Center for Research and Advanced Studies (CINVESTAV)

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Design and Integration of Multiple Open-Source Analog Circuits Fabricated in SKY130 Technology within Silicluster v2.

Presented by:

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Introduction

- This work integrates several compact analog modules inside the Silicluster v2 chip, using a completely open-source design flow in SKY130 technology.
- It includes filters, oscillators, a buffer, an inverter, and an operational amplifier, as well as mixed-signal blocks for their characterization.
- It demonstrates that it is possible to design and fabricate multiple analog modules on a single chip using only open-source tools, meeting physical-design rules and achieving consistent results.

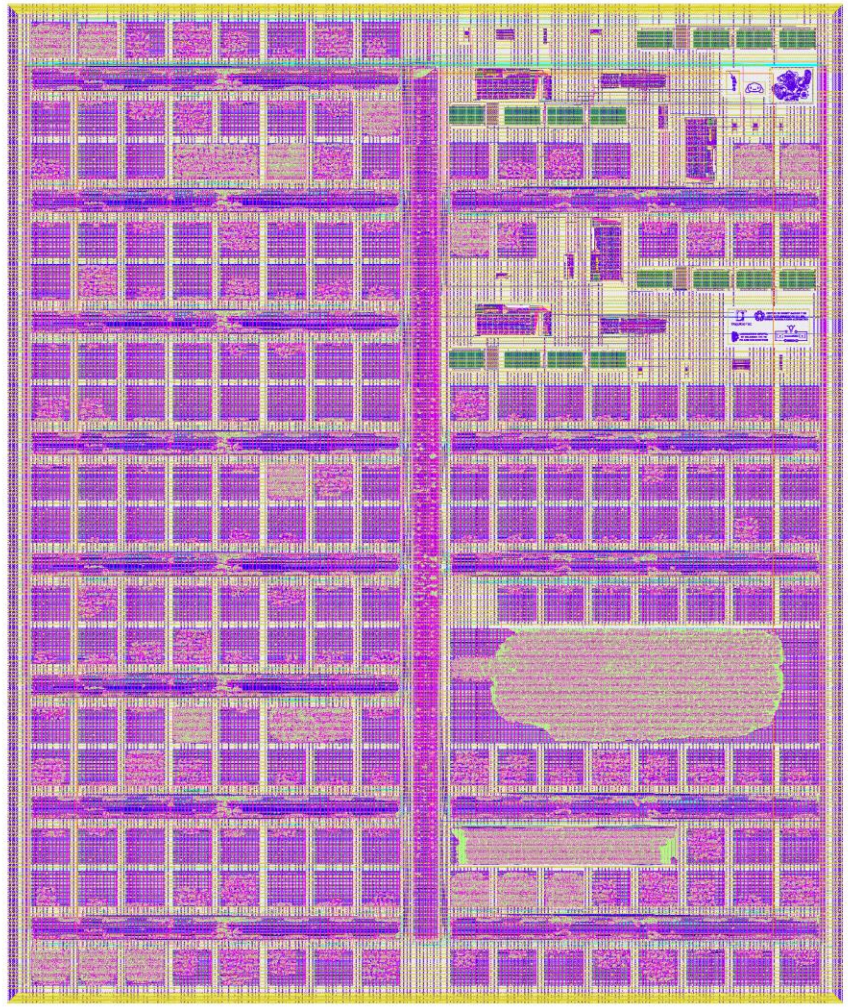
What is Silicluster?

•Silicluster is a circuit-integration platform that allows grouping dozens of independent modules into a single chip.

•It uses an internal multiplexing architecture that selects any module and connects it to common input/output pins, avoiding the need to fabricate a separate chip for each design.

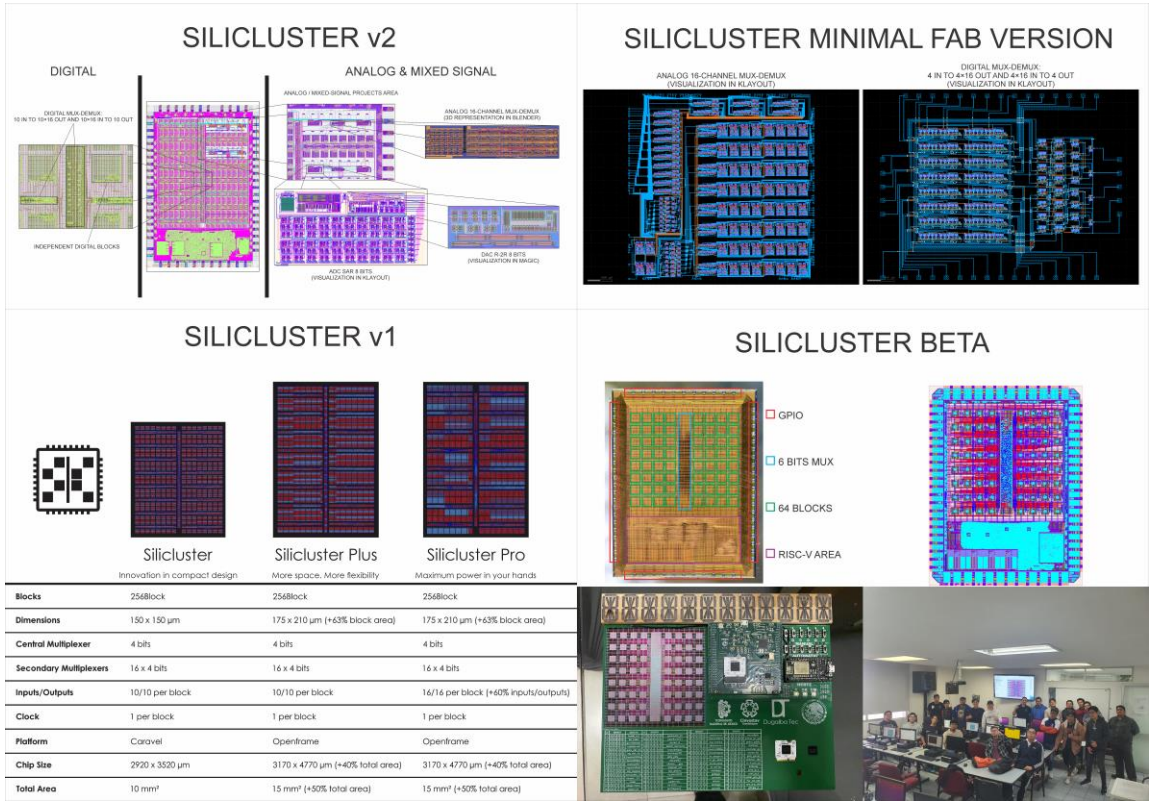
•It was created to enable testing, characterization, and rapid prototyping using open-source tools and PDKs.

