UNIC-CASS Mentoring Session 02

Introduction to the Digital Design Flow

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August 30th, 2023

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IEEE CIRCUITS AND SYSTEMS SOCIETY

IEEE

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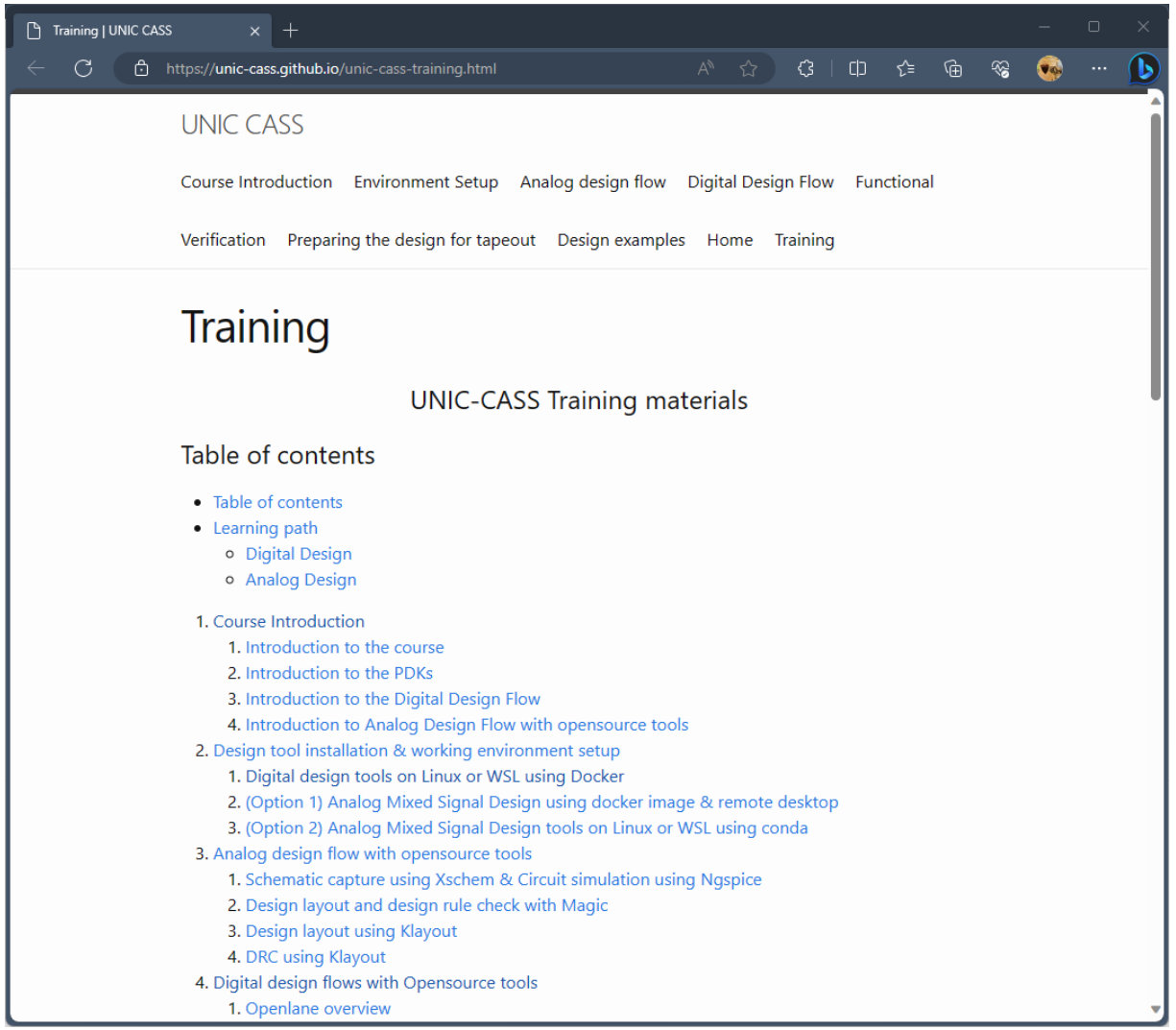
Universalization of IC Design from IEEE CASS

UNIC CASS Page

Do not miss the page created by Prof. Duy-Hieu Bui:

https://unic-cass.github.io/



Join the Open-EDA Community

UNIC-CASS Slack

https://join.slack.com/t/unic-cass/shared_invite/zt-1xxifr0ow-n8dpt0qNBxb4J50g8MEvmw

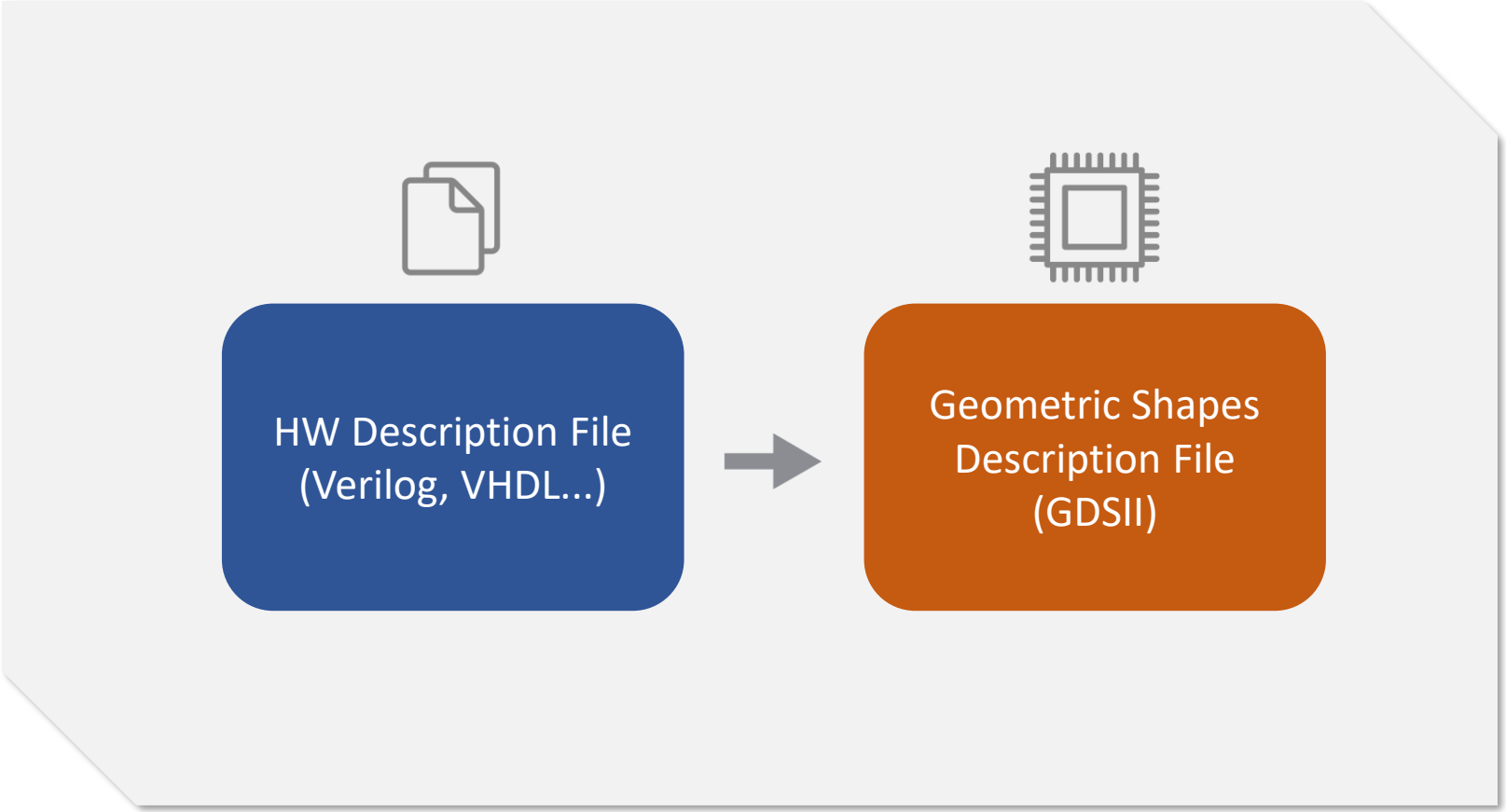
open-source-silicon Slack

https://join.slack.com/t/open-source-silicon/shared_invite/zt-1zopfd1gk-uI2eSlNXB54xN9RCowGa4g

