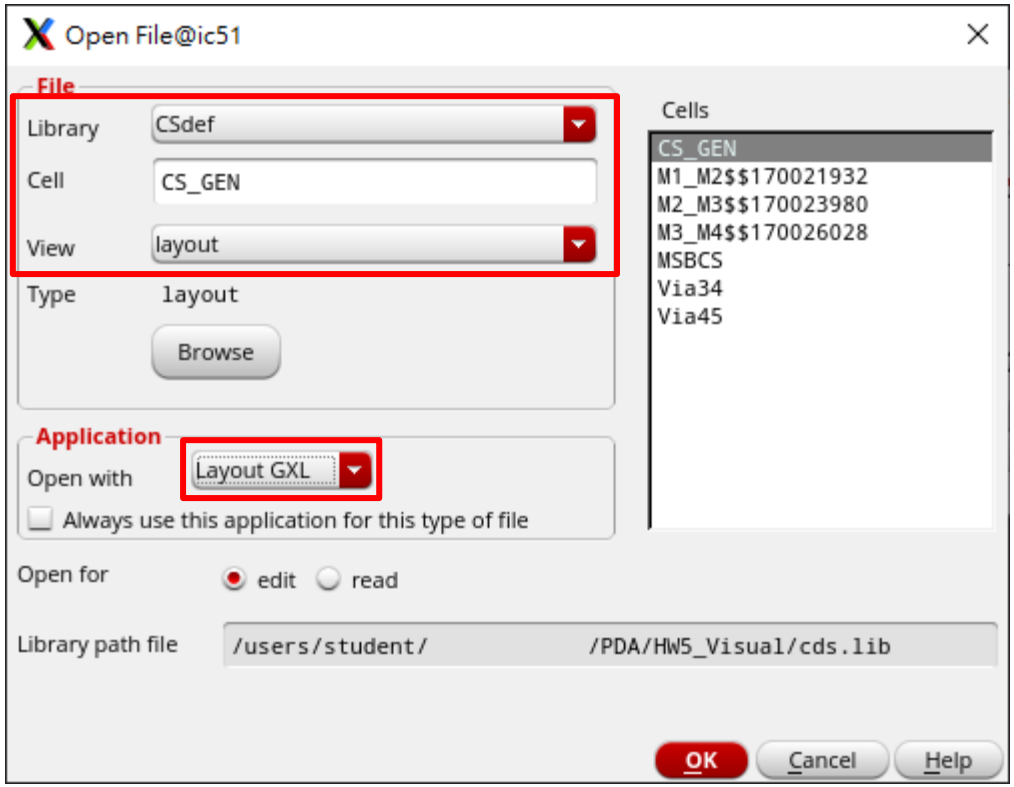
Import DEF (cont'd)

- **Step 3: import DEF to "CSdef"**
  - Left click: File → Import → DEF…
  - DEFIn File Name: DEF/CS.def
  - Target Library Name: CSdef
  - Left click: OK