Google + skywater TECHNOLOGY



Silicluster V2

Silicluster Versions



Blocks	256Block	256Block	256Block
Dimensions	150 x 150 µm	175 x 210 µm (+63% block area)	175 x 210 µm (+63% block area)
Central Multiplexer	4 bits	4 bits	4 bits
Secondary Multiplexers	16 x 4 bits	16 x 4 bits	16 x 4 bits
Inputs/Outputs	10/10 per block	10/10 per block	16/16 per block (+60% inputs/outputs)
Clock	1 per block	1 per block	1 per block
Platform	Caravel	Openframe	Openframe
Chip Size	2920 x 3520 µm	3170 x 4770 µm (+40% total area)	3170 x 4770 µm (+40% total area)
Total Area	10 mm²	15 mm² (+50% total area)	15 mm² (+50% total area)

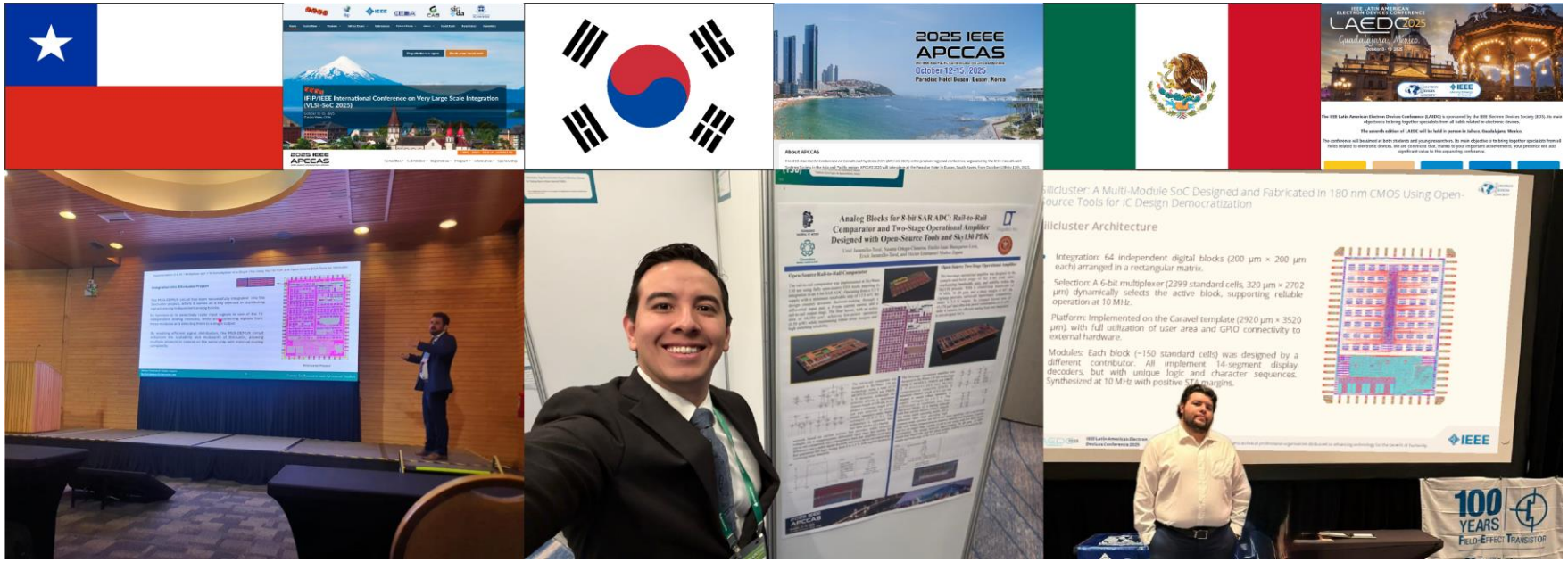
•Silicluster has gone through four versions. The Beta version integrated 64 digital modules, while version 1 increased the capacity to 256.

•Later, a test version was developed using Minimal Fab technology.

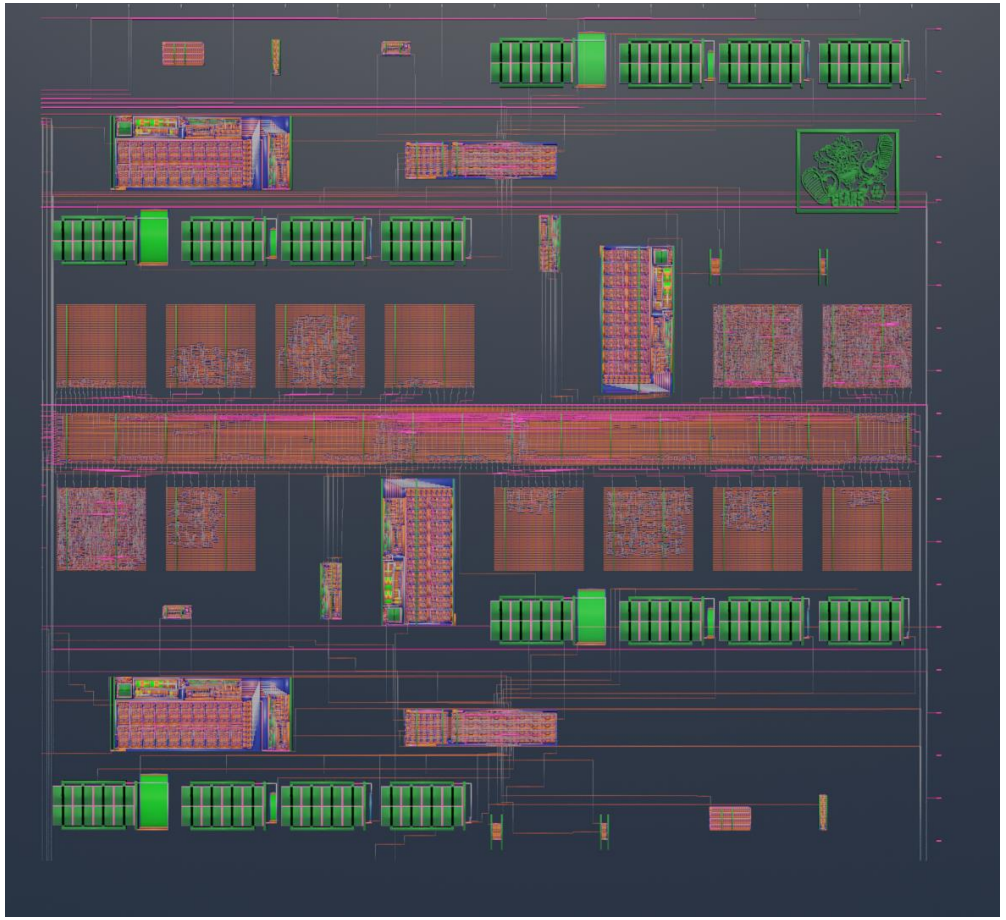
•Finally, version 2 kept the 256 modules but added the capability to include up to **48 analog or mixed-signal blocks**, enabling more complete characterization.