Outline

1. Introduction to the RTL2GDSII Flow
   - Logical Synthesis
   - Physical Synthesis
2. Open-EDA Ecosystem
3. OpenLane
4. Digital Design Environment Setup
5. Running Example

RTL2GDSII


HW Description File
(Verilog, VHDL...)
Geometric Shapes
Description File
(GDSII)

RTL2GDSII

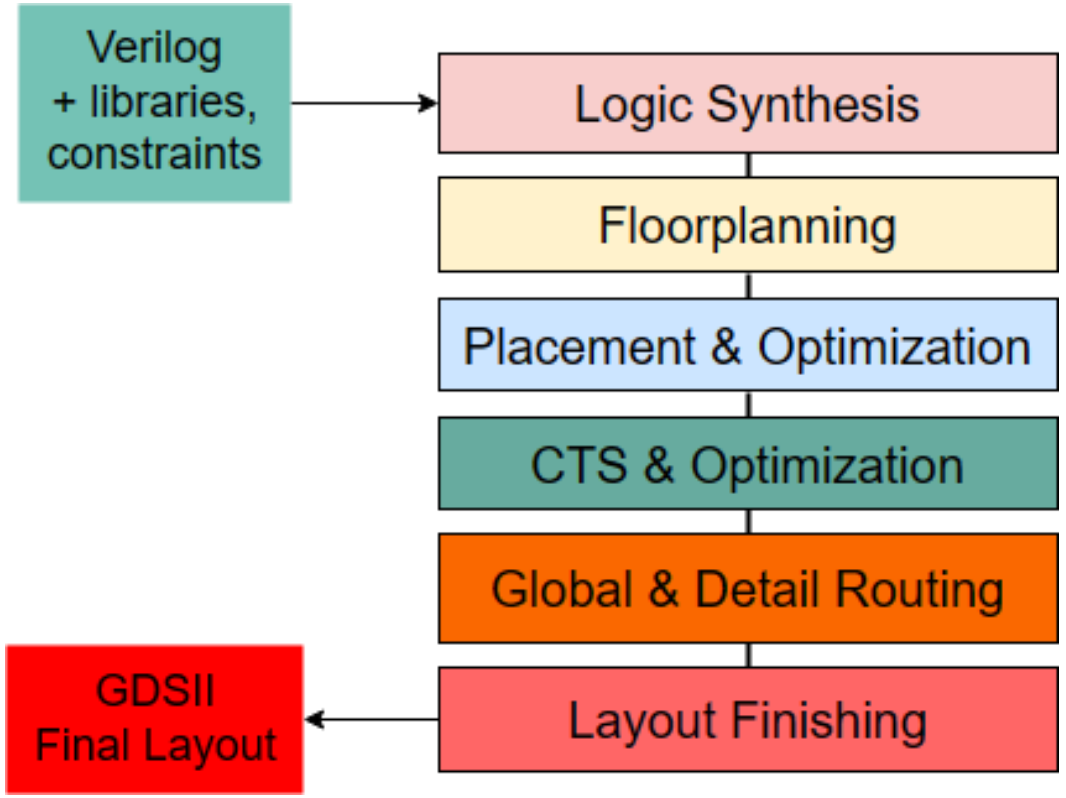


Figure Source: https://openroad.readthedocs.io/en/latest/main/README.html

Logic Synthesis

Transform a **HW Description** into a “mapped description” / netlist.

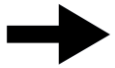
```
23  reg [SC_SIZE-1:0] scan_master;
24  reg [SC_SIZE-1:0] scan_slave;
25  wire [SC_SIZE-1:0] scan_next;
26
27  assign scan_next = {scan_data_in, scan_slave[SC_SIZE-1:1]};
28
29  always @ (posedge clk) begin
30  scan_master = scan_next;
31  end
32
33  always @ (negedge clk) begin
34  scan_slave = scan_master;
35  end
36
37  always @ (*)
38  if (scan_load_chip) begin
39  SC_to_the_chip=scan_slave;
40  end
```

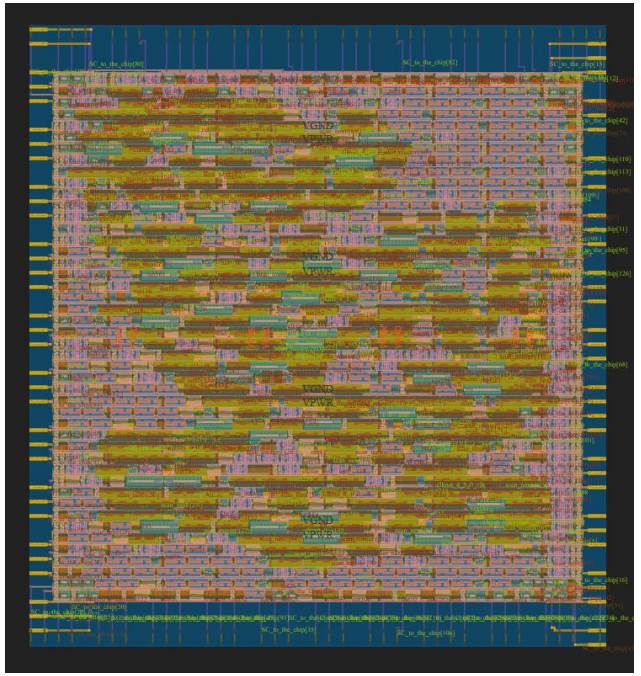
```
4655  sky130_fd_sc_hd__tapvpwrvgnd_1 TAP_99 (.VGND(VGND),
4656     .VPWR(VPWR));
4657  sky130_fd_sc_hd__buf_1 _142_ (.A(clknet_4_9_0_clk),
4658     .VGND(VGND),
4659     .VNB(VGND),
4660     .VPB(VPWR),
4661     .VPWR(VPWR),
4662     .X(_128_));
4663  sky130_fd_sc_hd__buf_1 _143_ (.A(clknet_1_1__leaf__128_),
4664     .VGND(VGND),
4665     .VNB(VGND),
4666     .VPB(VPWR),
4667     .VPWR(VPWR),
4668     .X(_129_));
4669  sky130_fd_sc_hd__inv_2 _144__9 (.A(clknet_1_1__leaf__129_),
4670     .VGND(VGND),
4671     .VNB(VGND),
```

Physical Synthesis

Transform the mapped netlist into a geometric shapes description (<*.gds>).

```
4655  sky130_fd_sc_hd__tapvpwrvgnd_1 TAP_99 (.VGND(VGND),
4656      .VPWR(VPWR));
4657  sky130_fd_sc_hd__buf_1 _142_ (.A(clknet_4_9_0_clk),
4658      .VGND(VGND),
4659      .VNB(VGND),
4660      .VPB(VPWR),
4661      .VPWR(VPWR),
4662      .X(_128_));
4663  sky130_fd_sc_hd__buf_1 _143_ (.A(clknet_1_1__leaf__128_),
4664      .VGND(VGND),
4665      .VNB(VGND),
4666      .VPB(VPWR),
4667      .VPWR(VPWR),
4668      .X(_129_));
4669  sky130_fd_sc_hd__inv_2 _144__9 (.A(clknet_1_1__leaf__129_),
4670      .VGND(VGND),
4671      .VNB(VGND),
```





Open-EDA Ecosystem

70+ open/free tools for IC Design

Source: https://semiwiki.com/wikis/industry-wikis/eda-open-source-tools-wiki/

Frameworks/Wrappers

OpenLane

OpenROAD Flow Scripts

SiliconCompiler

…

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...

