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Aristotle University of Thessaloniki
SCHOOL OF PHYSICS

Seminar at the University of Bonn
2026 International Fellowship Framework

Semiconductors Evolution

From Transistors to Wireless Applications, Automotive and AI

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ATLAS IC

May 2026

Content

- The Evolution of Semiconductors
- Transistor Miniaturization
- Semiconductors Applications
  - Wireless Technologies
  - Transforming the Automotive Industry
  - Driving AI and High-Performance Computing
- Chip Design Case Studies and AI usage
- Conclusion and Q&A

Introduction on Evolution of Semiconductors

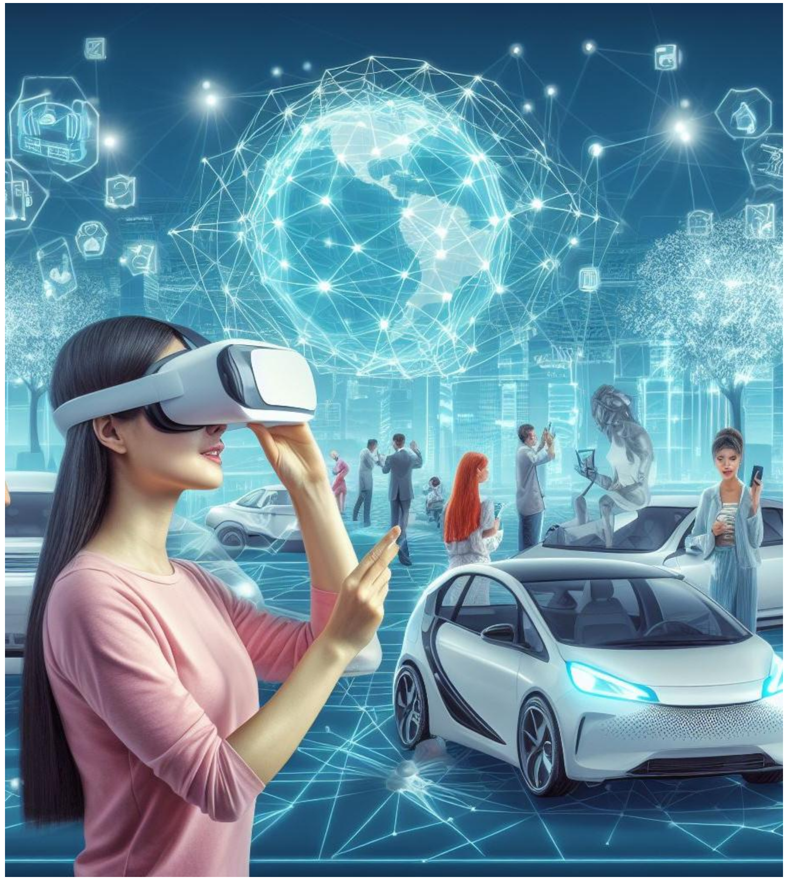
Semiconductors have revolutionized **modern technology**

Their evolution started with **early transistors** and progressed to advanced **microchips**