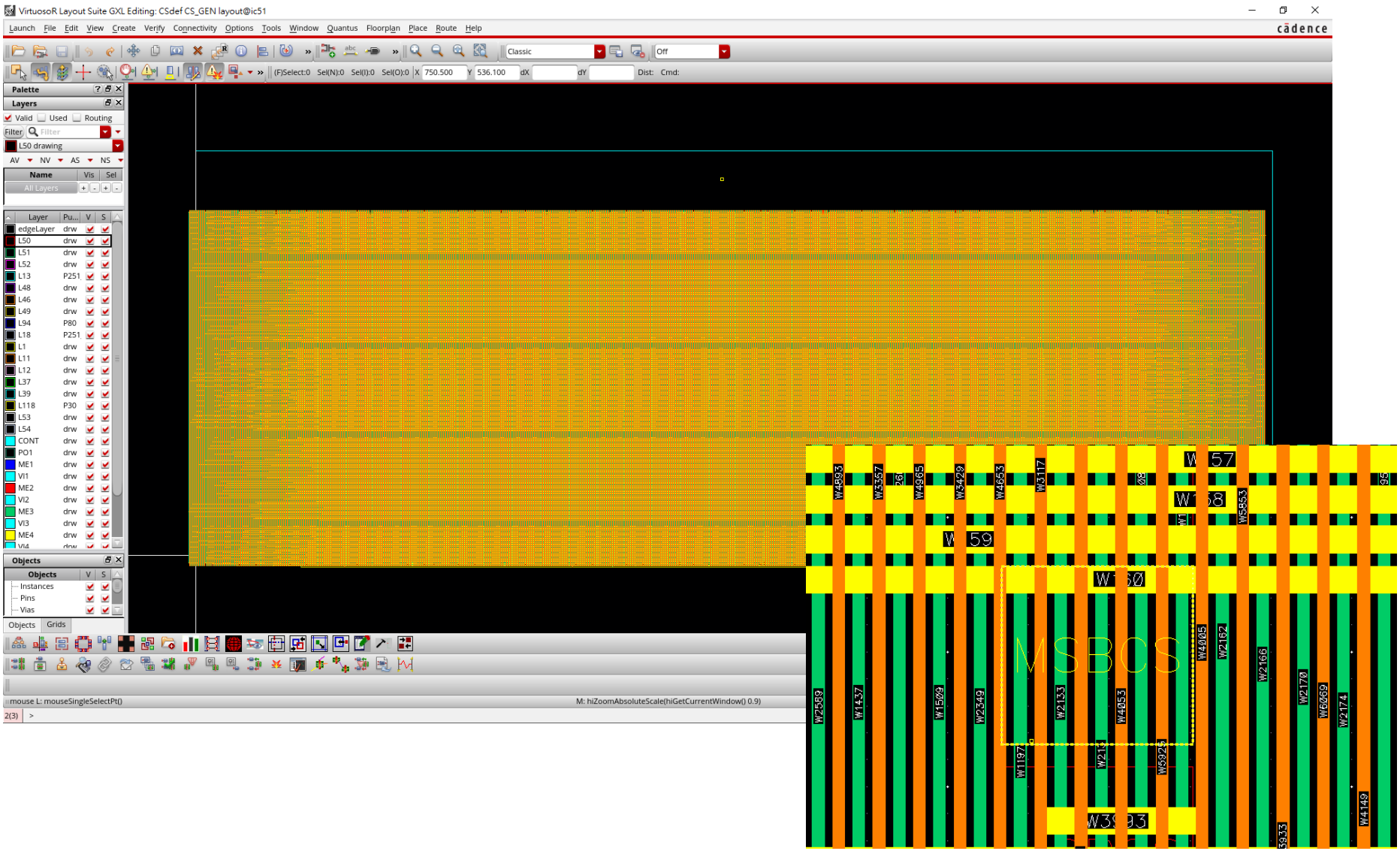


Import DEF (cont'd)

- **Open the layout**
  - Left click: File → Open…
  - Library: CSdef
  - Cell: CS_GEN
  - View: layout
  - Application: Layout GXL
  - Left click:OK



Import DEF (cont'd)