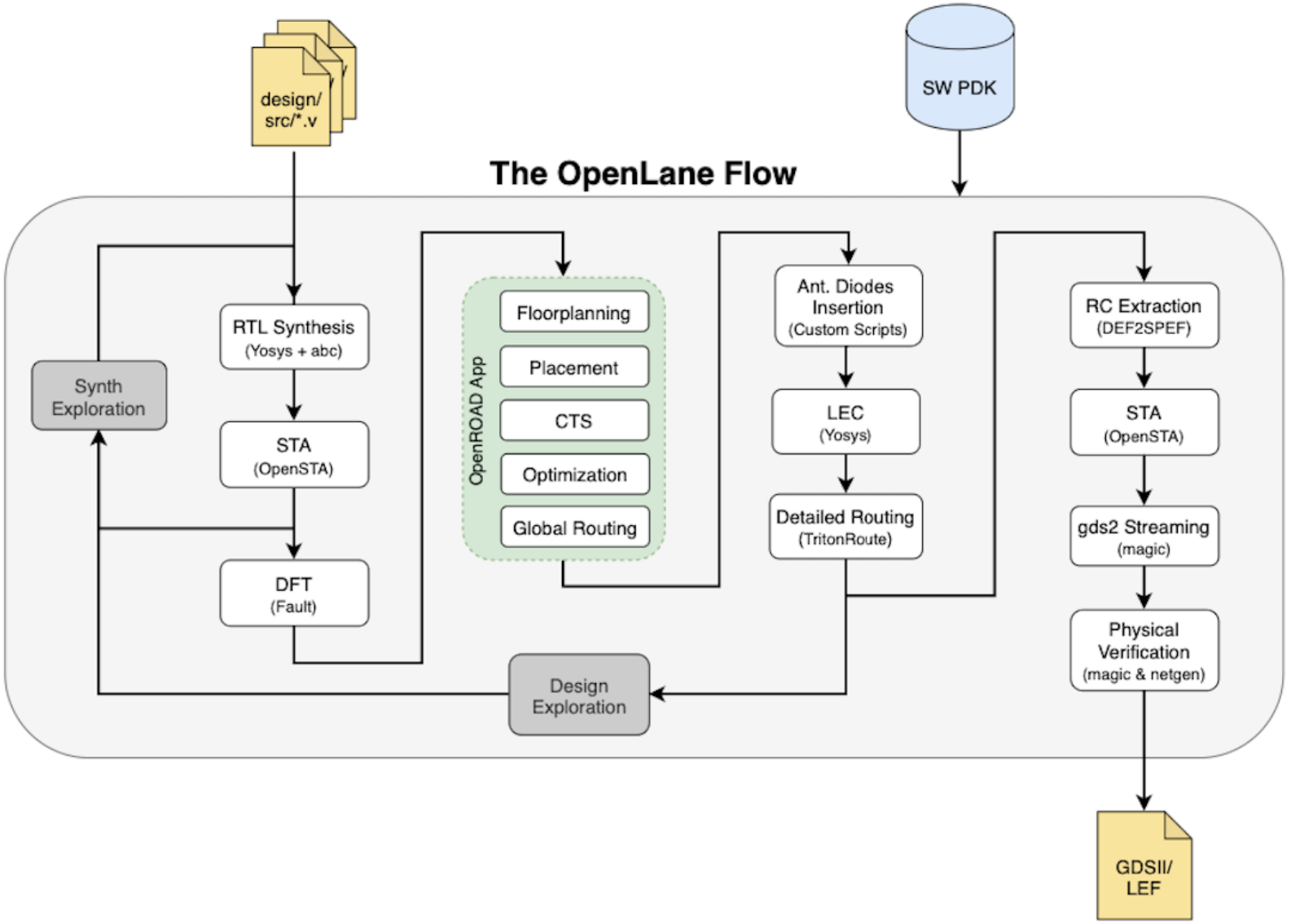
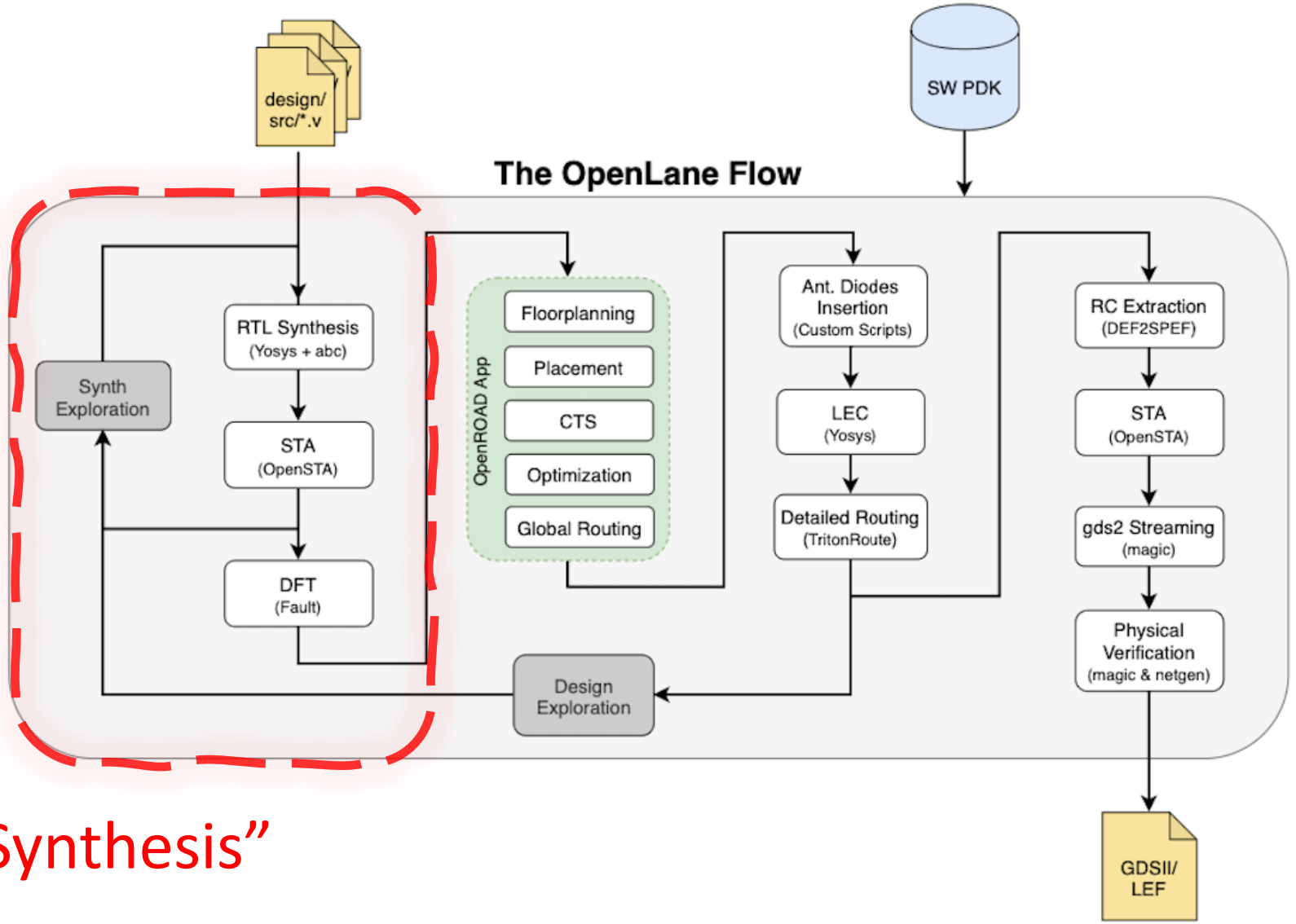
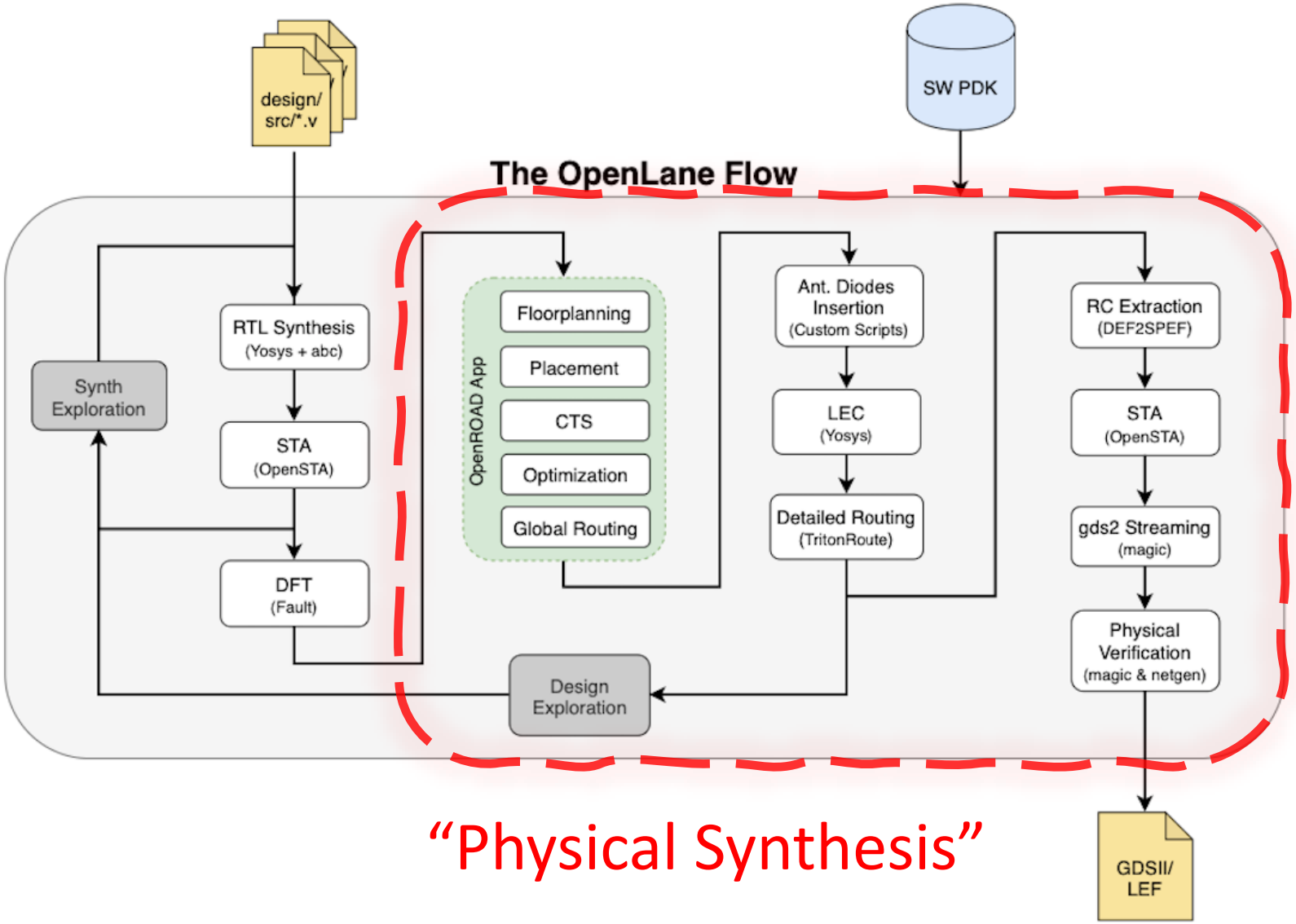