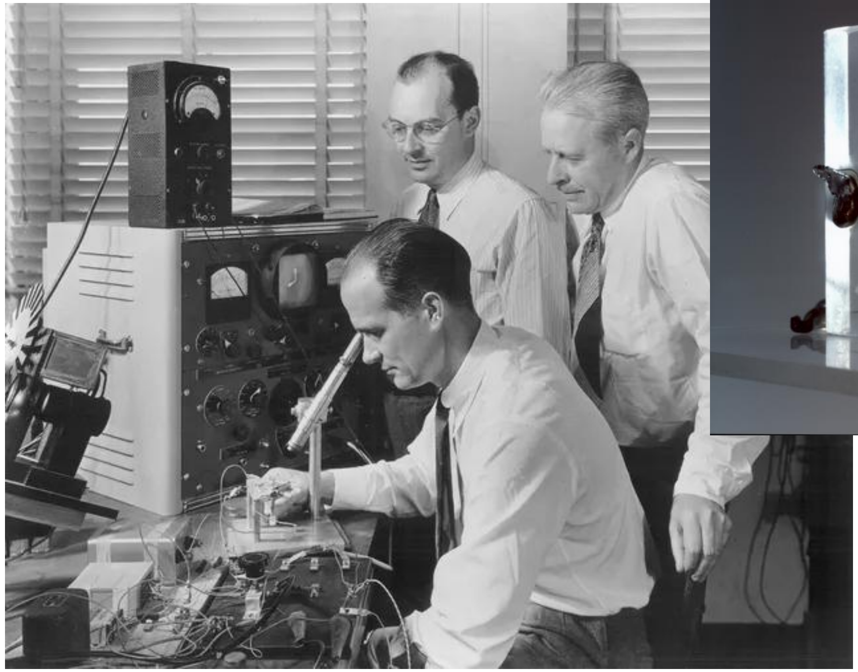
Key developments include **transistor** miniaturization, integrated circuits, and high-performance computing

They enable innovations in **wireless communications**, **automotive technology**, **and artificial intelligence**

