# Introduction to analog design with open source tools

Using the SkyWater PDK and Efabless platform

Tim Edwards

SVP Analog & Platform

efabless

efabless.com

Open Circuit Design

opencircuitdesign.com

Google Cloud

google.com

SkyWater sky130 open PDK

skywatertechnology.com

# The SkyWater Open PDK

## Public repository

**Documentation**

https://skywater-pdk--136.org.readthedocs.build

**Efabless design respositories**

https://github.com/efabless/caravel

https://github.com/efabless/caravel_user_project_analog

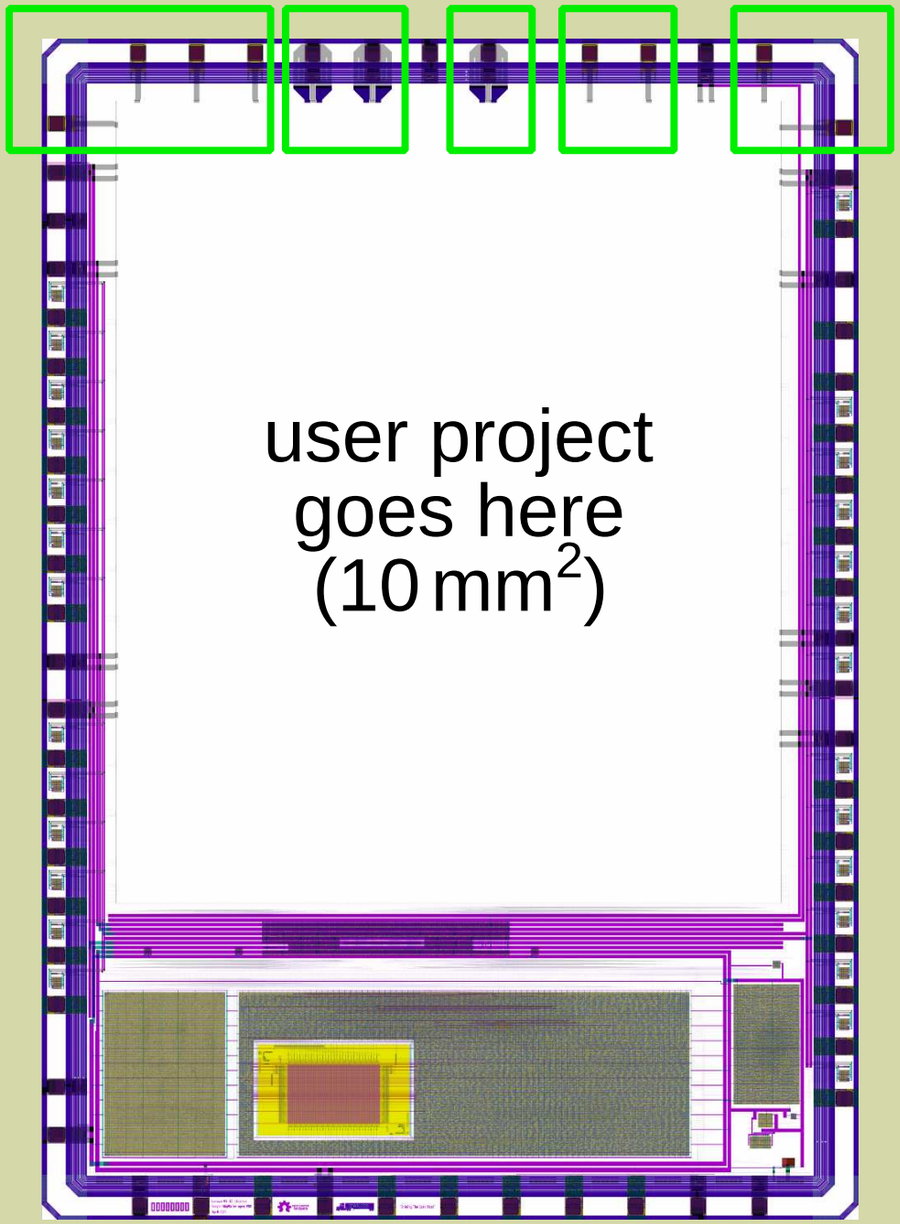
**Community**

**slack**

**https://join.skywater.tools**

#analog-design
#xschem
#magic

# “Caravan” analog project harness




← These pads on the top have been repuposed for analog (11 pads)

← GPIO for the rest (27 pads)

–analog signals can be connected to the GPIO pads (except lower 7)

–additional 3.3V digital GPIO inputs available to the user area.

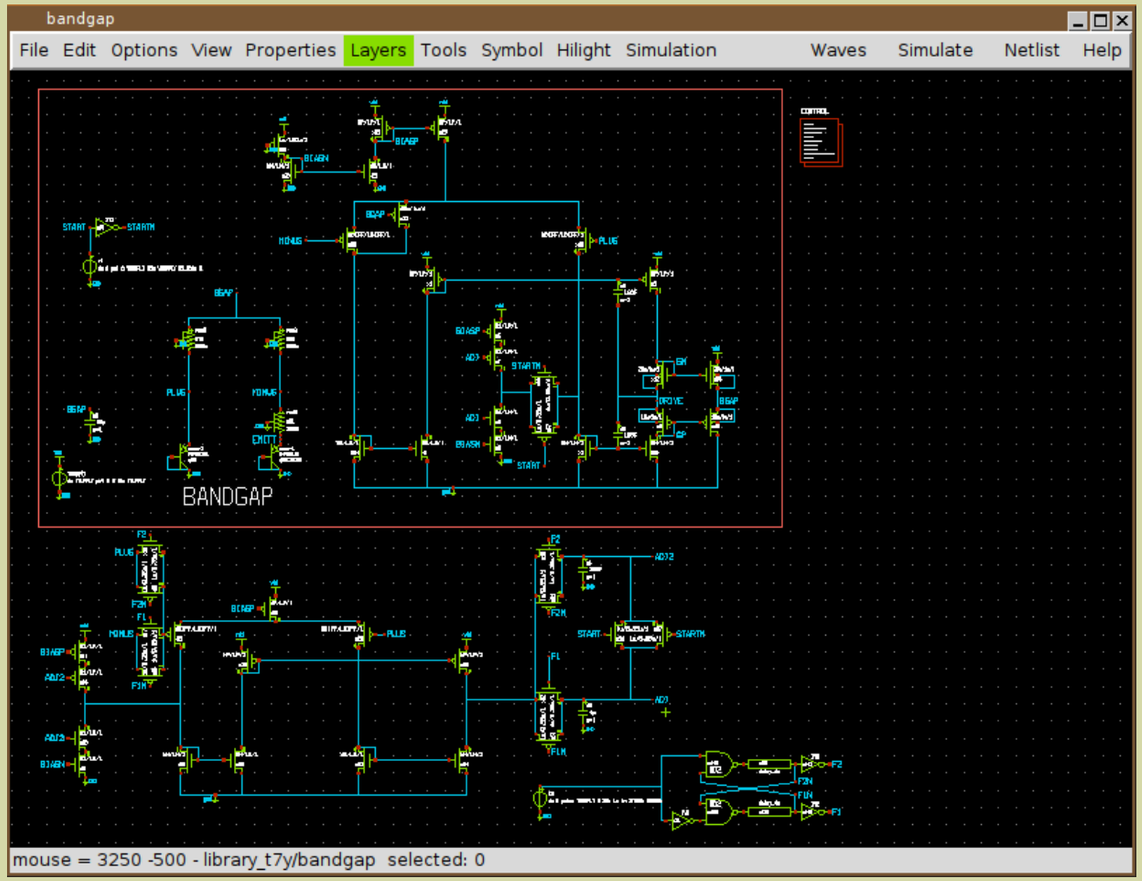
–No digital power rings; project connects directly to wrapper pins