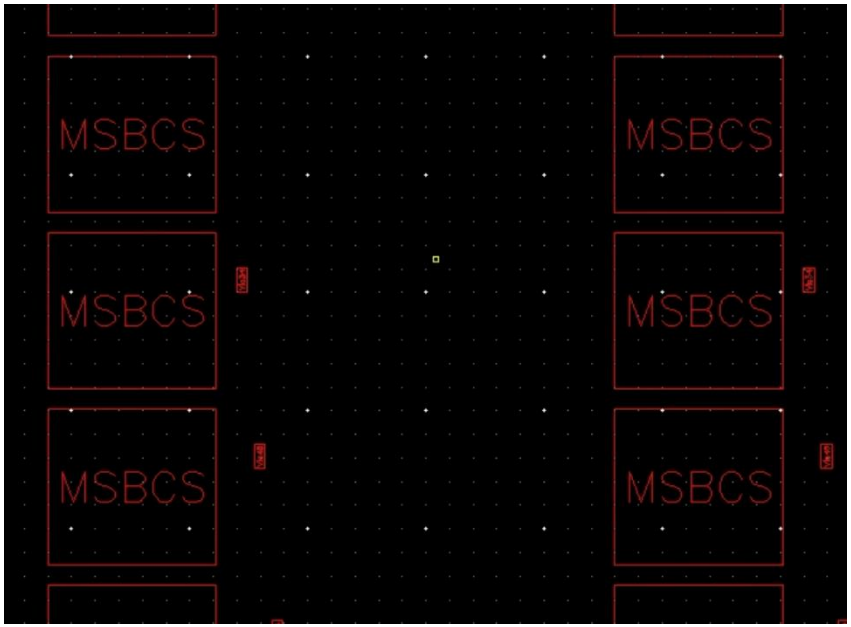


Shortcuts

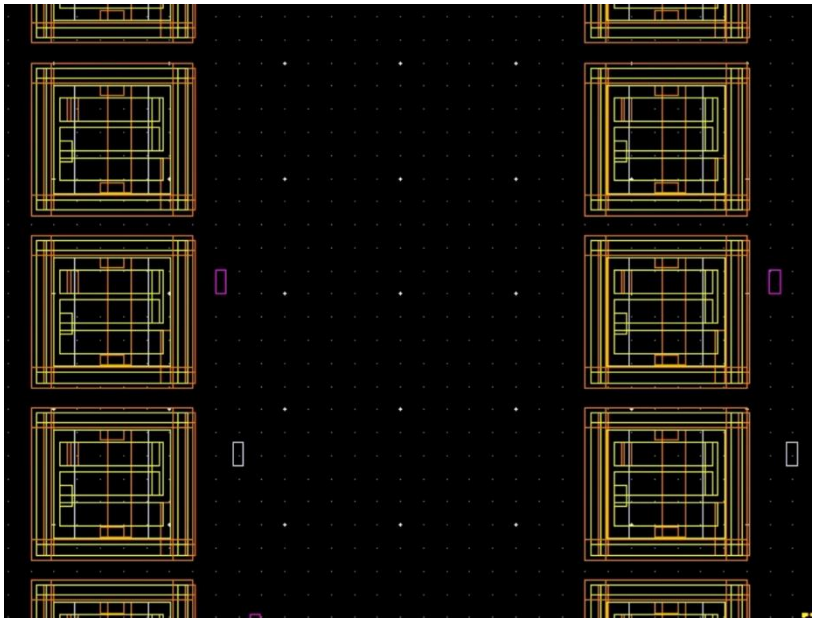
- **shift+z**
  - Zoom out
- **ctrl+z**
  - Zoom in
- **z**
  - Zoom to area
- **f**
  - Zoom to fit all
- **shft+f**
  - Show cell layouts
- **ctrl+f**
  - Hide cell layouts

Reminding

- **Cell layouts can only be seen after importing the gds file of device components**



Hide cell layouts (ctrl+f)



Show cell layouts (shift+f)

Python Introduction

Python

- **High level interpreted programming language**
- **We will use python to accomplish CS placement and routing automation**
- **Pre-training**
  - Run python
  - Define variable
  - Different type of variables
  - Operator computation
  - For loop and list of variables definition
  - Instance instantiation
  - Run python script

Run Python

- **Just type “python” in your terminal**

  `$ python3`

```
[      @ic51 python]$ python3
Python 3.6.8 (default, Nov 16 2020, 16:55:22)
[GCC 4.8.5 20150623 (Red Hat 4.8.5-44)] on linux
Type "help", "copyright", "credits" or "license" for more information.
>>>
```

- **Exit python**

  `>>> quit()`

```
[      @ic51 python]$ python3
Python 3.6.8 (default, Nov 16 2020, 16:55:22)
[GCC 4.8.5 20150623 (Red Hat 4.8.5-44)] on linux
Type "help", "copyright", "credits" or "license" for more information.
>>> quit()
[      @ic51 python]$
```

Define Variable

- **Give a name and initial value**

```
Python 3.6.8 (default, Nov 16 2020, 16:55:22)
[GCC 4.8.5 20150623 (Red Hat 4.8.5-44)] on linux
Type "help", "copyright", "credits" or "license" for more information.
>>> x = 10
>>> y = 20
>>>
```

- **Print variables**

```
>>> x = 10
>>> y = 20
>>> print(x)
10
>>> print(y)
20
>>>
```

Different Type of Variables

- **The variable types can be int, float, string, or even an instance defined by users**

```
>>> x = 5
>>> y = 5.7
>>> z = 'current source array'
>>> type(x)
<class 'int'>
>>> type(y)
<class 'float'>
>>> type(z)
<class 'str'>
>>>
```

```
>>> from myObject import Component
>>> c = Component('MCBCS', 'C1', 0, 0)
>>> type(c)
<class 'myObject.Component'>
>>>
```