International Recognition of Silicluster

Silicluster has gained international visibility with three IEEE 2025 conference publications: **APCCAS in South Korea, VLSI-SoC in Chile, and LAEDC in Mexico**, establishing it as a notable platform for integrated-circuit design



Analog Circuits Designed for Silicluster V2

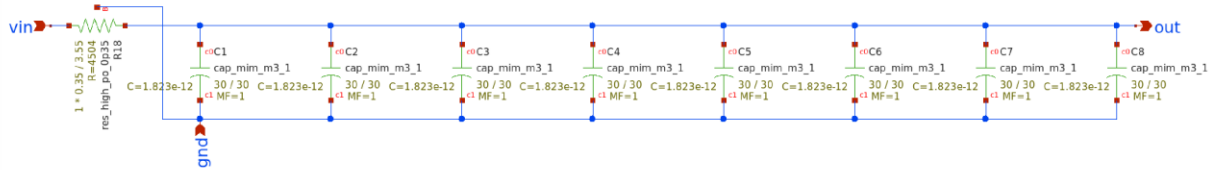


- Low-pass filters
- Ring oscillators
- Buffer
- Inverter
- Operational amplifier
- Analog demultiplexer

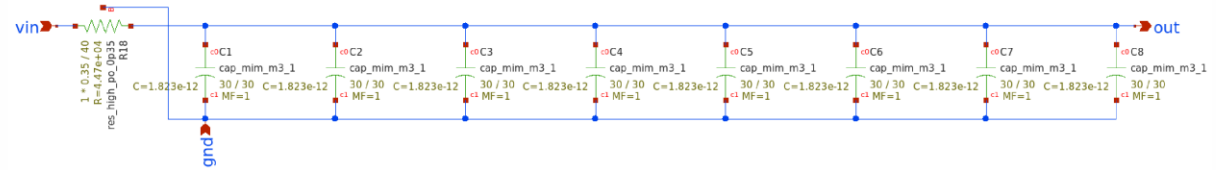
RC Low-Pass Filters

- The four low-pass filters were implemented using eight parallel capacitors while maintaining the same total capacitance.
- Different cutoff frequencies were obtained by modifying only the resistance, achieving −3 dB points from a few kHz up to several MHz.
- Simulations confirmed the expected behavior, and the layout showed a compact integration compatible with SKY130.

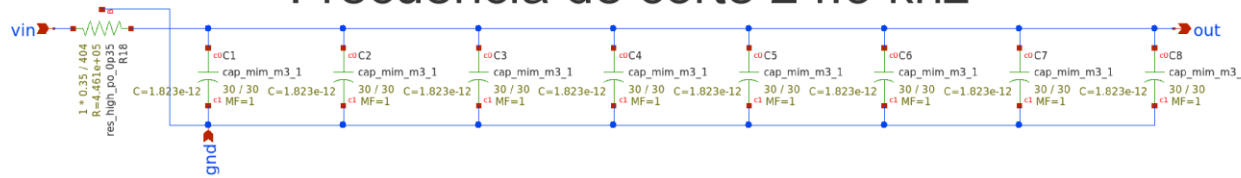
Frecuencia de corte 2.43 Mhz



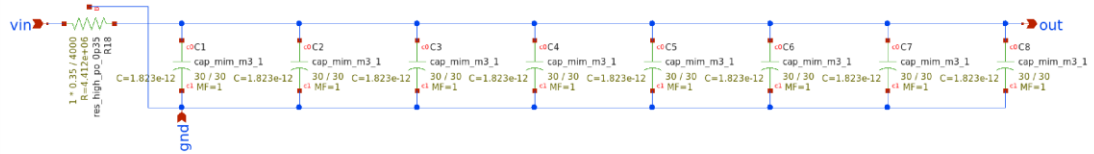
Frecuencia de corte 243 khz



Frecuencia de corte 24.3 khz

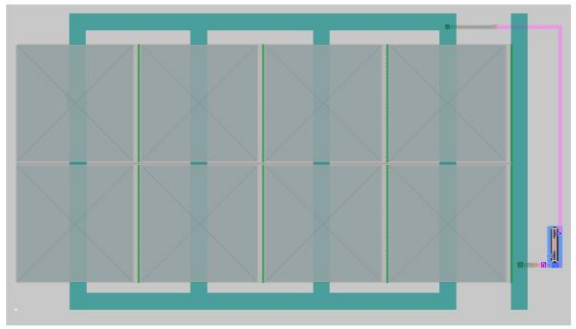


Frecuencia de corte 2.43 khz



Low-Pass Filters

Frecuencia de corte 2.43 Mhz



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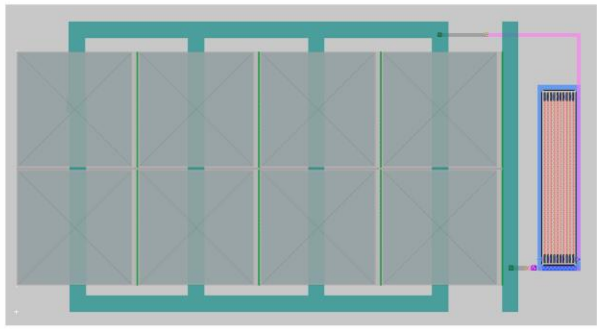

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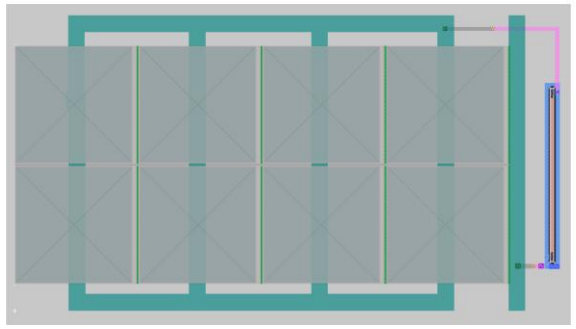
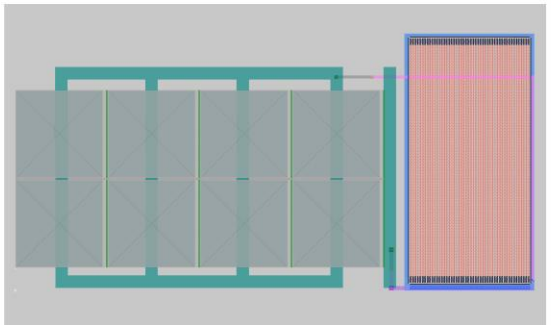
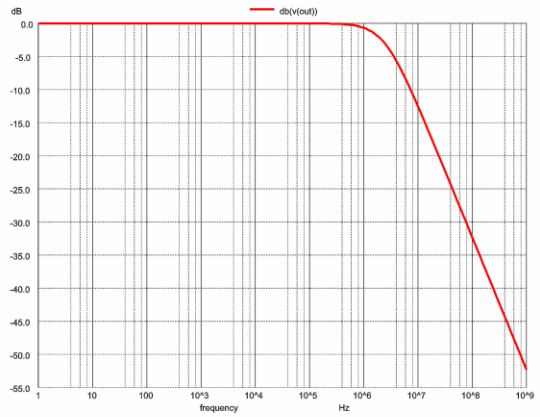