← Same RISC-V managment SoC and support circuitry as Caravel

# Open-Source EDA Tools

## Tools Currently Supported by the open PDK

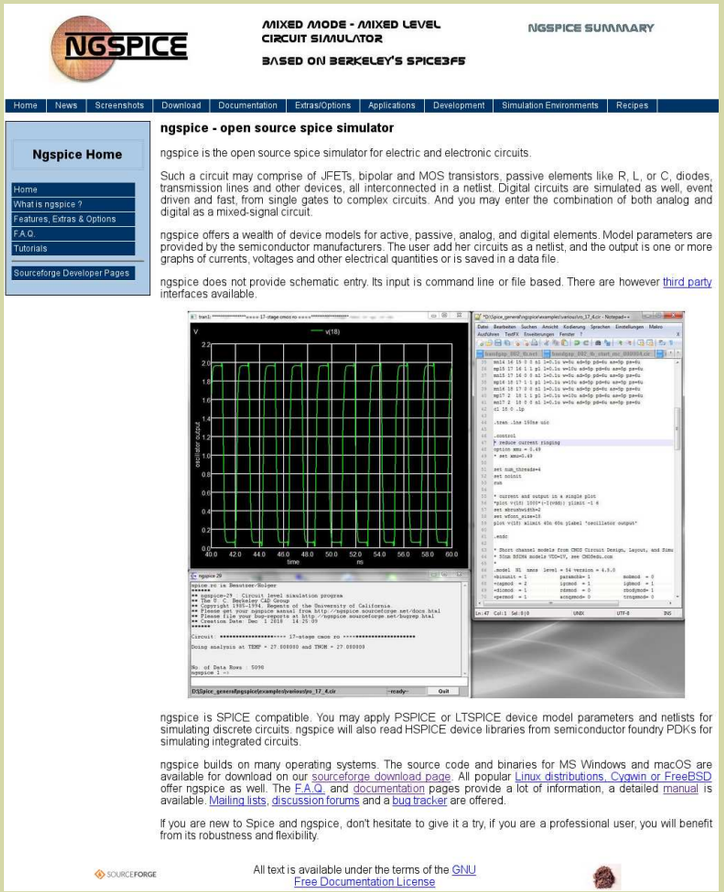
**Xschem** https://github.com/StefanSchippers/xschem



# Open-Source EDA Tools

## Tools Currently Supported by the open PDK

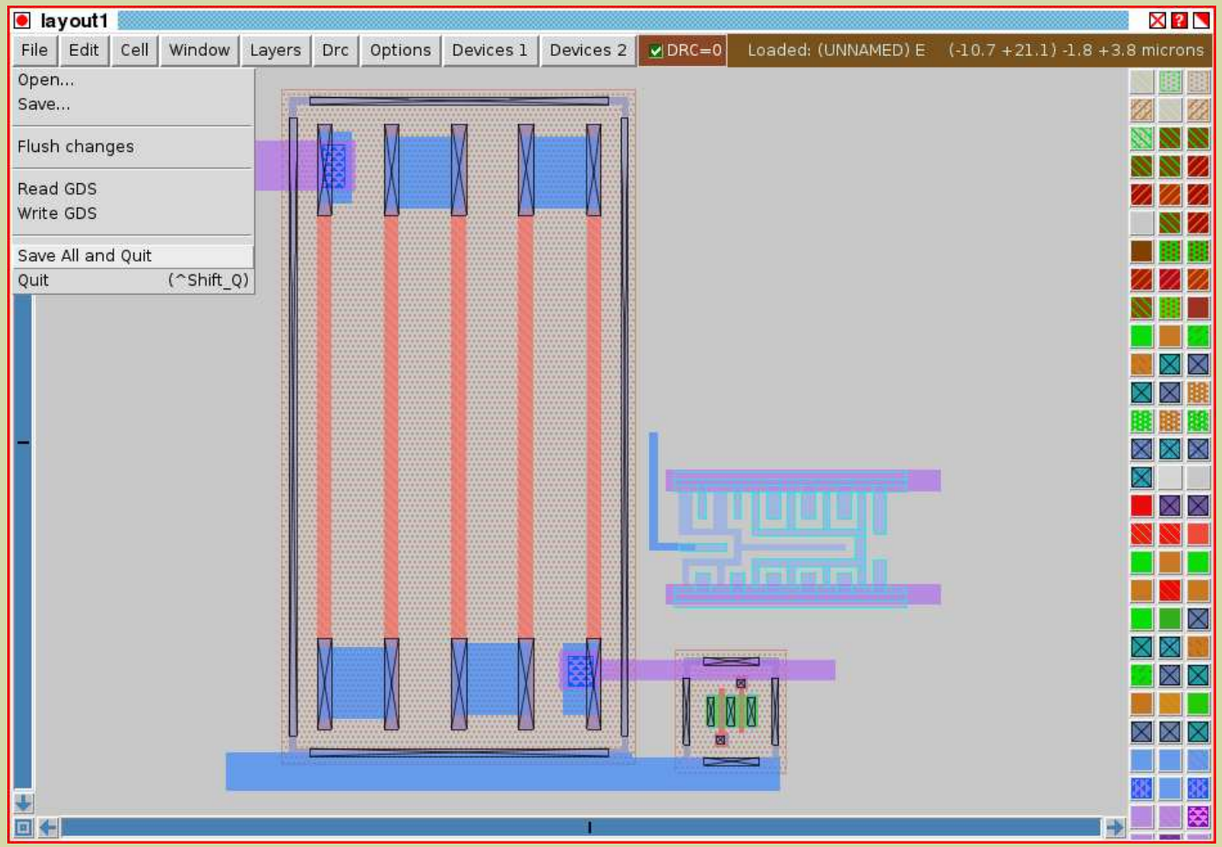
**Ngspice** https://ngspice.sourceforge.net