IC Products



The First Transistor



1956 Nobel Prize in Physics
John Bardeen, Walter H. Brattain and William Shockley

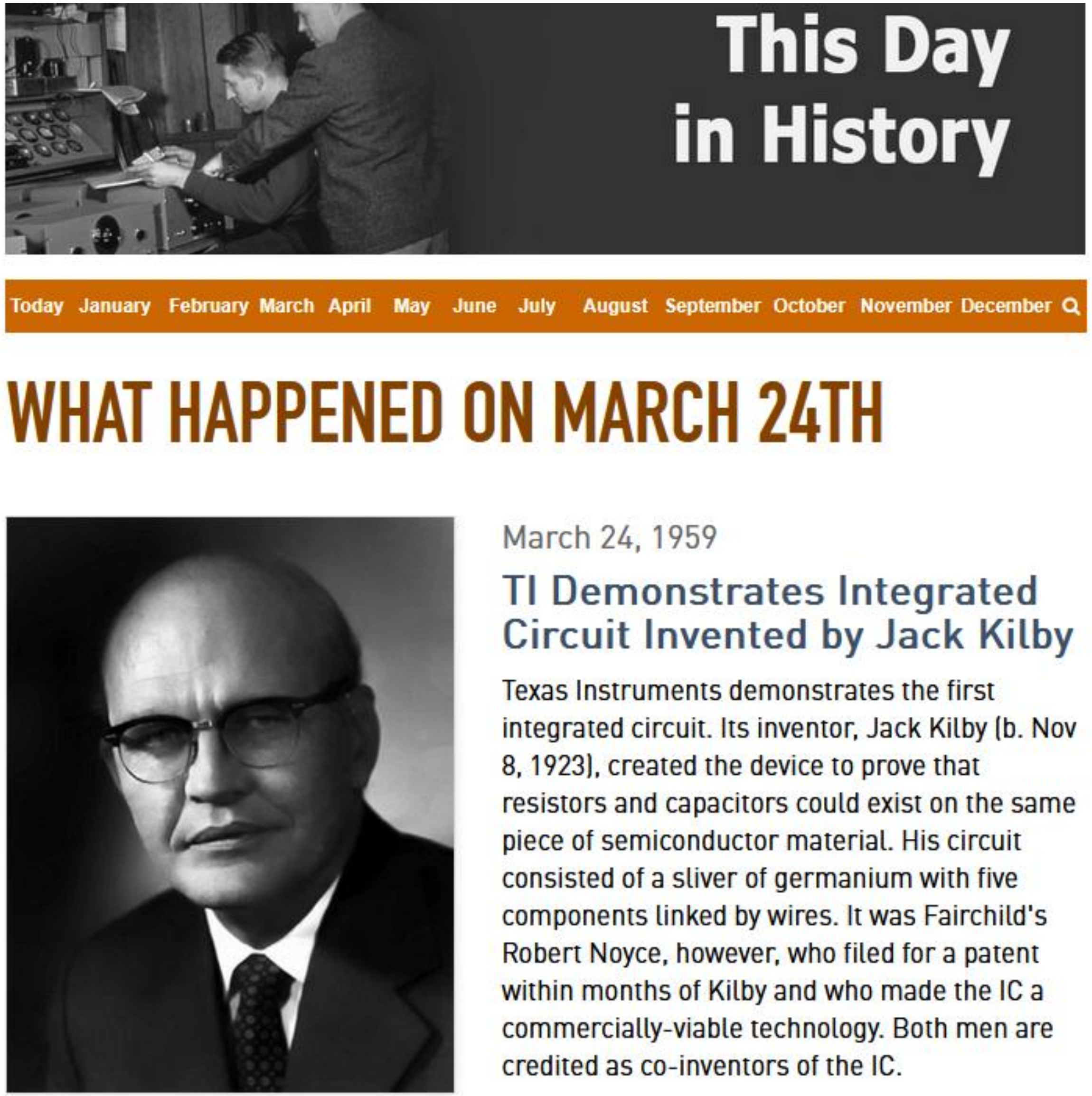
A small semiconductor device that would change the world