Figure Source: https://openlane.readthedocs.io/en/latest/flow_overview.html



"Logic Synthesis"

Figure Source: https://openlane.readthedocs.io/en/latest/flow_overview.html

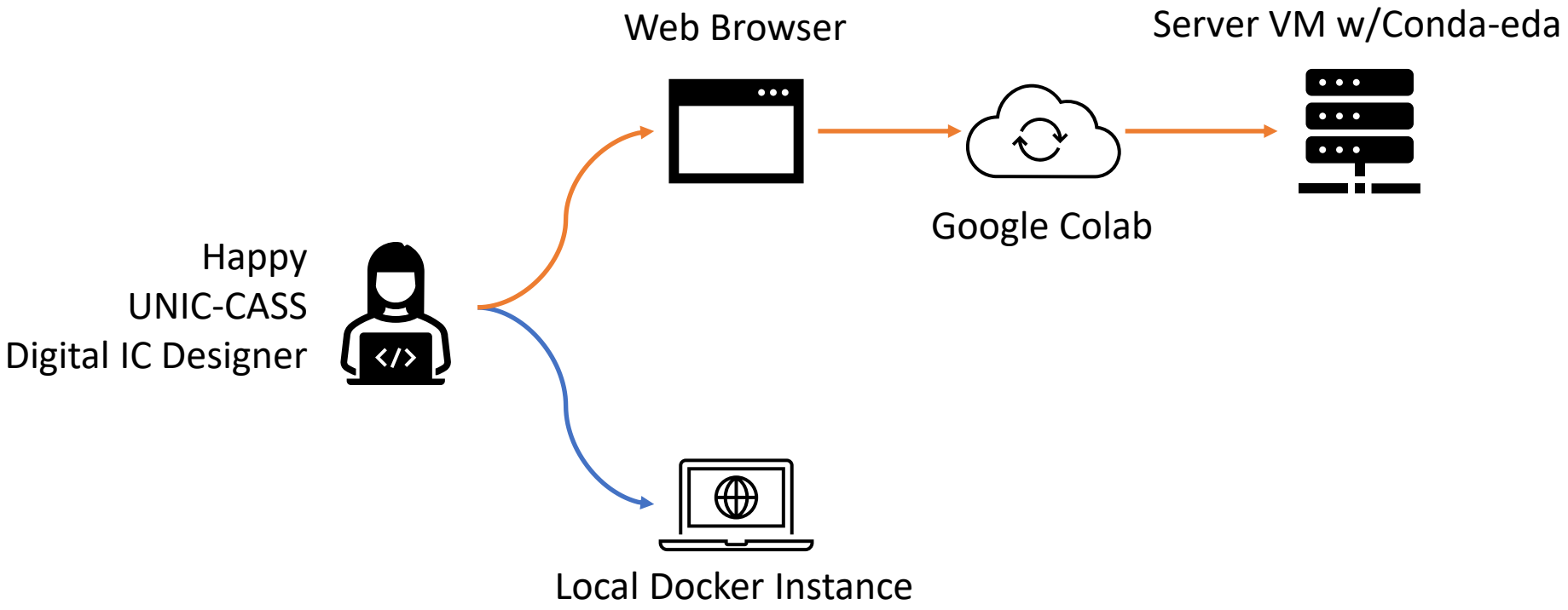


"Physical Synthesis"