# Open-Source EDA Tools

## Tools Currently Supported by the open PDK

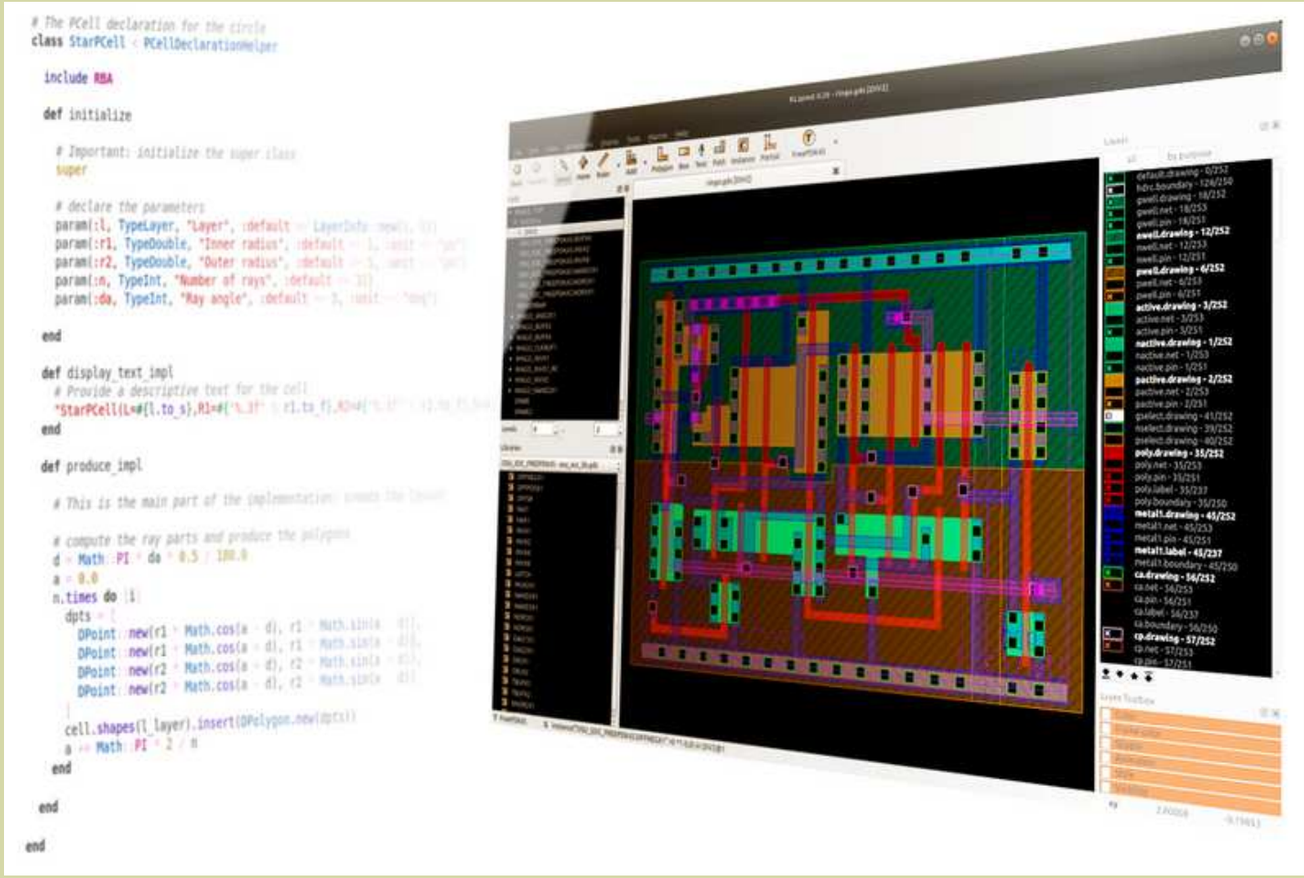
**Magic** http://opencircuitdesign.com/magic



# Open-Source EDA Tools

## Tools Currently Supported by the open PDK

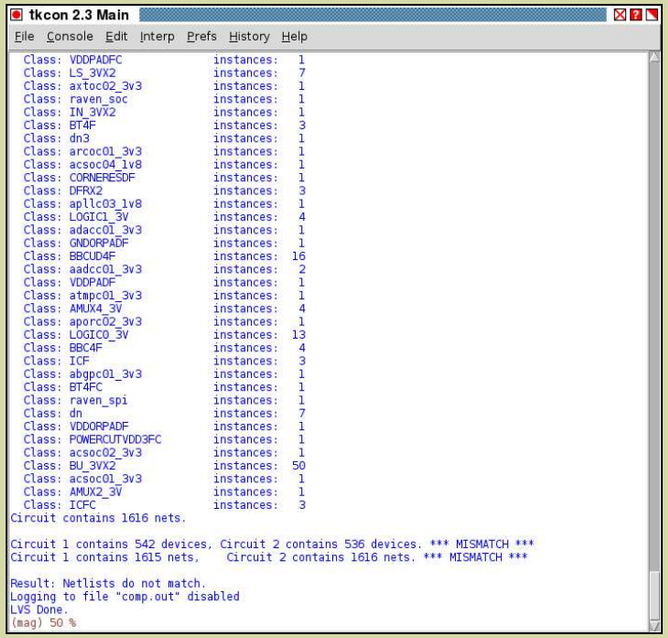
**Klayout** https://www.klayout.de

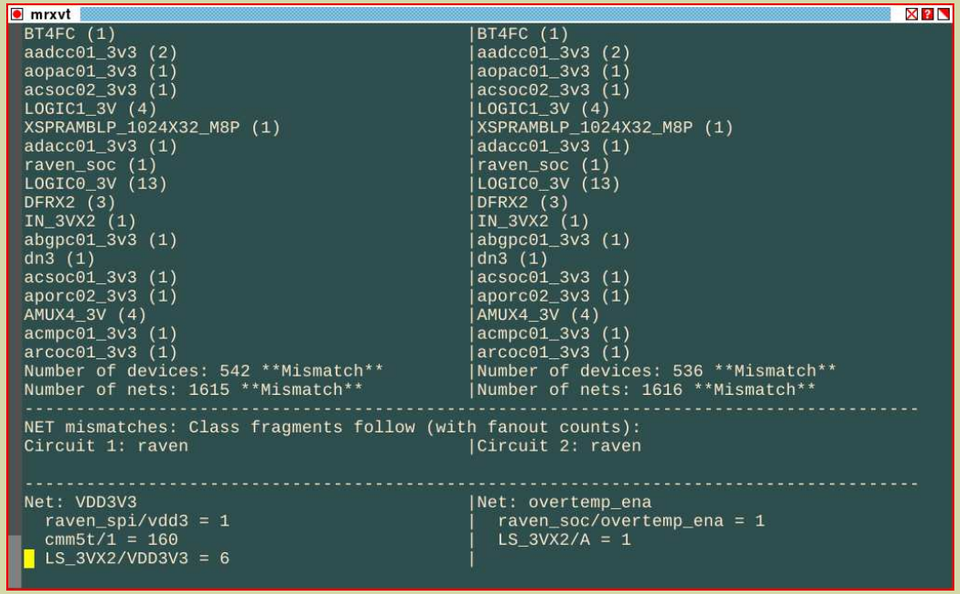


# Open-Source EDA Tools

## Tools Currently Supported by the open PDK

**Netgen** http://opencircuitdesign.com/netgen



# Open-Source EDA Tools

## SkyWater SKY130 Libraries

1. **Digital standard cells**
   - sky130_fd_sc_hd
   - sky130_fd_sc_hdll
   - sky130_fd_sc_hs
   - sky130_fd_sc_ms
   - sky130_fd_sc_ls
   - sky130_fd_sc_lp
   - sky130_fd_sc_hvl