- On December 16, 1947, Bardeen, Brattain and Shockley managed to make point-contact transistor.
- On Christmas Eve, the input signal was amplified about eighteen times.
- A new era in electronics dawned - the invention of the transistor became the basis for the electronic age.

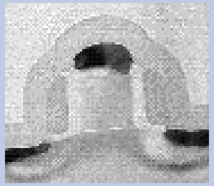
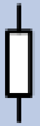
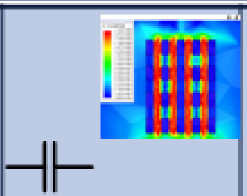
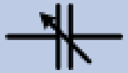
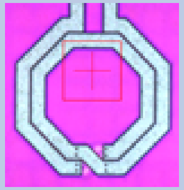
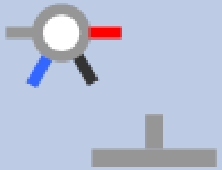
Taken from
https://www.bell-labs.com/about/awards/1956-nobel-prize-physics/#gref

The Evolution of Semiconductors

- Early development of transistors (1947, Bell Labs).
- Miniaturization leading to integrated circuits (1958, Jack Kilby and Robert Noyce).
- Advancements in microchip architectures enabling high-performance computing.



Devices and Applications

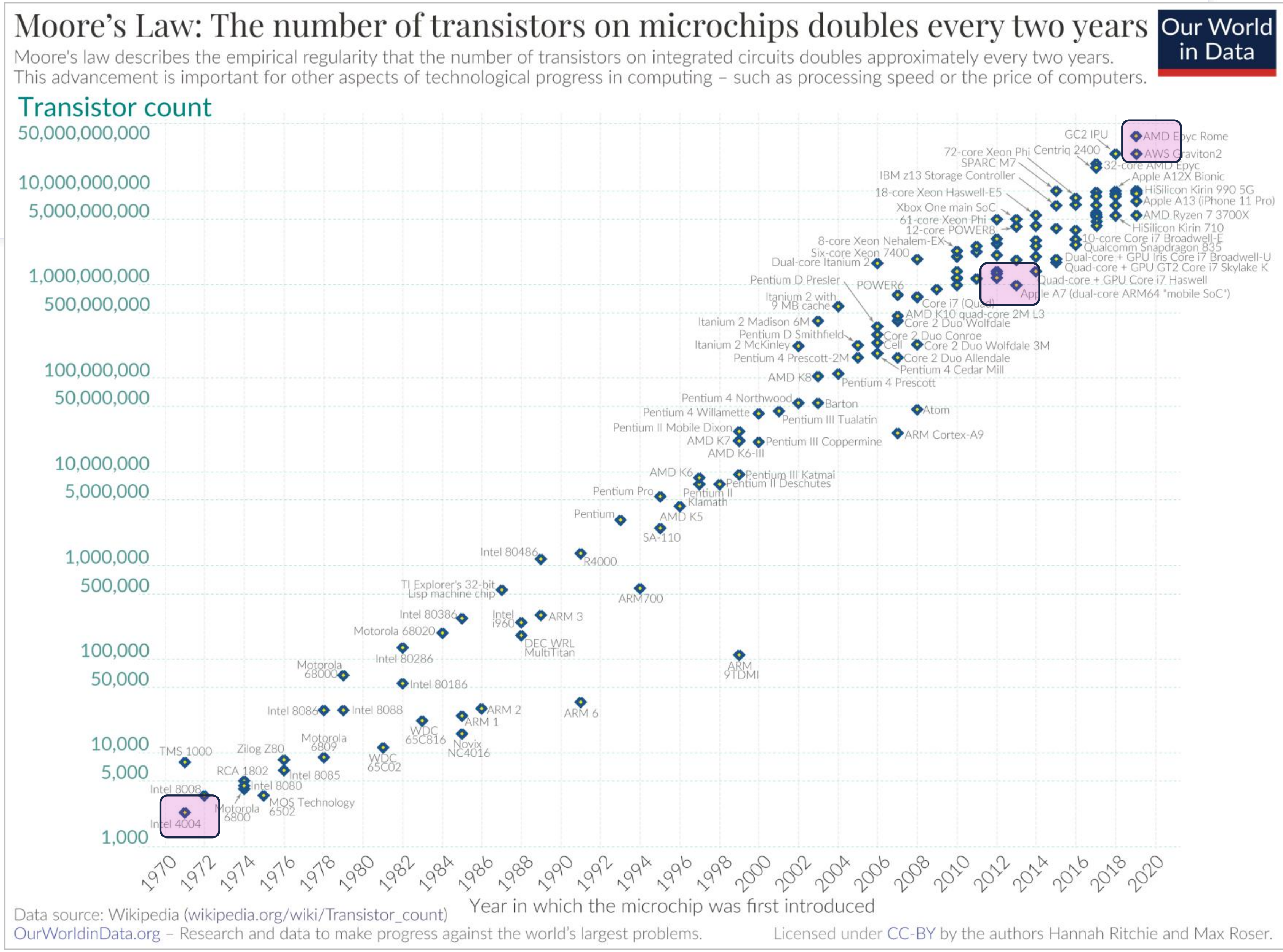
						
Digital	Lmin		Supply Buffering			
Analog f~ MHz λ~m	>= 3*Lmin	√	√			
RF f~GHz λ~cm	Lmin… 3*Lmin	√	√	√	√	
mm-Wave f~50GHz λ~mm	Lmin	√	√	√	√	√

P. Baumgartner "RF & Noise Characterization of RFCMOS Devices and Circuits" Sinano Summerschool 2008

- Digital Design (e.g. CPUs, GPUs)
- Analog Design – Baseband (e.g. Audio Amplifiers, filters)
- RF Design (e.g. Bluetooth transceivers)
- mmWave Design (e.g. Radar Transceivers)