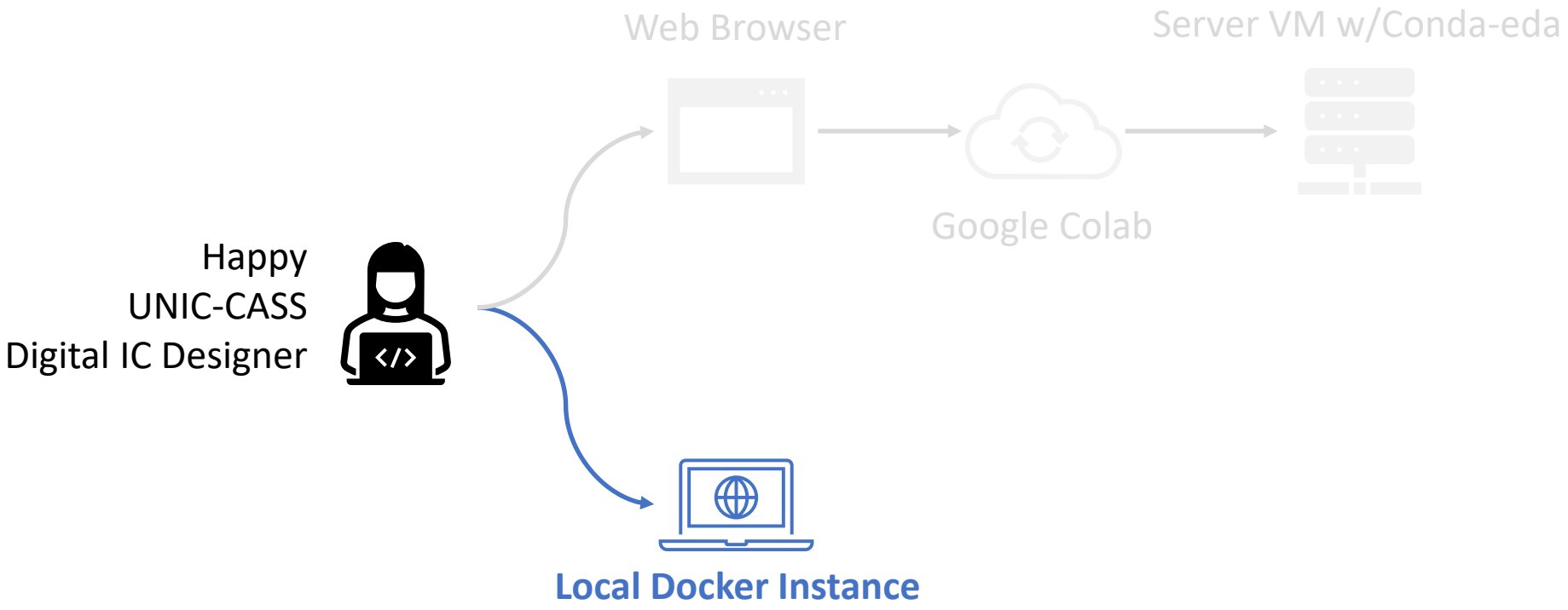
Figure Source: https://openlane.readthedocs.io/en/latest/flow_overview.html

Digital Design Environment Setup

Docker/Local vs Jupyter Notebook



Docker/Local vs Jupyter Notebook



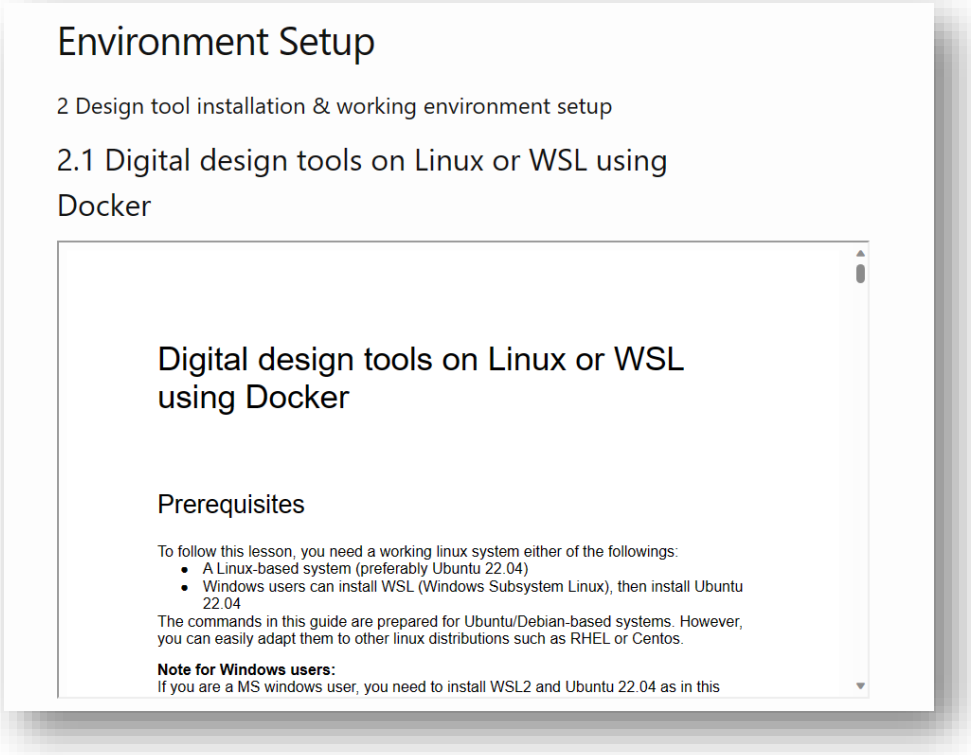
How to Start with the Docker Download and Installation

Prerequisites

To follow this lesson, you need a working linux system either of the followings:

- A Linux-based system (preferably Ubuntu 22.04)
- Windows users can install WSL (Windows Subsystem Linux), then install Ubuntu 22.04

The commands in this guide are prepared for Ubuntu/Debian-based systems. However, you can easily adapt them to other linux distributions such as RHEL or Centos.



Source: https://unic-cass.github.io/02-env-setup.html

Installing Docker

Terminal

```
sudo apt-get update

sudo apt-get install ca-certificates curl gnupg

sudo install -m 0755 -d /etc/apt/keyrings

curl -fsSL https://download.docker.com/linux/ubuntu/gpg | sudo gpg --dearmor -o /etc/apt/keyrings/docker.gpg

sudo chmod a+r /etc/apt/keyrings/docker.gpg

echo   "deb [arch="$(dpkg --print-architecture)" signed-
by=/etc/apt/keyrings/docker.gpg] https://download.docker.com/linux/ubuntu  "$(. /etc/os-release && echo
"$VERSION_CODENAME")" stable" |   sudo tee /etc/apt/sources.list.d/docker.list > /dev/null

sudo apt-get update

sudo apt-get install docker-ce docker-ce-cli containerd.io docker-buildx-plugin docker-compose-plugin
```

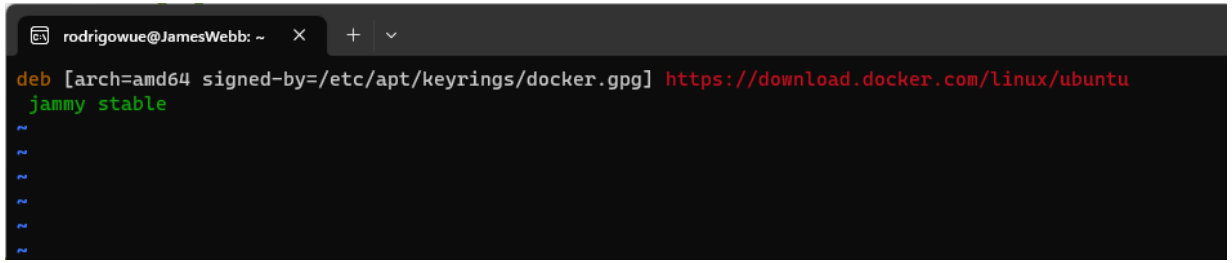
Source: https://unic-cass.github.io/02-env-setup.html