2. **Primitive devices / analog**
   - sky130_fd_pr

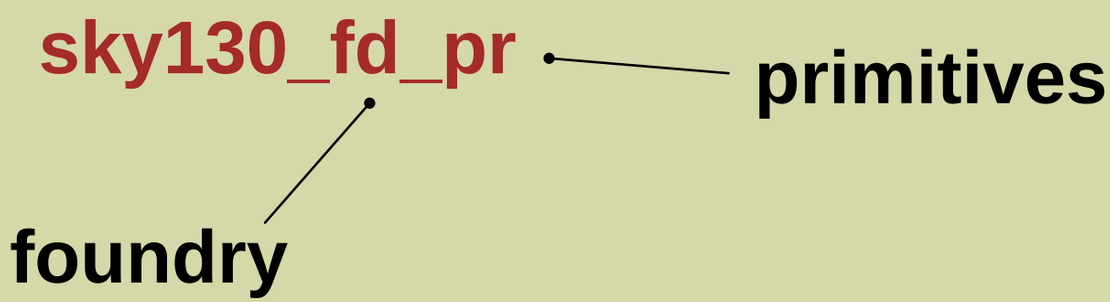
3. **I/O cells**
   - sky130_fd_io

4. **3rd-party libraries**
   - sky130_ml_xx_hd
   - sky130_sram_macros

# Understanding the SkyWater PDK

## Libraries

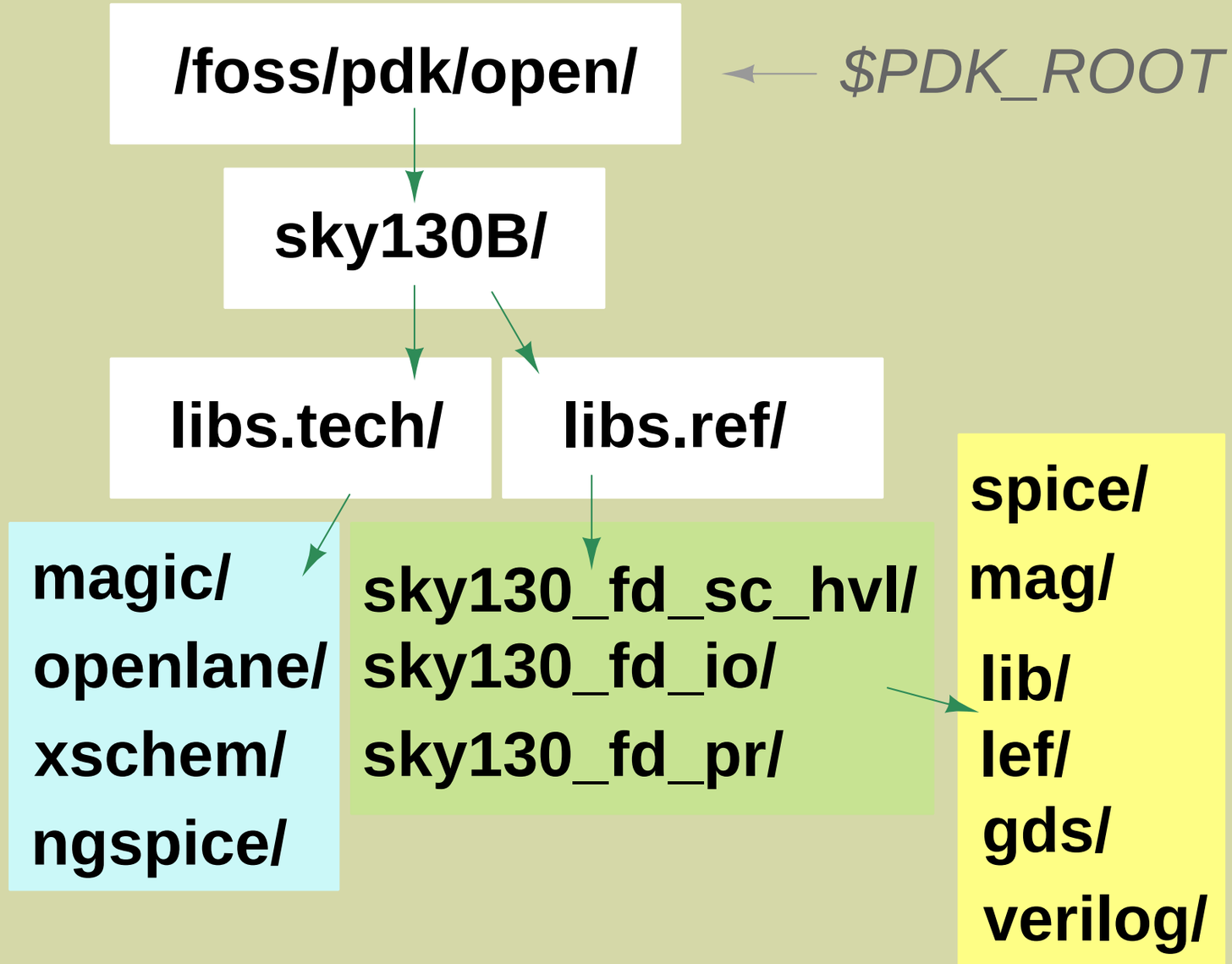
### primitive devices and models




MOSFET transistors (1.8V and 3.3−5.0V)
Bipolar transistors
Resistors
Capacitors
Diodes
Varactors