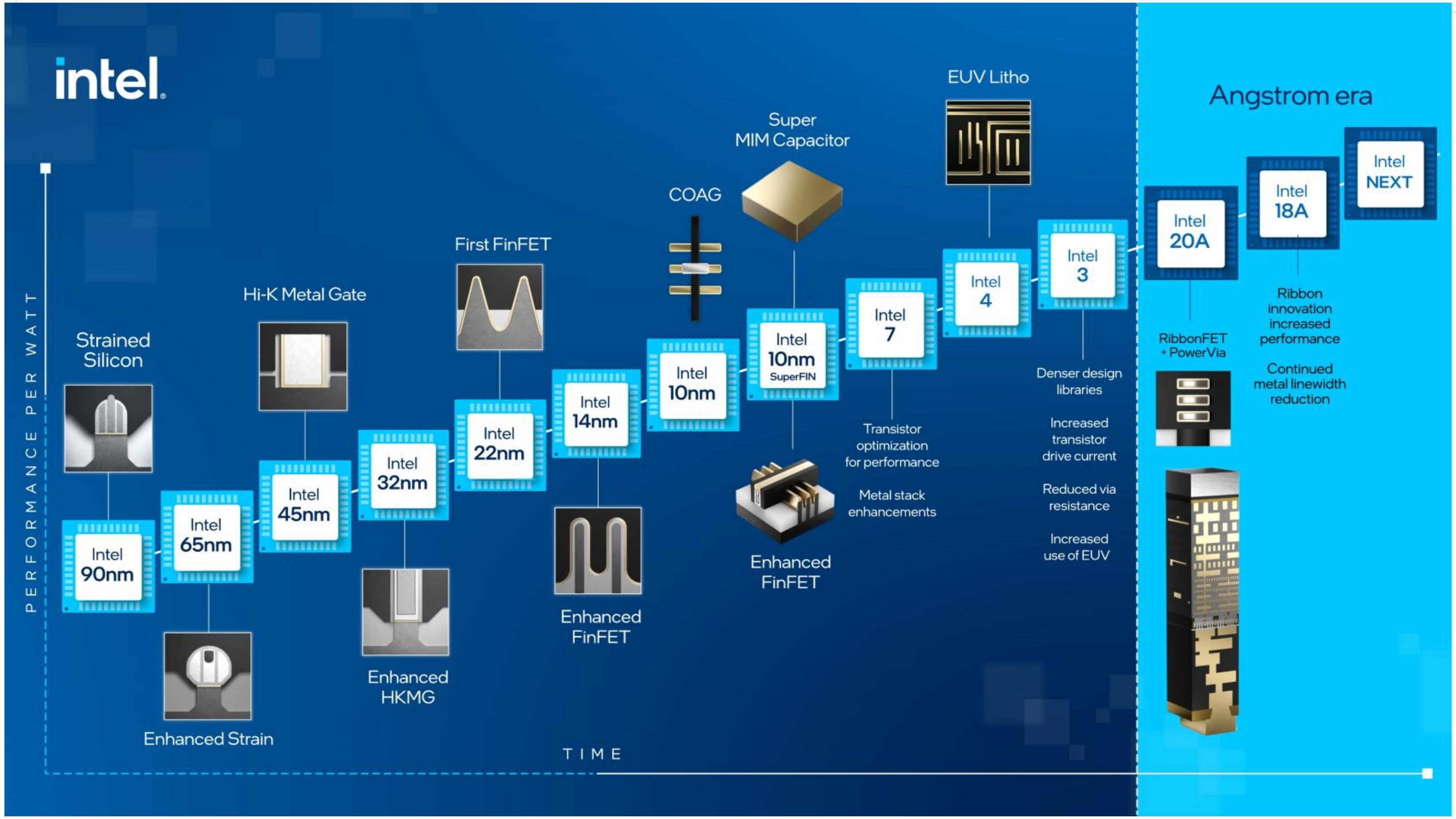
Moore's Law

Semiconductor Market is driven by Moore's Law



Taken from
https://en.wikipedia.org/wiki/Moore%27s_law

Moore's Law on Device Level



From CMOS to FinFET and from FinFET to RibbonFET

Taken from https://download.intel.com/newsroom/2022/manufacturing/id-process-technology-graphic.jpg

