

# Open-Source Hardware

Open Source Flow for FPGA and ASIC Design

---

Leo Moser

January 17, 2024

- Proprietary and Open Source Flows
- Open Source FPGA Design Flow
- Open Source ASIC Design Flow
- Offline Demo
- "Case Study"

# Comparison of Proprietary and Open Source Flows

What's the difference?

- Cost
- Availability
- Ease of use
- Integration
- Support
- Capabilities



**Figure 1:** Bag of Money (CC0)

# Open Source FPGA Design Flow

---

# Reverse-Engineering FPGAs

Project IceStorm - Lattice iCE40 FPGAs  
Bitstream Documentation  
Developed since 2015

- "Chip database"
- Internal representation
- Tools to map from and to bitstream

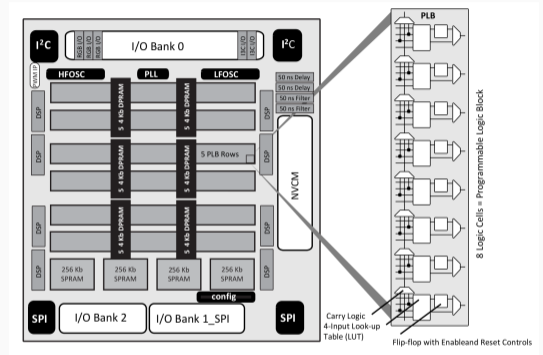


Figure 2: Internal architecture iCE40UP5K [1]

- YosysHQ
  - Yosys + ABC9
  - nextpnr
- Verilog to Routing [2]
  - ODIN II + ABC
  - VPR



Figure 3: YosysHQ - Products and Services [3]

# Supported Platforms - nextpnr

- Supported

- Lattice iCE40 - Project IceStorm
- Lattice ECP5<sup>a</sup> - Project Trellis
- Lattice Nexus - Project Oxide
- Gowin LittleBee - Project Apicula

- Experimental

- Cyclone V - Mistral
- Lattice MachXO2 - Project Trellis

---

<sup>a</sup>Magic trick: 12F is 25F, 45F is 85F

- Generic Backends

- Generic - Python based
- Viaduct - C++ based, <20k LUTs
- Himbächel - deduplicated database, 200k+ LUTs

- Other

- nextpnr-xilinx: Xilinx 7-series - Project X-Ray
- Quicklogic EOS-S3?
- Cologne GateMate (planned!)

# Open Source ASIC Design Flow

---



# What Do We Need?

## PDKs! (Process Design Kit)

- Primitives
  - Symbols, device param., PCells
- Verification Checks
  - DRC, LVS, ERC, PEX, antenna rules
- Simulation models
- Standard cell libraries
- And more...

## Open Source PDKs:

- SKY130, GF180, IHP130, ICPS

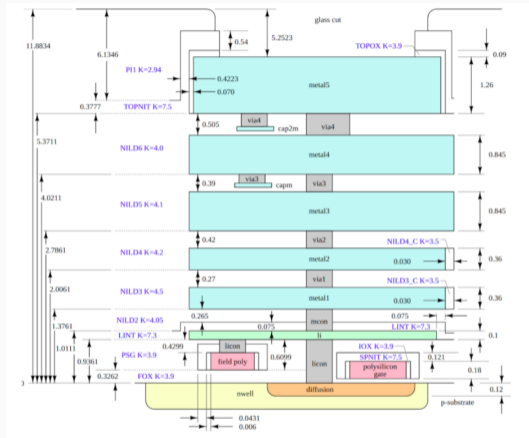


Figure 4: SKY130 stackup [4]

# Digital ASIC Design Flow

- Synthesis
- Floorplan
- Placement
- CTS
- Routing
- Finishing

Place & route on silicon (37C3) [5]

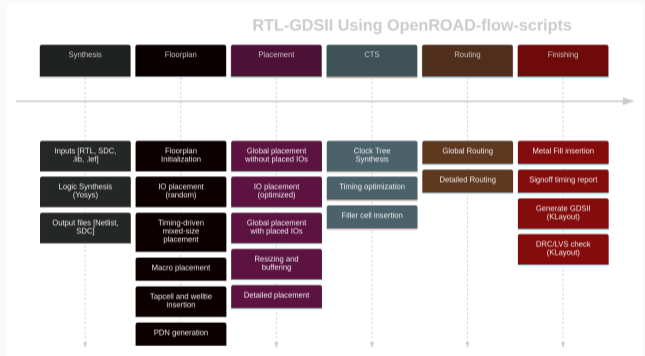


Figure 5: Typical Digital ASIC Design Flow [6]