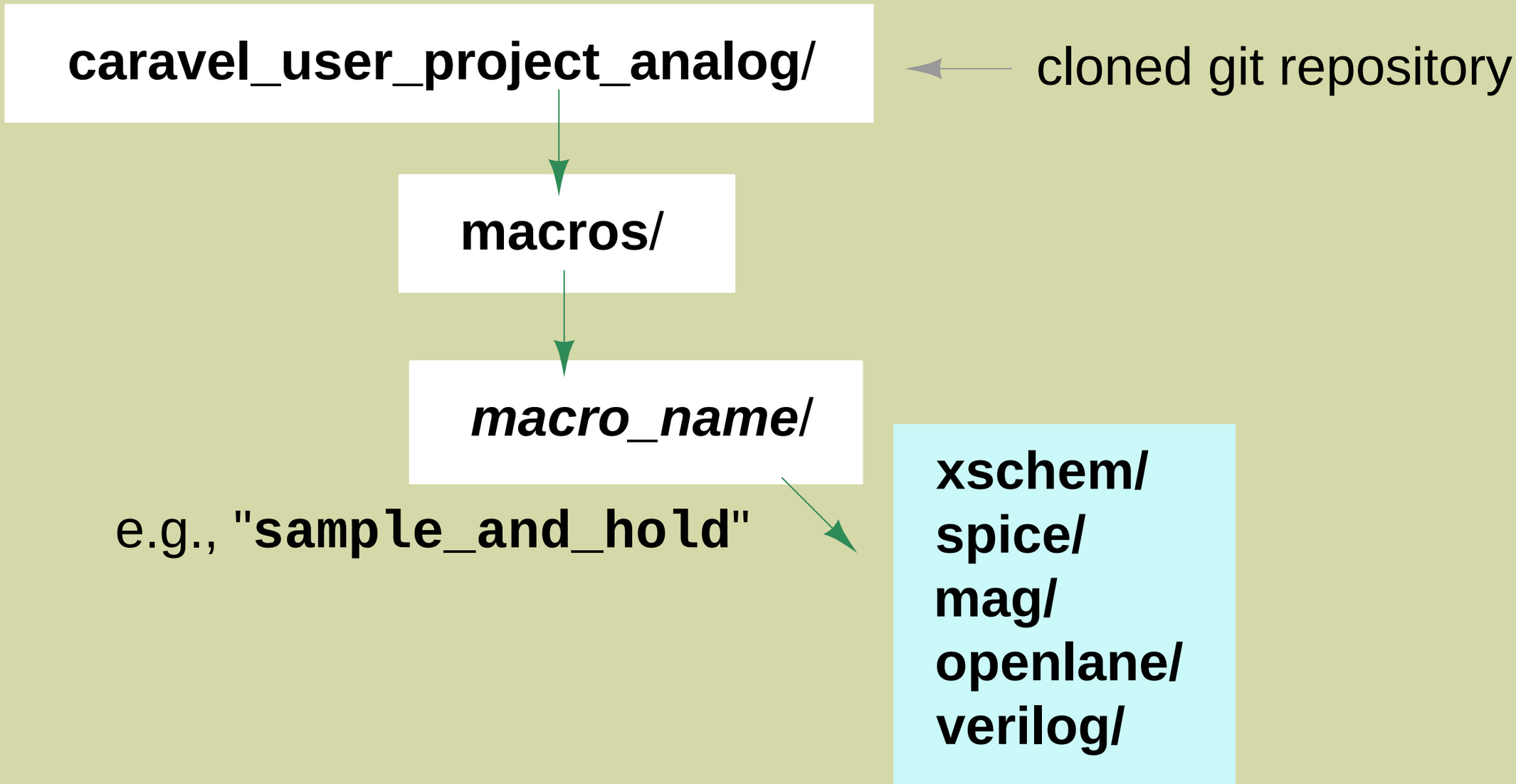
# Open-Source EDA Tools

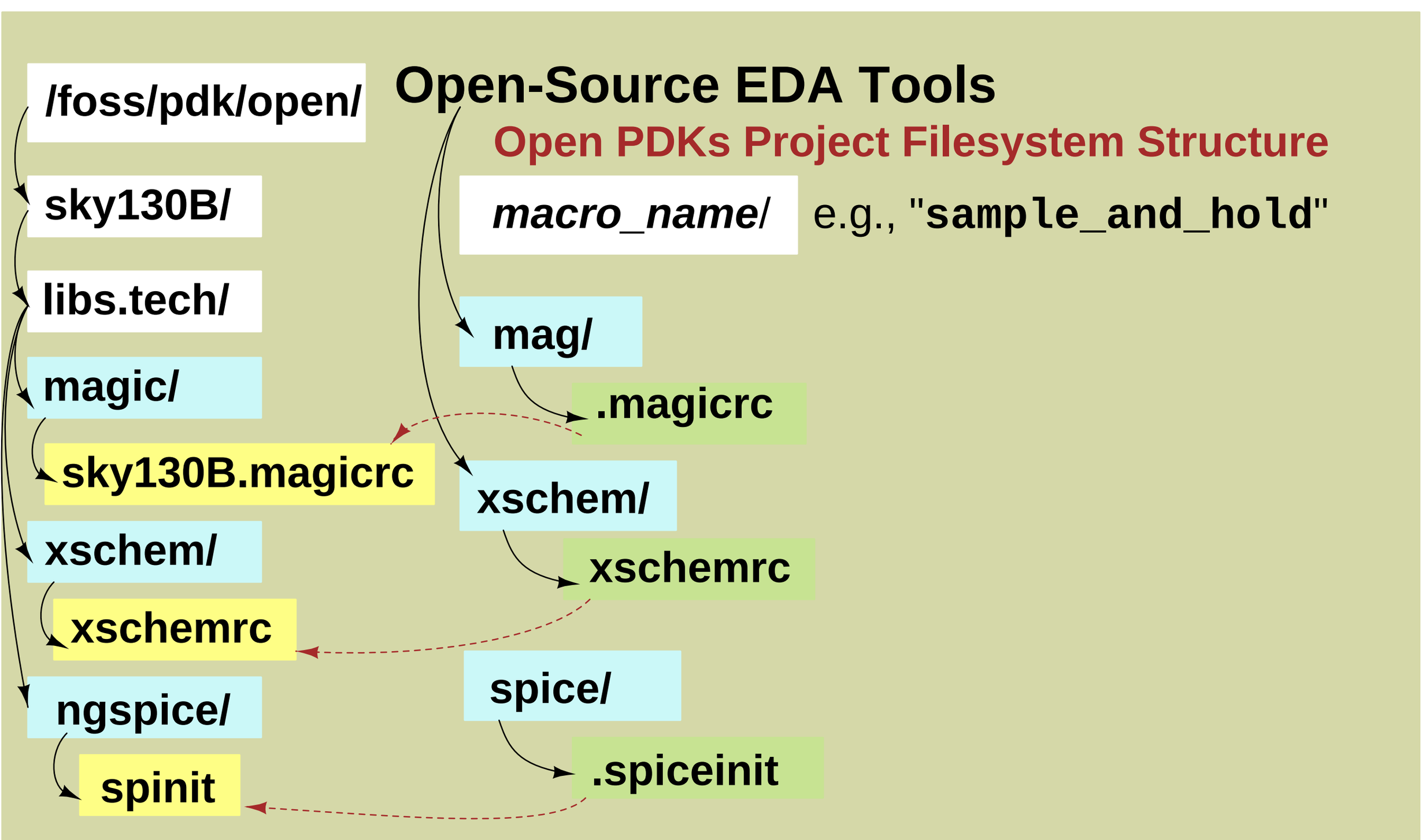
## SkyWater SKY130 Installed Filesystem Structure