Frecuencia de corte 2.43 khz

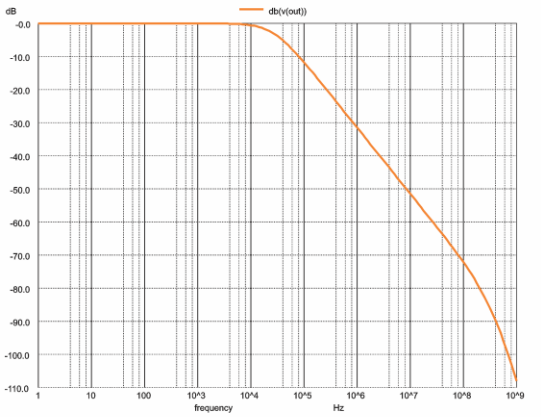


Layouts

Frecuencia de corte 2.43 Mhz

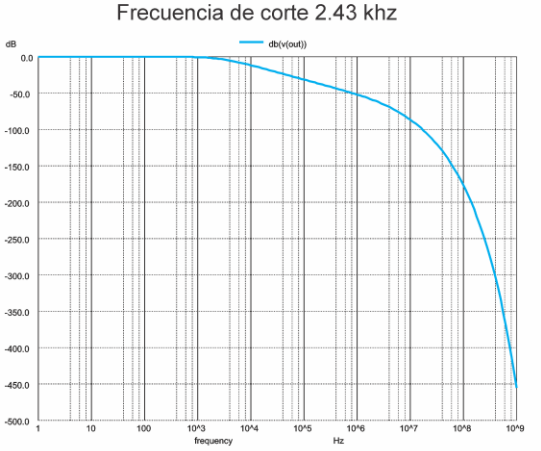


Frecuencia de corte 24.3 khz



Frecuencia de corte 243 Mhz

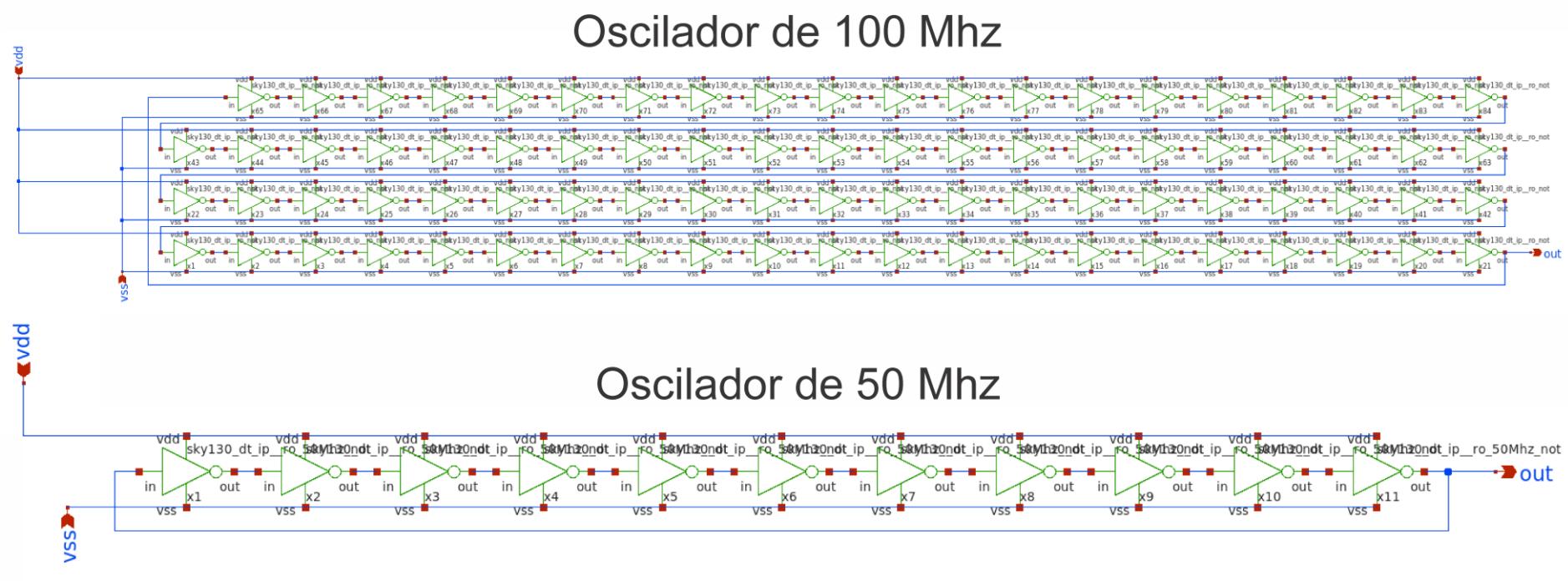
Frecuencia de corte 2.43 khz



AC Analysis

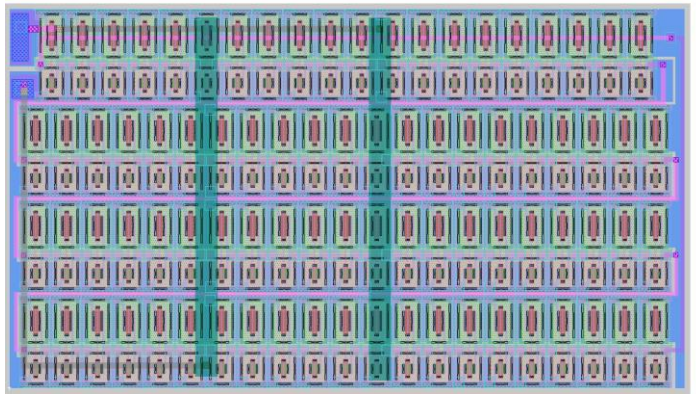
Ring Oscillators

Two ring oscillators were implemented at 50 MHz and 100 MHz using chains of inverters. Simulations confirmed stable oscillation, and the layout showed a symmetric distribution suitable for SKY130. These blocks enable testing of internal high-frequency signals in an open-source environment.