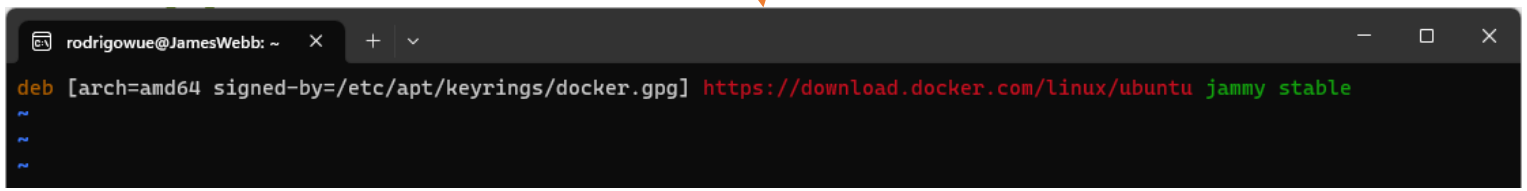
If this happens…

Terminal

```
E: Malformed entry 1 in list file /etc/apt/sources.list.d/docker.list (Suite)
```

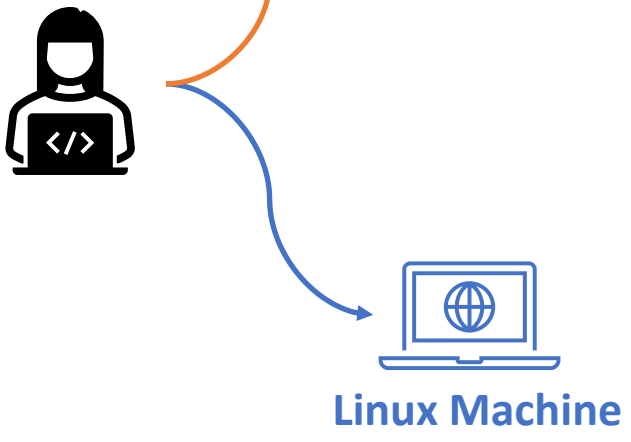
Edit “/etc/apt/sources.list.d/docker.list” and remove line break





Source: https://unic-cass.github.io/02-env-setup.html

Starting Docker



Terminal

```
sudo service docker start
```

Terminal

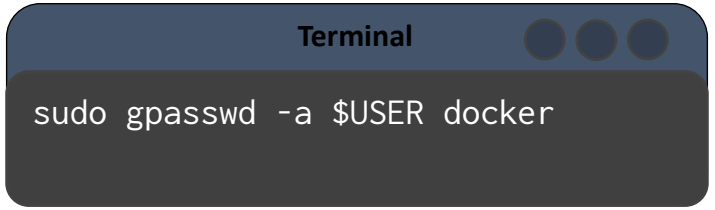
```
$ sudo systemctl start docker
$ sudo systemctl enable docker
```

This works for WSL that has systemd support
So try this first!

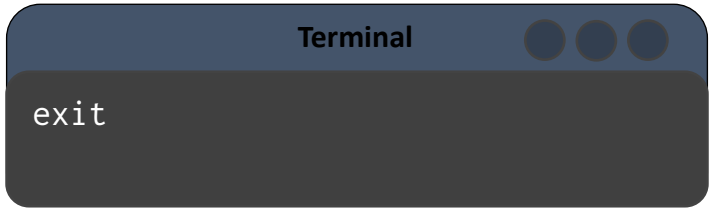
Source: https://unic-cass.github.io/02-env-setup.html

Add User to Docker Group

You will also need to add your user to docker group so that you have permission to pull the docker image as normal users:



To get the above command taking effect, you have to log out:



Source: https://unic-cass.github.io/02-env-setup.html

Pulling OpenLane Docker Image

Terminal

```
docker pull efabless/openlane:latest
```

Source: https://unic-cass.github.io/02-env-setup.html

Installing the Skywater130 PDK

Terminal

```
python3 -m pip install --upgrade --no-cache-dir volare
echo 'export PATH=$HOME/.local/bin:$PATH' >> .bashrc
source .bashrc
```

If pip is not found, then:

sudo apt install python3-pip

and redo the command sequence.

Source: https://unic-cass.github.io/02-env-setup.html

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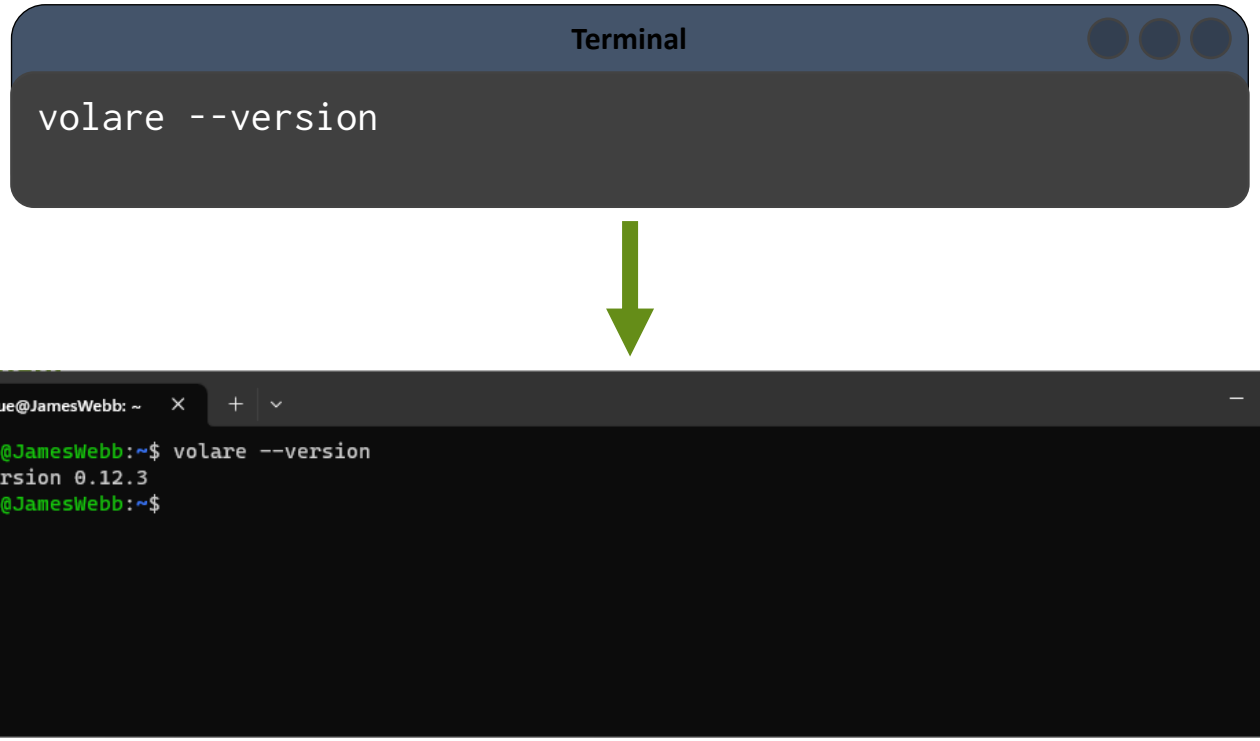
Test if Volare is Working



Source: https://unic-cass.github.io/02-env-setup.html

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Installing the Skywater130 PDK

Terminal

```
export PDK_ROOT=$HOME/unic-cass/pdks
export PDK=sky130A
volare ls-remote --pdk sky130
volare enable --pdk sky130 78b7bc32ddb4b6f14f76883c2e2dc5b5de9d1cbc
```

Source: https://unic-cass.github.io/02-env-setup.html

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Running Example

Create Directory and Generate OpenLane Template

Terminal

```
mkdir gcd_example
cd gcd_example
docker run -it -v $(pwd):/gcd_example/ -v $PDK_ROOT:$PDK_ROOT -e PDK_ROOT=$PDK_ROOT -u $(id -u $USER):$(id -g $USER)
efabless/openlane:latest
cd /gcd_example
#flow.tcl -design <design name> -init_design_config - this will create a template structure and files for OpenLane
flow.tcl -design gcd -init_design_config
```

Source: https://unic-cass.github.io/02-env-setup.html

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Enter Directory and Download RTL Files