# Open-Source EDA Tools

## Open PDKs Project Filesystem Structure



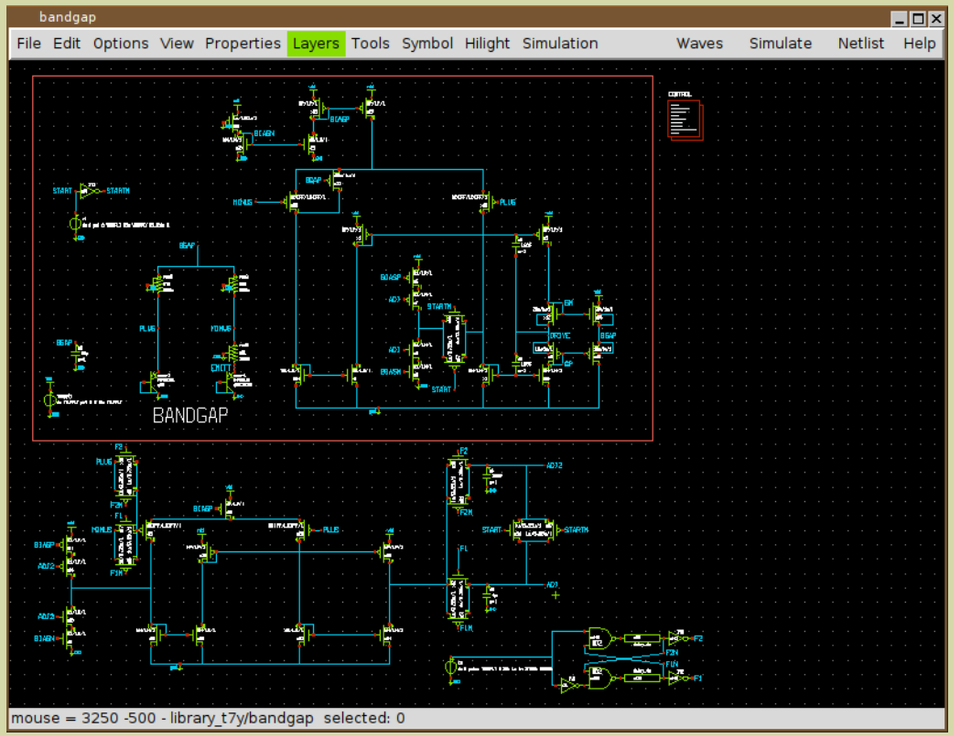

/foss/pdk/open/
Open-Source EDA Tools
Open PDKs Project Filesystem Structure
sky130B/
macro_name/
e.g., "sample_and_hold"
libs.tech/
mag/
magic/
.magicrc
sky130B.magicrc
xschem/
xschem/
xschemrc
xschemrc
spice/
ngspice/
.spiceinit
spinit

# Open Source Tools and Flows

## A simple manual design flow

**Schematic**

**xschem** → **netlist** (SPICE format)



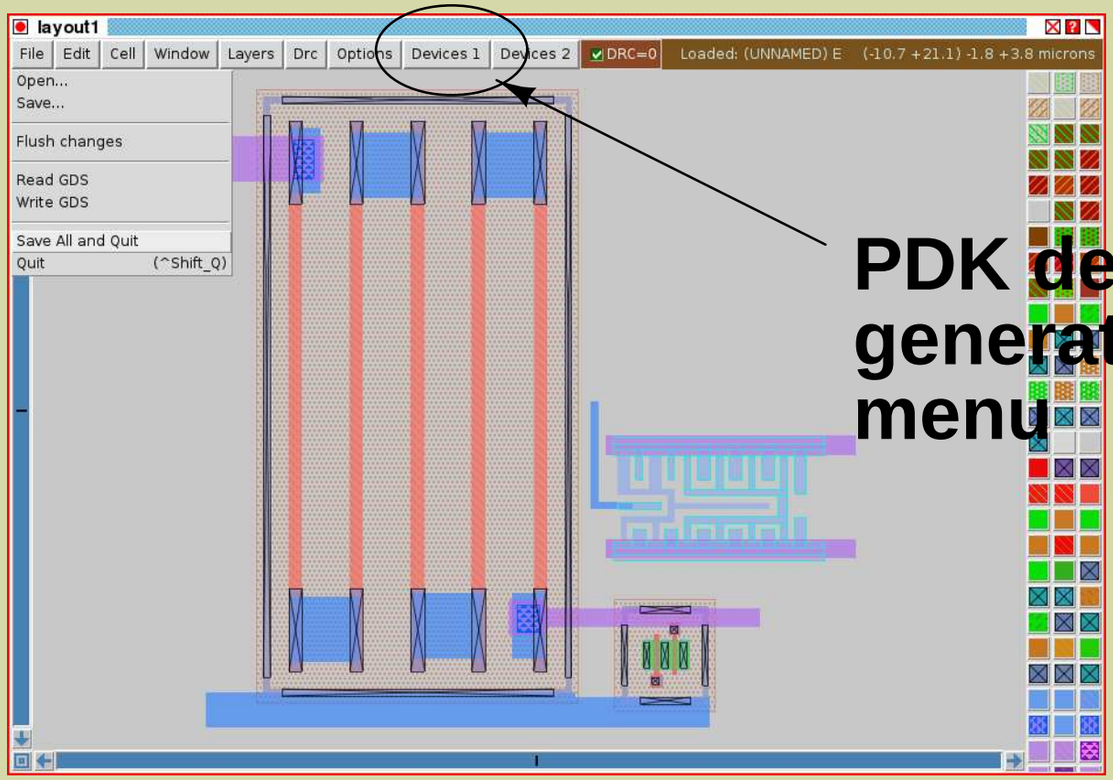

- **ngspice** (analog simulation, waveform viewing)
- **magic** (layout)
- **netgen** (LVS)