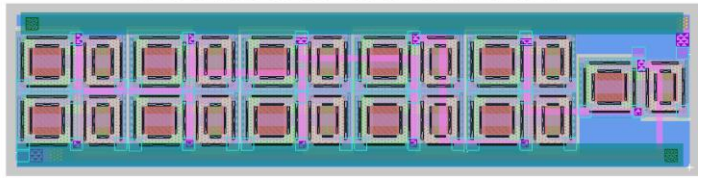


Ring Oscillators

Oscilador de 100 Mhz



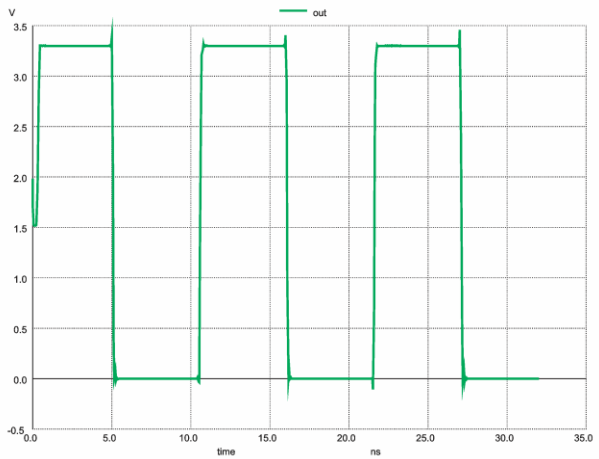
Oscilador de 50 Mhz



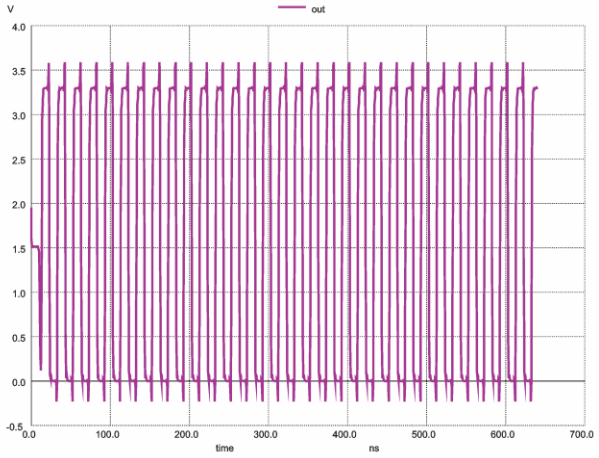
Layouts

Transient Analysis

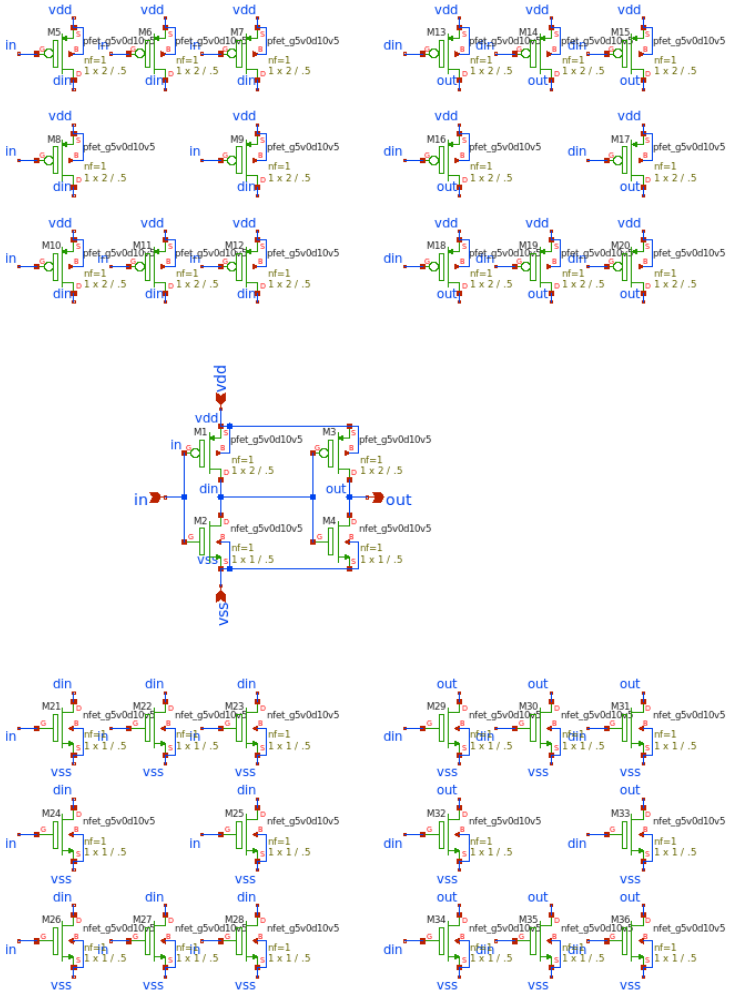
Oscilador de 100 Mhz



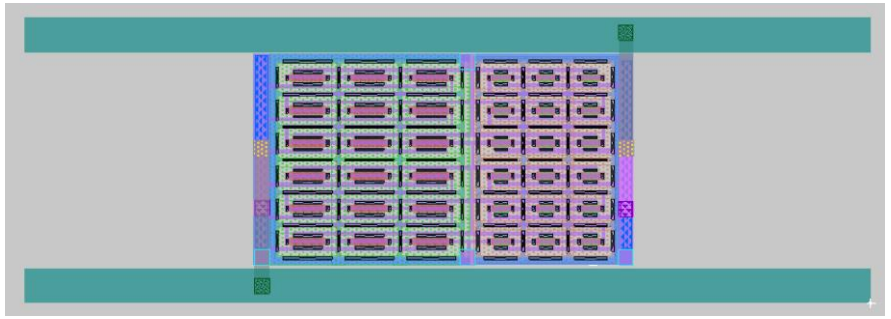
Oscilador de 50 Mhz



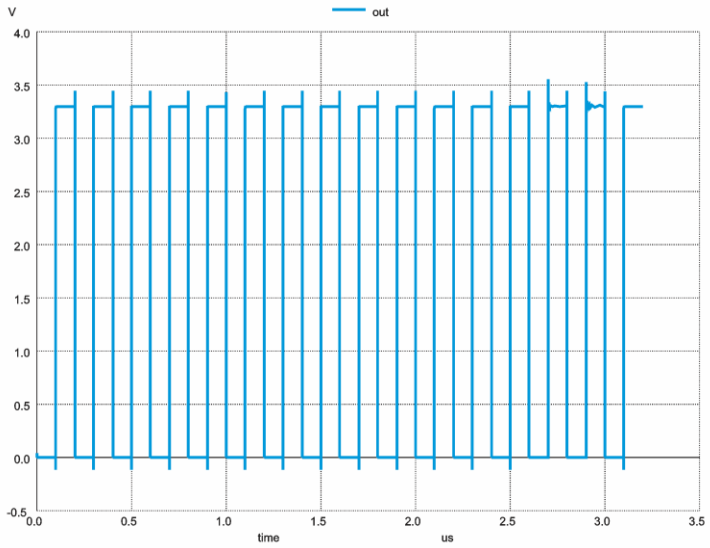
Buffer



- A buffer was implemented using discrete SKY130 transistors, designed as a simple, compact stage. Transient simulations show stable response to input variations, and the layout meets process-design rules.
- This block serves as a reference for evaluating small conditioning stages inside Silicluster v2.