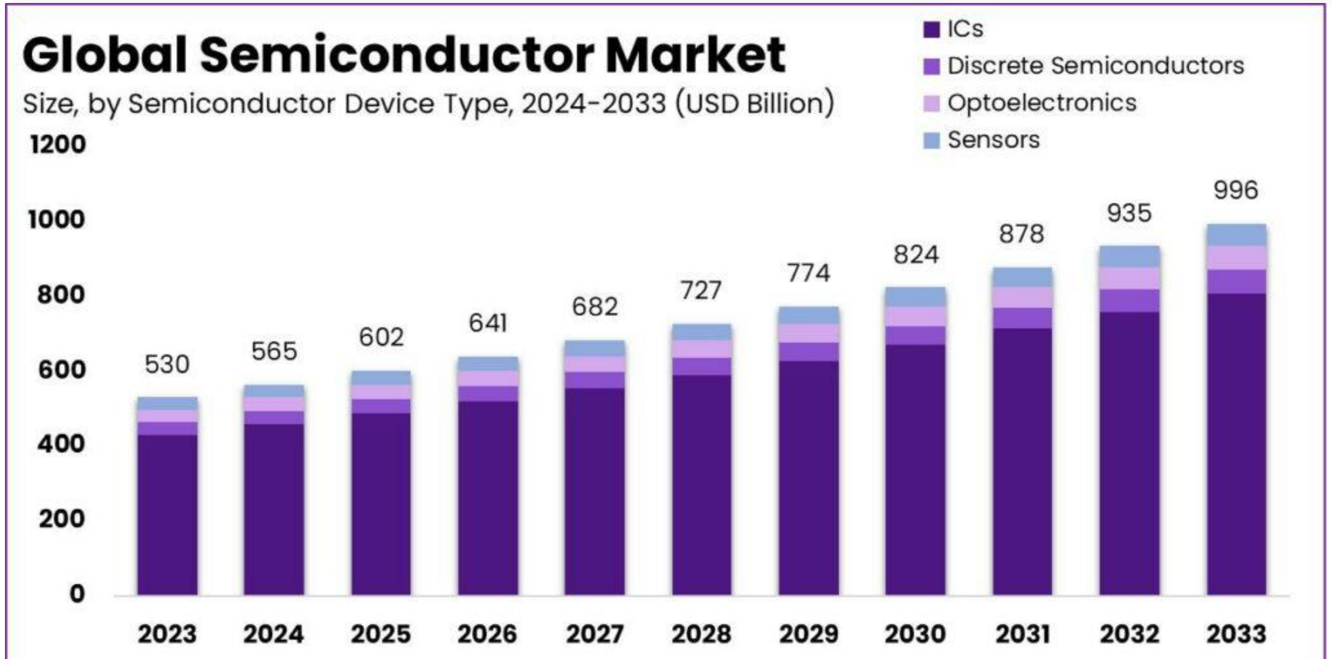
Integrated Circuits and Microchips

THE IMPACT OF ICS IN COMPUTING AND CONSUMER ELECTRONICS.

ADVANCEMENTS IN FABRICATION TECHNOLOGIES LIKE EUV LITHOGRAPHY.

THE ROLE OF SEMICONDUCTOR FOUNDRIES LIKE TSMC, INTEL, AND SAMSUNG.

Semiconductors Market



Taken from https://market.us/report/semiconductor-market/

Taken from https://www.linkedin.com/pulse/global-chip-foundry-latest-market-share-tsmc-becomes-biggest-%E9%83%AD-guo--fcuef/

Consumer Electronics Impact

- Miniaturization and Portability (smartphones, tablet, or smartwatch)
- Computing Power (CPUs, GPUs)
- Mobile Devices and Wireless Comm's (Bluetooth, WLAN, 4G, 5G, LTE, Radar)
- Consumer Electronics (TVs, kitchen appliances and game consoles)
- Automobiles – Self Driving cars – Electromobility
- Healthcare (Pacemakers, Hearing Aids, MRI machines)
- Augmented and Virtual Reality products (Smart glasses)
- 
  HPC and Artificial Intelligence Enablement
- Space Exploration (Satellites and spacecraft Ics)

Semiconductors in Wireless Technologies

Enabling 5G and next-generation communication networks.