Operator Computation

- **Let's try all operators**

```
>>> 10 + 7
17
>>> 10 - 7
3
>>> 10 * 7
70
>>> 10 / 7
1.4285714285714286
>>> 10 // 7
1
>>> 10 ** 7
10000000
>>> pow(10, 7)
10000000
>>>
```

```
>>> import math
>>> math.sqrt(100)
10.0
>>> math.sin(math.radians(90))
1.0
>>>
```

For Loop

- **Single and double for loop example**

```
>>> for i in range(10):
...     x = i * 10
...     print(x)
...
0
10
20
30
40
50
60
70
80
90
>>>
```

```
>>> for i in range(3):
...     for j in range(3):
...             print('({:d} {:d})'.format(i, j))
...
(0 0)
(0 1)
(0 2)
(1 0)
(1 1)
(1 2)
(2 0)
(2 1)
(2 2)
>>>
```

List of Variables

- **Initialize a one/two-dimensional list**

```
>>> listA = [1, 2, 3]
>>> type(listA)
<class 'list'>
>>> listA[0]
1
>>> listA[1]
2
>>> listA[2]
3
>>>
```

```
>>> listA = [[1, 2, 3], [4, 5, 6]]
>>> listA[0]
[1, 2, 3]
>>> listA[1]
[4, 5, 6]
>>> listA[0][0]
1
>>> listA[1][2]
6
>>>
```

List of Variables (cont'd)

- **Initialize a one/two-dimensional empty list with designated type**

```
>>> listA = [float for i in range(4)]
>>> listA
[<class 'float'>, <class 'float'>, <class 'float'>, <class 'float'>]
>>> len(listA)
4
>>>
```

```
>>> listA = [[int for j in range(3)] for i in range(2)]
>>> listA
[[<class 'int'>, <class 'int'>, <class 'int'>], [<class 'int'>, <class 'int'>, <class 'int'>]]
>>> len(listA)
2
>>> len(listA[0])
3
>>>
```

List Append

- **Incrementally append elements to a list**

```
>>> listA = [1, 2, 3]
>>> listA
[1, 2, 3]
>>> listA.append(4)
>>> listA
[1, 2, 3, 4]
>>>
```

Instance Instantiation

- **Three pre-defined instances will be applied**
  - Die
    - design_name
    - _x1
    - _y1
    - _x2
    - _y2

```
>>> from myObject import Die
>>> die = Die('cs_array', 0, 0, 10000, 10000)
>>> die.design_name
'cs_array'
>>> die._x1
0
>>> die._x2
10000
>>> die._y1
0
>>> die._y2
10000
>>>
```

Instance Instantiation (cont'd)

- Component
  - lib_name
  - inst_name
  - _x
  - _y

```
>>> from myObject import Component
>>> cs_unit = Component('MSBCS', 'cs1', 0, 0)
>>> cs_unit.lib_name
'MSBCS'
>>> cs_unit.inst_name
'cs1'
>>> cs_unit._x
0
>>> cs_unit._y
0
>>>
```

Instance Instantiation (cont'd)

- SpecialNet
  - inst_name
  - layer
  - _x1
  - _y1
  - _x2
  - _y2

```
>>> from myObject import SpecialNet
>>> net = SpecialNet('n1', 'ME3', 0, 0, 440, 700)
>>> net.inst_name
'n1'
>>> net.layer
'ME3'
>>> net._x1
0
>>> net._y1
0
>>> net._x2
440
>>> net._y2
700
>>>
```

Run Python Script

- **Create a “test.py” file**

```
$ vim test.py
```

- **Write some python command in “test.py” and save**

```
1 import sys
2
3 argc = len(sys.argv)
4 print('read {:d} args'.format(argc))
5
6 for i, arg in enumerate(sys.argv):
7     print('arg{}: {}, type: {}'.format(i, arg, type(arg)))
8
~
```

- **Run “test.py” script in terminal**

```
$ python3 test.py abc 123
```

```
[      @ic51 python]$ vim test.py
[      @ic51 python]$ python3 test.py abc 123
read 3 args
arg0: test.py, type: <class 'str'>
arg1: abc, type: <class 'str'>
arg2: 123, type: <class 'str'>
[      @ic51 python]$
```