Terminal

```
cd /gcd_example/openlane/gcd
#Download from Berkley the RTL files
wget https://inst.eecs.berkeley.edu/~cs250/fa20/files/gcd.tar.xz
#Uncompress, remove compressed file, and exit
tar xvf gcd.tar.xz
rm gcd.tar.xz
exit
```

Source: https://unic-cass.github.io/02-env-setup.html

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Edit Template to Fit Design Specs

After exiting the Docker run, we need to modify the `config.json` and add a `pin_order.cfg` to implement the design. These two file can be created using `gedit` commands as follows:

Terminal

```
gedit openlane/gcd/config.json
```

config.json
~/gcd_example/openlane/gcd

Open Save

```
{
    "DESIGN_NAME": "gcd",
    "VERILOG_FILES": "dir::src/*.v",
    "CLOCK_PORT": "clk",
    "CLOCK_NET": "ref::$CLOCK_PORT",
    "FP_PIN_ORDER_CFG": "dir::pin_order.cfg",
    "FP_PDN_VOFFSET": 7,
    "FP_PDN_HOFFSET": 7,
    "FP_PDN_SKIPTRIM": true,
    "FP_CORE_UTIL" : 45,
    "CLOCK_PERIOD": 10.0,
    "DESIGN_IS_CORE": true
}
```

Source: https://unic-cass.github.io/02-env-setup.html

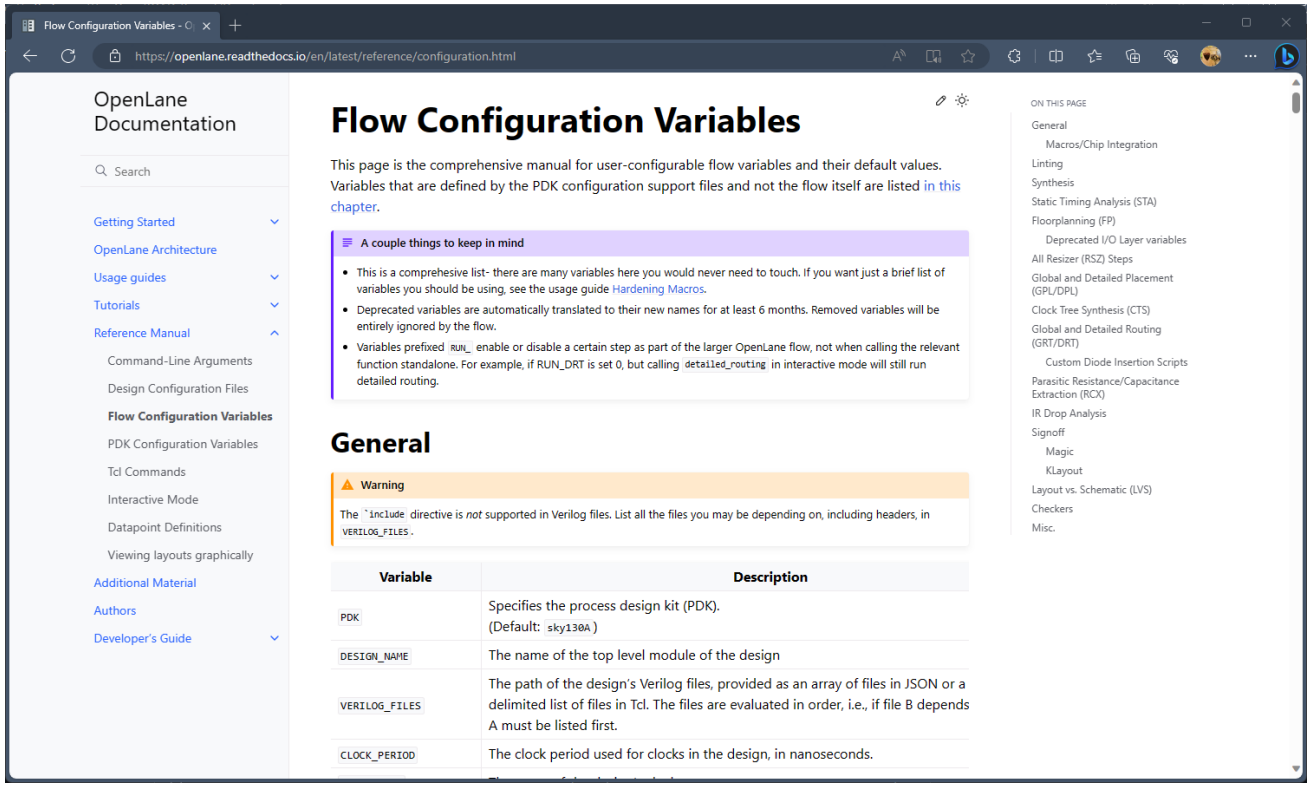
About the Configuration File (config.json)

Here is where the design freedom lives.

Check the documentation to know what each variable does.

Open | config.json ~/gcd_example/openlane/gcd | Save

```
{
        "DESIGN_NAME": "gcd",
        "VERILOG_FILES": "dir::src/*.v",
        "CLOCK_PORT": "clk",
        "CLOCK_NET": "ref::$CLOCK_PORT",
        "FP_PIN_ORDER_CFG": "dir::pin_order.cfg",
        "FP_PDN_VOFFSET": 7,
        "FP_PDN_HOFFSET": 7,
        "FP_PDN_SKIPTRIM": true,
        "FP_CORE_UTIL" : 45,
        "CLOCK_PERIOD": 10.0,
        "DESIGN_IS_CORE": true
}
```



https://openlane.readthedocs.io/en/latest/reference/configuration.html

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Edit Template to Fit Design Specs

After exiting the Docker run, we need to modify the `config.json` and add a `pin_order.cfg` to implement the design. These two file can be created using `gedit` commands as follows:

Terminal

```
gedit openlane/gcd/pin_order.cfg
```

Source: https://unic-cass.github.io/02-env-setup.html

Run Script

Terminal

```
#Start Docker
docker run -it -v $(pwd):/gcd_example -v $PDK_ROOT:$PDK_ROOT -e PDK=$PDK -e PDK_ROOT=$PDK_ROOT -u $(id -u $USER):$(id -g
$USER) efabless/openlane:latest
#Enter Directory
cd /gcd_example/openlane
#Run OpenLane
flow.tcl -design gcd
```

Source: https://unic-cass.github.io/02-env-setup.html

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If this happens... Its not the end of the world

Terminal

```
OpenLane Container (00caae2):/gcd_example/openlane$ flow.tcl -design gcd
OpenLane 00caae2b3186bb6b24a0b7db7ee1a6f056ad1702
All rights reserved. (c) 2020-2022 Efabless Corporation and contributors.
Available under the Apache License, version 2.0. See the LICENSE file for more details.

[ERROR]: The version of open_pdks used in building the PDK does not match the version OpenLane was tested on (installed:
78b7bc32ddb4b6f14f76883c2e2dc5b5de9d1cbc, tested: e3b630d9b7c0e23615367d52c4f78b2d2ede58ac)
This may introduce some issues. You may want to re-install the PDK by invoking `make pdk`.
[ERROR]: Please update your environment. OpenLane will now quit.
```

Exit docker and redo the following command with the correct version:

Terminal

```
//volare enable --pdk sky130 <version that appears on “tested”>
 volare enable --pdk sky130 e3b630d9b7c0e23615367d52c4f78b2d2ede58ac
```