# Open Source Tools and Flows

## A simple manual design flow

## Layout

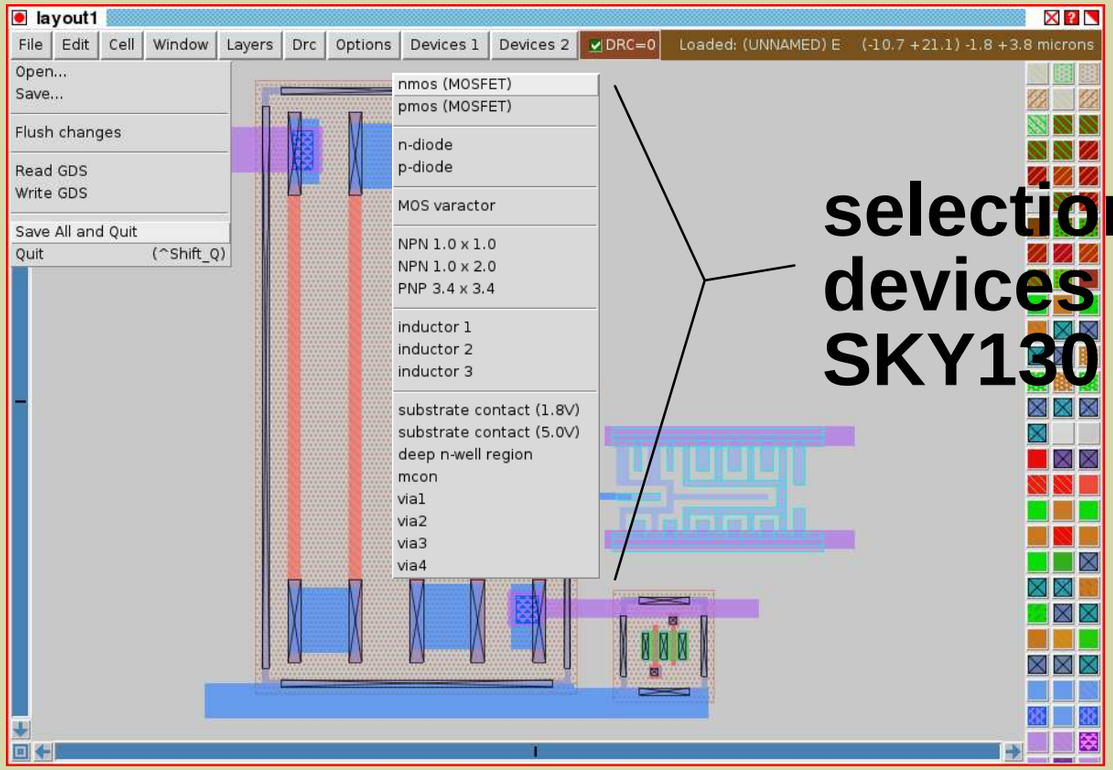
### Parameterized devices in magic



# Open Source Tools and Flows

## A simple manual design flow

## Parameterized devices in magic




**selection of devices from SKY130 PDK**

# Open Source Tools and Flows

## A simple manual design flow

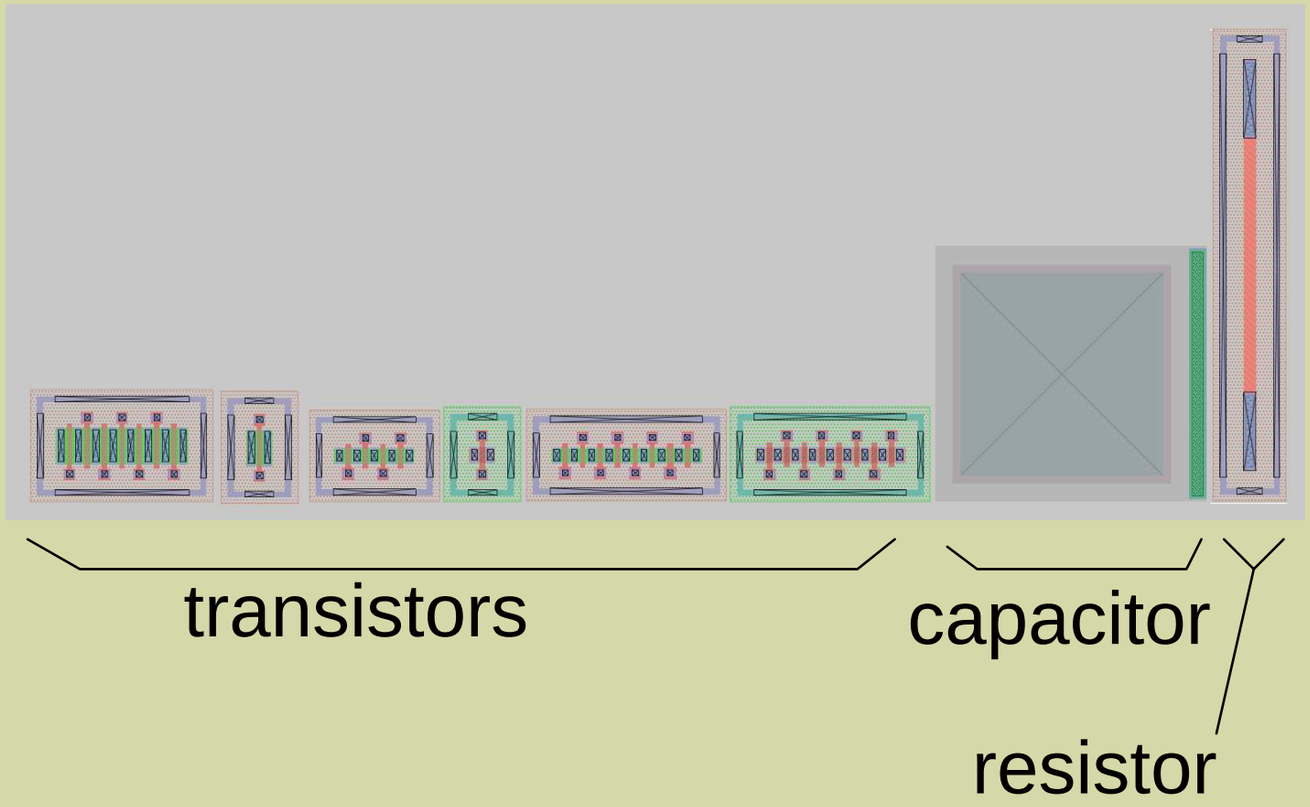
## Parameterized devices in magic

parameter selection window

# Open Source Tools and Flows

## A simple manual design flow

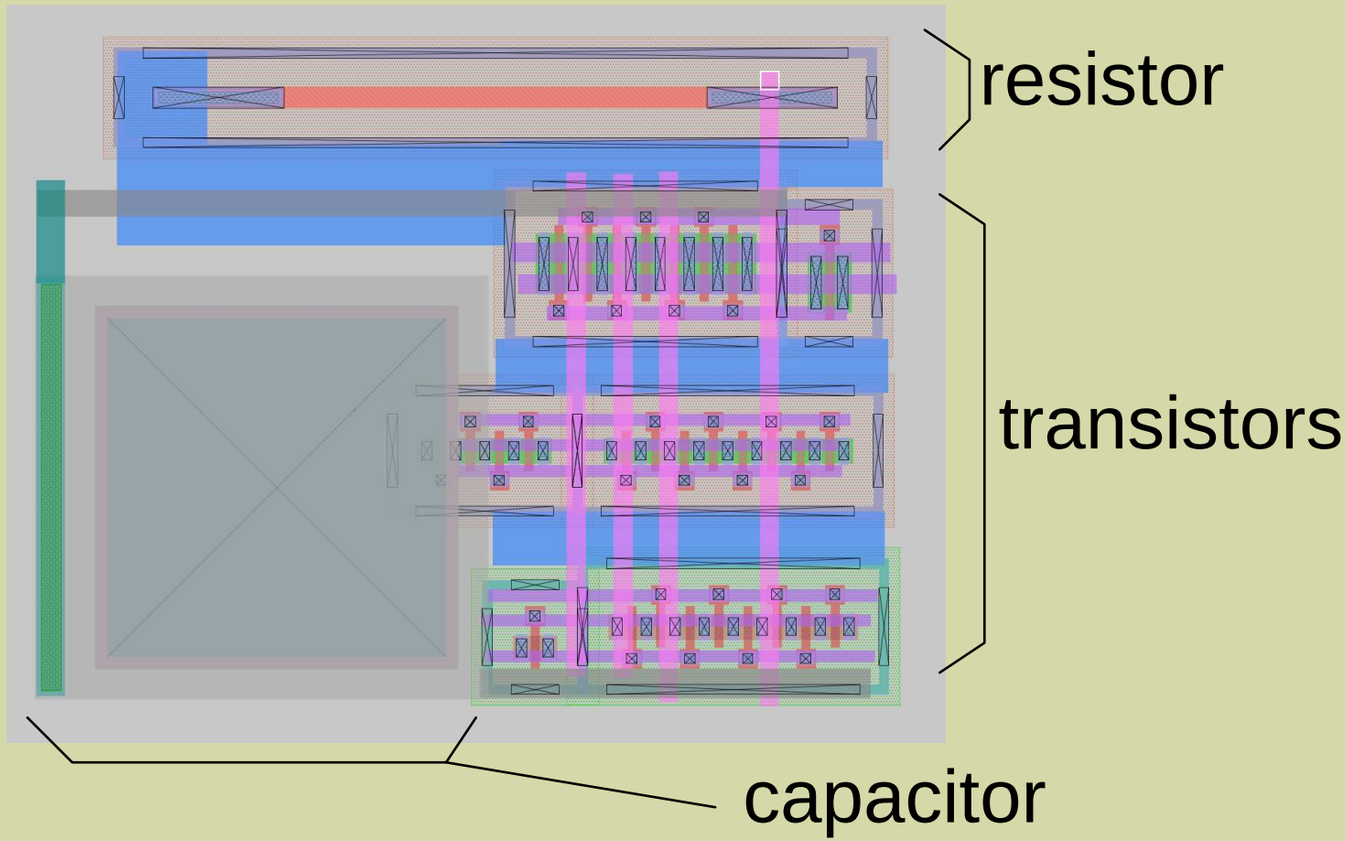