# Open Source ASIC Design Flows

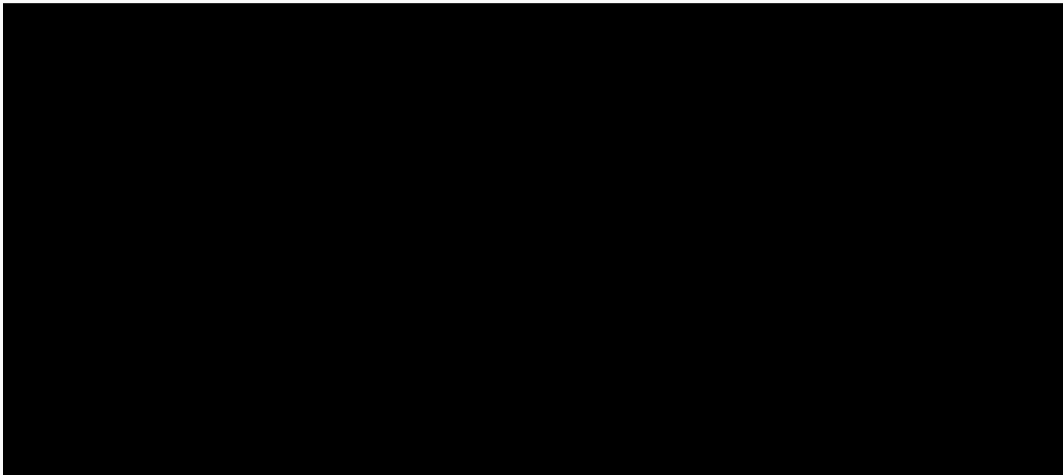
- Qflow: graywolf + qrouter [7]
- Alliance / Coriolis [8]
- LunaPnR [9]
- OpenROAD - DARPA [10]
  - OpenROAD-flow-scripts from OpenROAD
  - OpenLane from Efabless
  - Silicon Compiler from Zero ASIC
  - Hammer from UC Berkeley
  - OpenFASoC from IDEA-FASoC for mixed-signal design flows

# Offline Demo

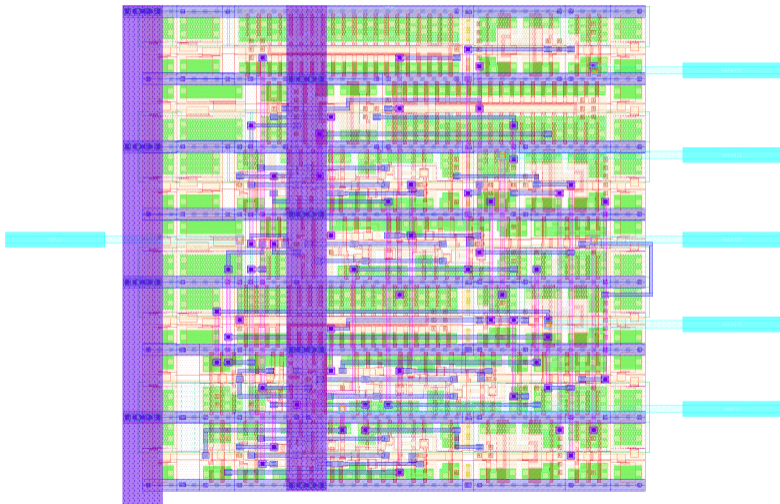
---

## OpenLane Example - Counter

```
1  'default_nettype none
2
3  module counter (
4      input  logic      clk_i ,
5      input  logic      rst_ni ,
6      output logic [3:0] value
7  );
8
9      always_ff @(posedge clk_i, negedge rst_ni) begin
10         if (!rst_ni) begin
11             value <= '0;
12         end else begin
13             value <= value + 1'b1;
14         end
15     end
16
17 endmodule
```



# OpenLane Example - Result



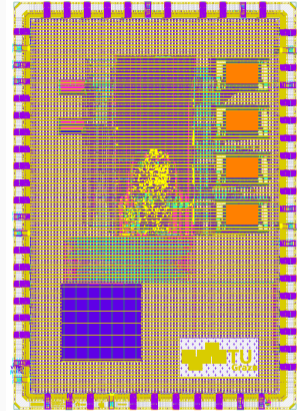
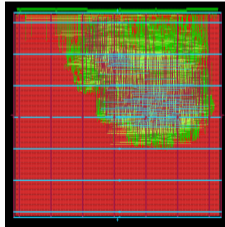
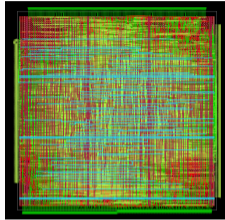
# "Case Study"

---



Your chance to experience  
Open Source ASIC design!

- Create your own block-cipher
- Harden it as a macro
- Integrate it into an SoC



**Figure 7:** Open Flow ASIC [11]

Thank You

---

## References

---

- [1] iCE40 UltraPlus Family Data Sheet, [Online]. Available: [https://www.latticesemi.com/-/media/LatticeSemi/Documents/DataSheets/FPGA-DS-02008-2-3-iCE40-UltraPlus-Family-Data-Sheet.ashx?document\\_id=51968](https://www.latticesemi.com/-/media/LatticeSemi/Documents/DataSheets/FPGA-DS-02008-2-3-iCE40-UltraPlus-Family-Data-Sheet.ashx?document_id=51968).
- [2] Verilog to Routing, [Online]. Available: <https://verilogtorouting.org/> (visited on 01/13/2024).
- [3] Products and Services, de. [Online]. Available: <https://www.yosyshq.com/products-and-services> (visited on 01/13/2024).
- [4] Skywater pdk, [Online]. Available: <https://skywater-pdk.readthedocs.io/en/main/>.

- [5] Place & route on silicon, [Online]. Available:  
[https://media.ccc.de/v/37c3-11820-place\\_route\\_on\\_silicon](https://media.ccc.de/v/37c3-11820-place_route_on_silicon).
- [6] Openroad documentation, [Online]. Available:  
<https://openroad.readthedocs.io/en/latest/>.
- [7] Qflow, [Online]. Available: <http://opencircuitdesign.com/qflow/>.
- [8] Coriolis, [Online]. Available: <http://coriolis.lip6.fr/>.
- [9] Lunapnr, [Online]. Available: <https://www.asicsforthemasses.com>.
- [10] Openroad, [Online]. Available: <https://github.com/The-OpenROAD-Project/OpenROAD>.
- [11] iaik open flow, [Online]. Available:  
<https://extgit.iaik.tugraz.at/sesys/iaik-open-flow>.