Source: https://unic-cass.github.io/02-env-setup.html

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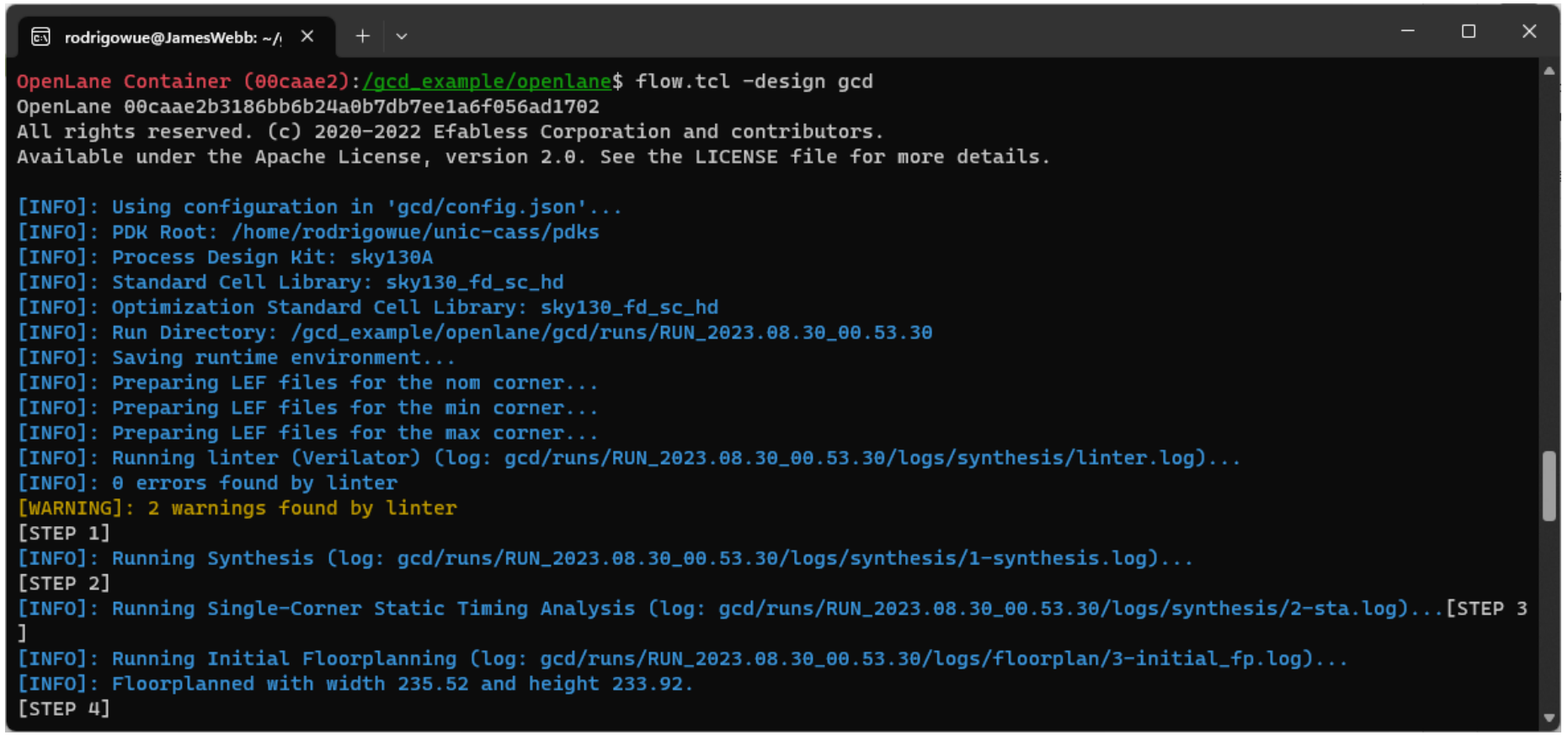
Run Again and Voilà



Source: https://unic-cass.github.io/02-env-setup.html

Installing Klayout for Viewing the .GDS

(exit docker before continuing)

Terminal

```
wget https://www.klayout.org/downloads/Ubuntu-22/klayout_0.28.10-1_amd64.deb
sudo apt-get install libqt5designer5 libqt5multimedia5 libqt5opengl5 libqt5multimediawidgets5 \
                     libqt5printsupport5 libqt5sql5 libqt5sql5 libqt5xmlpatterns5 libruby3.0
sudo dpkg -i klayout_0.28.10-1_amd64.deb
```

Source: https://unic-cass.github.io/02-env-setup.html

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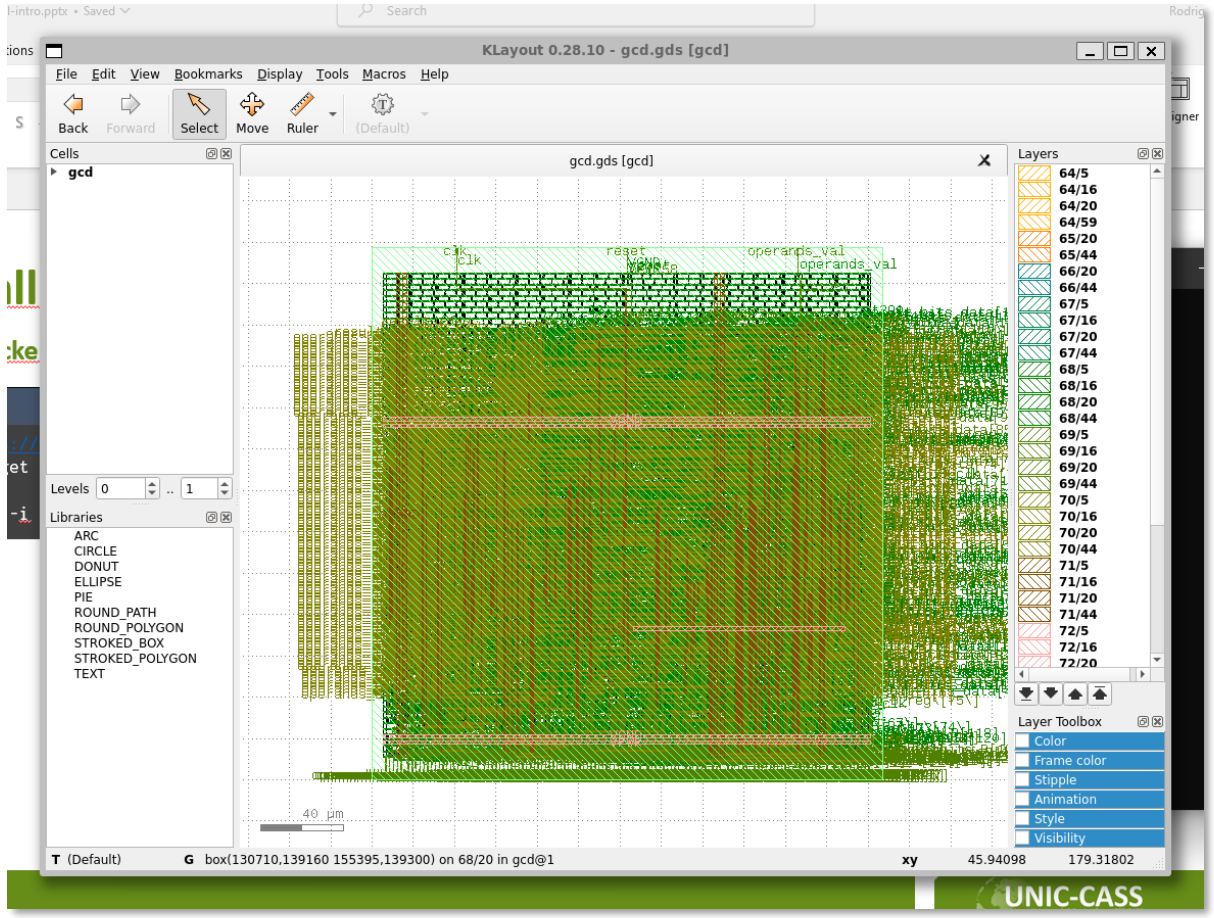
Opening <*.gds>

Terminal

```
klayout openlane/gcd/runs/RUN_*/results/signoff/gcd.gds
```



Source: https://unic-cass.github.io/02-env-setup.html

Thanks, any questions? :)

feel free to reach me out

rnwuerdig@inf.ufrgs.br