### Example initial layout of devices in magic, imported from schematic



# Open Source Tools and Flows

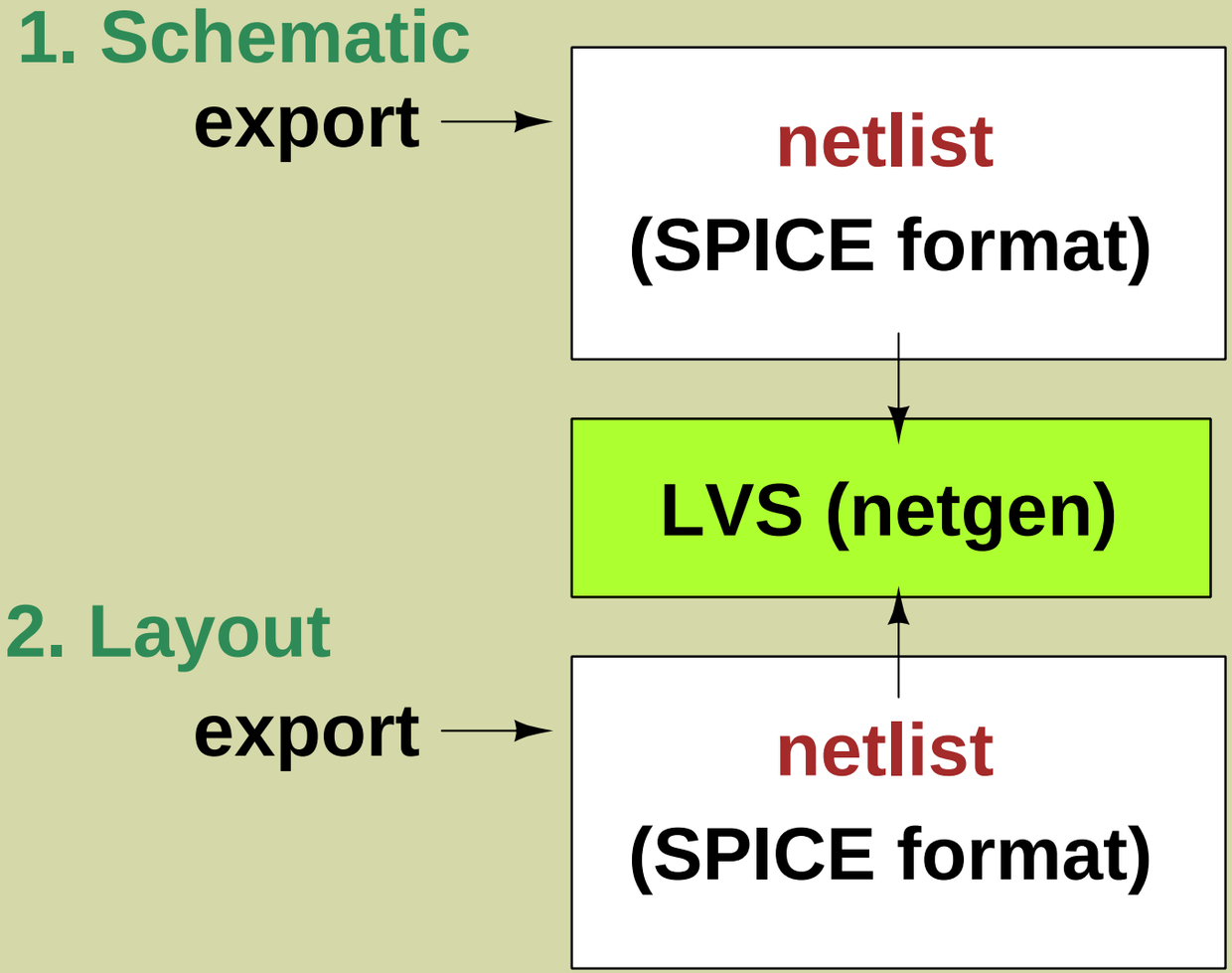
## A simple manual design flow

### Analog example layout
### work in progress in magic



# Open Source Tools and Flows

## A simple manual design flow



# Analog design flow summary

1. **xschem** — Create a schematic, netlist extraction
2. **ngspice** — Simulation validation
3. **magic** — Layout, netlist extraction, DRC validation
4. **netgen** — LVS validation