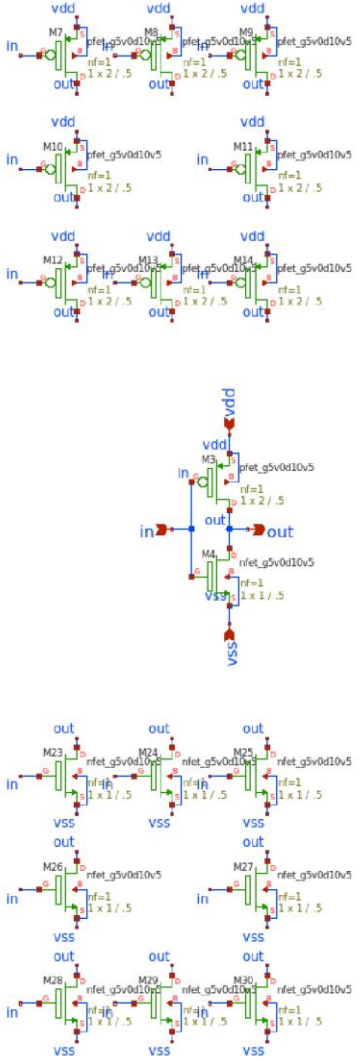
Layout



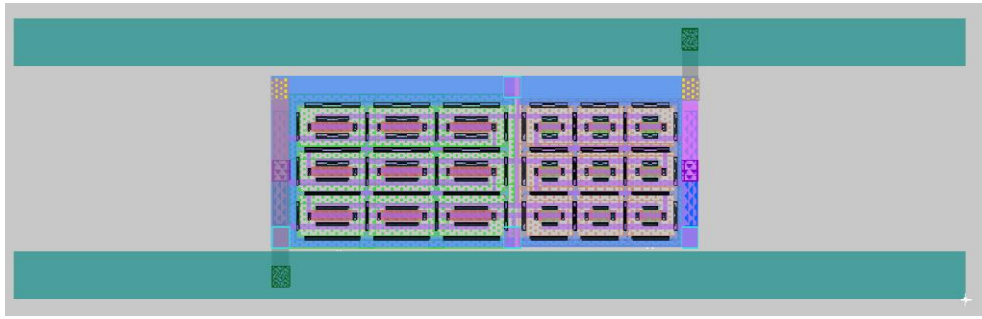
Transient Analysis

Inverter

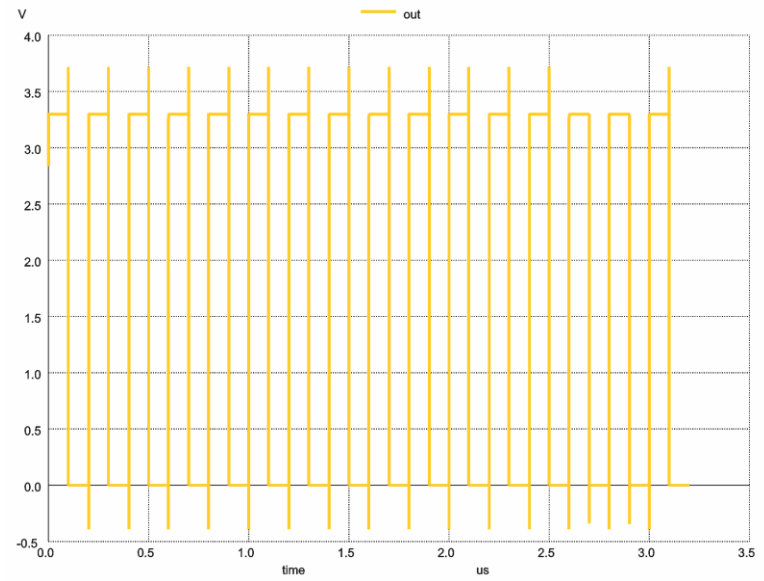
- An inverter was integrated with dummy transistors on the edges to improve matching and reduce edge effects in a compact area.
- Simulations show stable switching, and the layout demonstrates a symmetric arrangement with properly placed dummies.
- This block enables evaluation of how physical design influences switching behavior in SKY130.



Schematics



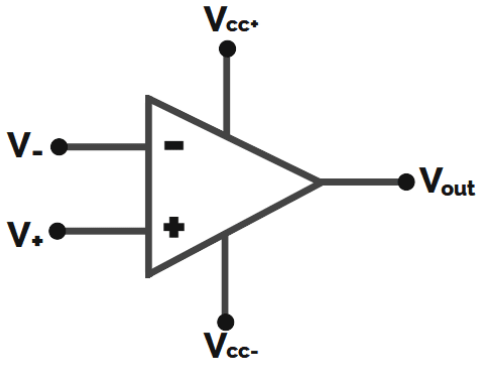
Layout



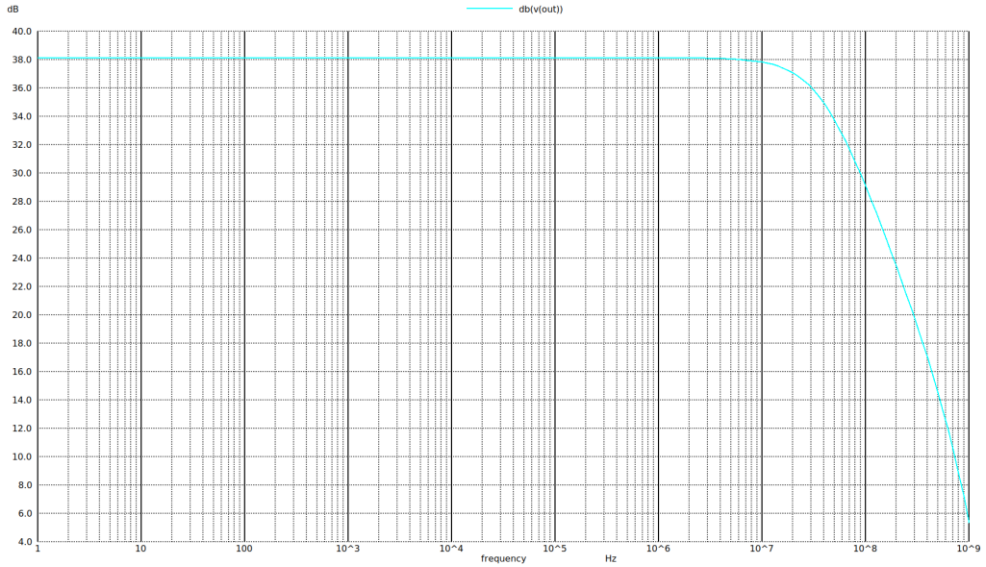
Transient Analysis

Two-Stage Analog Operational Amplifier

- The open-loop gain of the amplifier was measured at **38 dB**.
- The linear-gain bandwidth extends up to **7 MHz**.
- The cutoff frequency is measured at **400 MHz**.

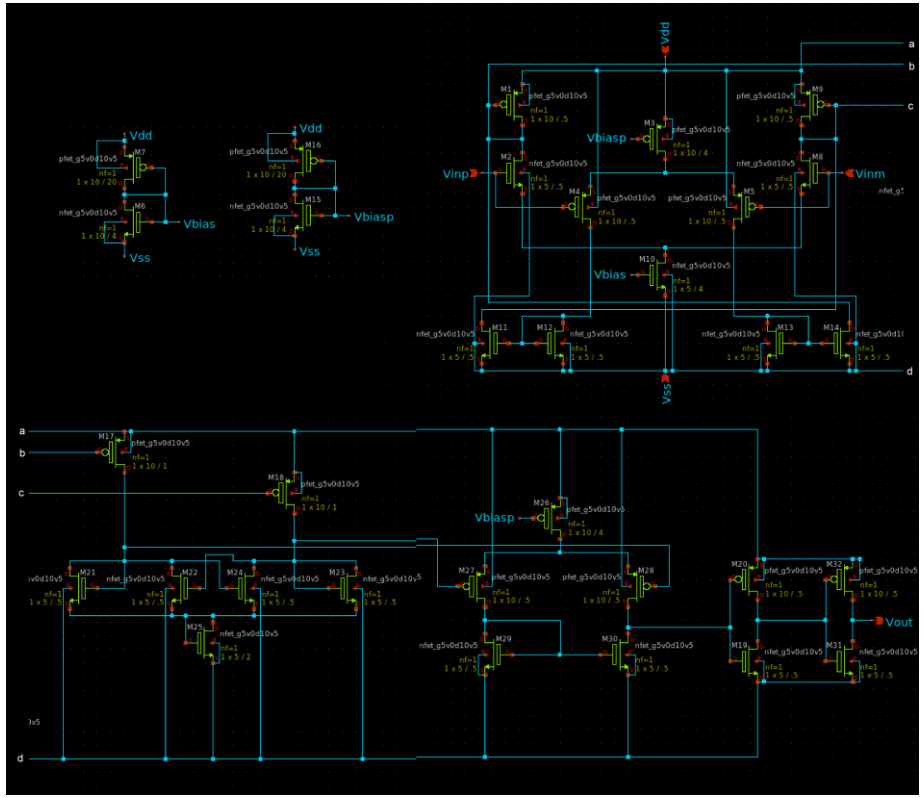


Opamp

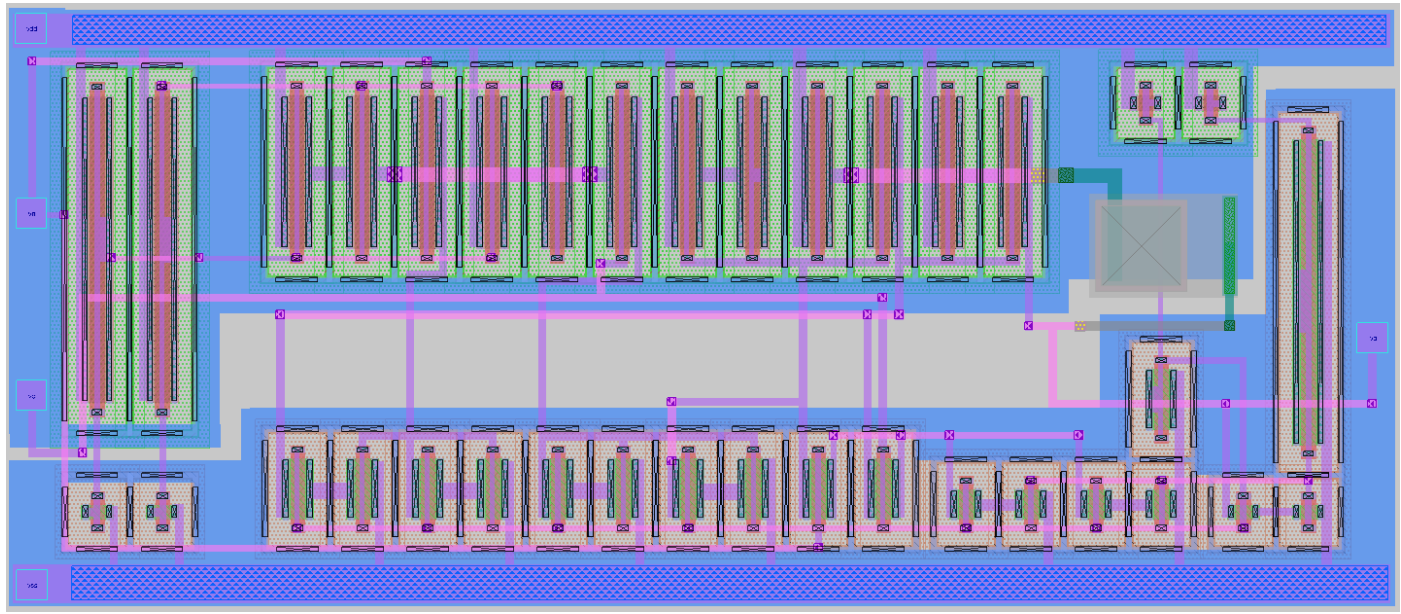


AC Analysis

Two-Stage Analog Operational Amplifier



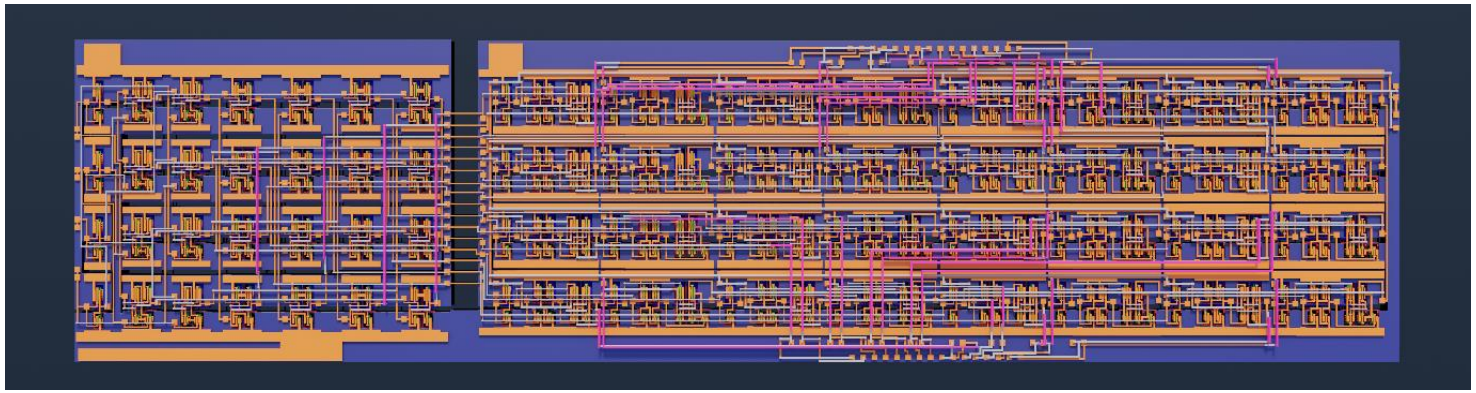
Schematic



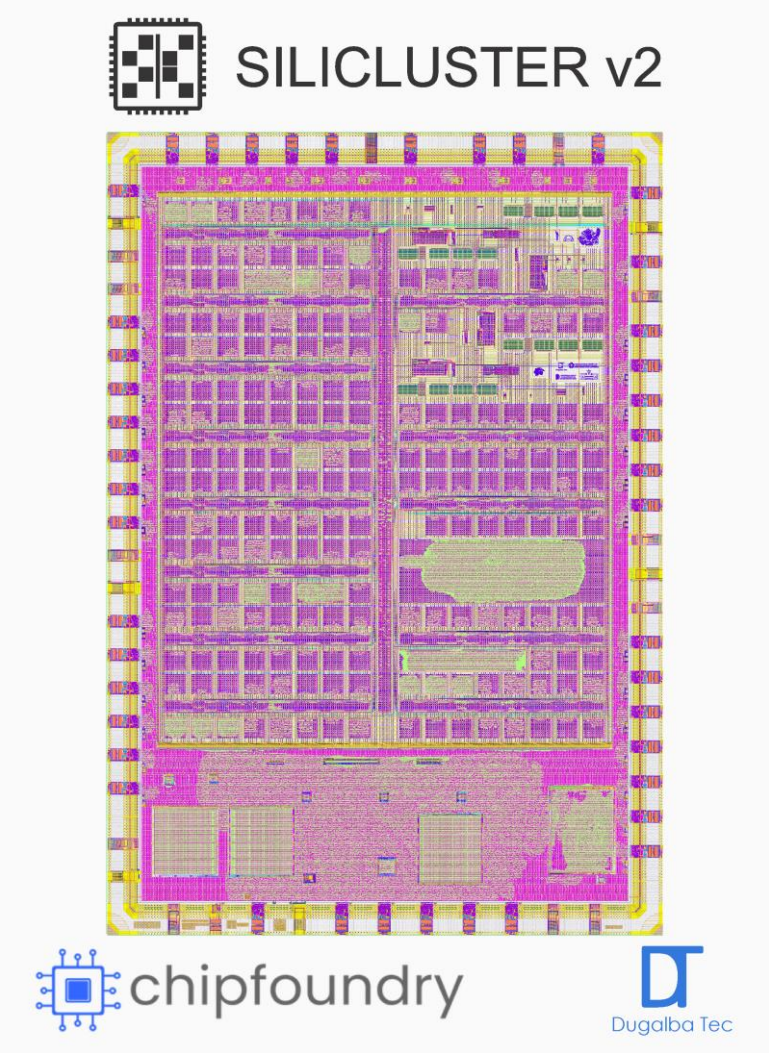
Layout

Analog Multiplexer

- The analog multiplexer connects each analog block to a common input and output line. It operates in the analog domain at **3.3 V**, allowing the selected blocks to directly deliver their signal to the outside without requiring additional interface stages.



Render — Analog Demultiplexer Layout

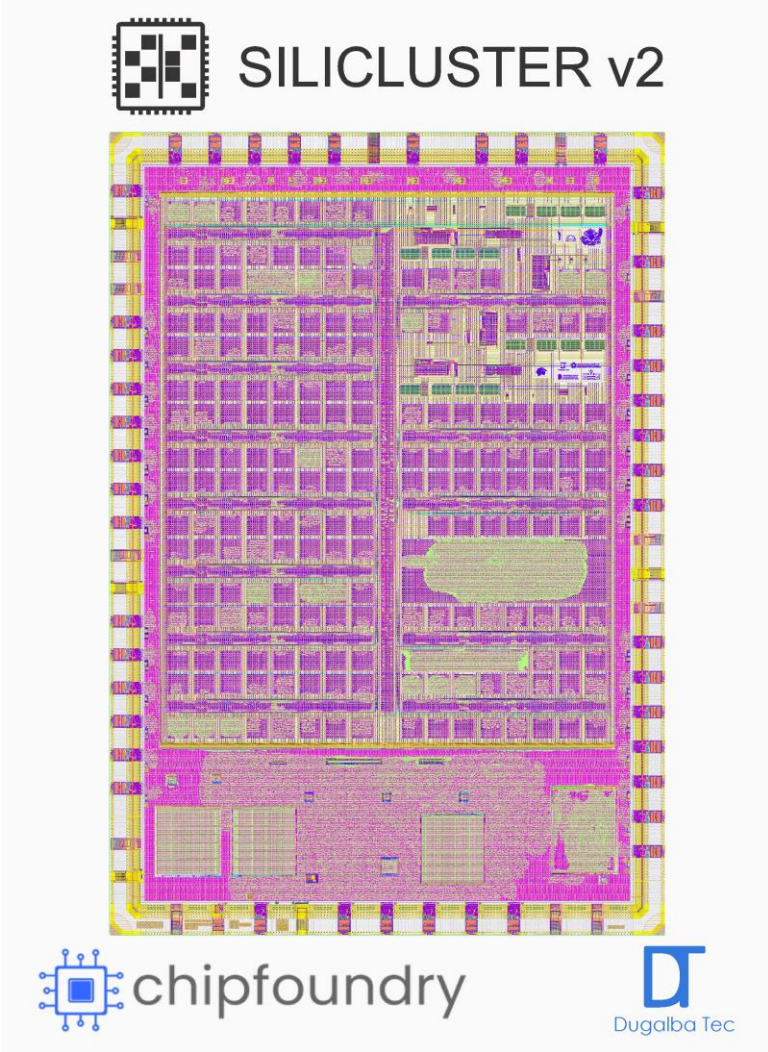


Silicluster also includes digital and mixed-signal designs such as:

- A 4-bit Flash Analog-to-Digital Converter (ADC) and an 8-bit Successive Approximation Register (SAR) ADC.
- An 8-bit R-2R Digital-to-Analog Converter (DAC).
- 16-bit counters.
- Neural networks.
- State Machines.
- Encryptors, among others.

Conclusion

- This work demonstrated that it is possible to integrate several compact analog modules into a single chip using only open-source tools and the SKY130 technology.
- The filters, oscillators, buffer, inverter, and operational amplifier were implemented and validated through simulation and layout within Silicluster v2, confirming stability and compliance with physical-design rules.
- These results show the maturity of the open-source ecosystem for analog design and enable the integration of more complex circuits in future versions of the project.



Thank you very much for your attention!
Any questions?