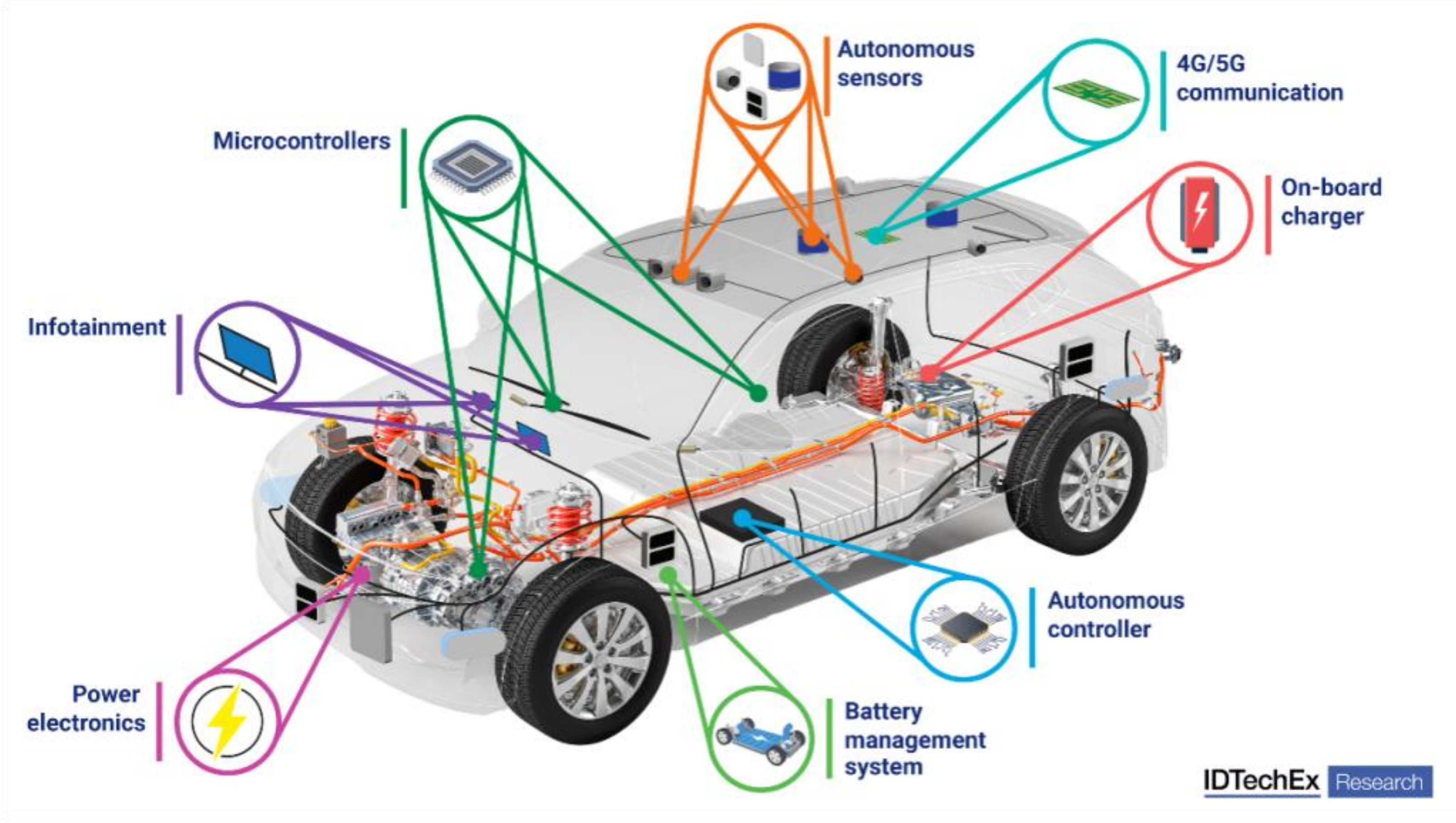
RF and mmWave chips for enhanced wireless performance.

Impact on IoT and smart devices.

- RFCMOS and FinFET Technology Usage (90nm to 22nm, 16nm fown to 7nm)
- Transceiver Development with processor into the same silicon
- Higher speed and low power > higher frequencies > moving from RF (0.7GHz to 28GHz to mmWave (i.e. Radar an 5G, 28GHz and above)
- Minimum Transistor Channel Length Usage
- 1 to 3 years lifetime

Transforming the Automotive Industry

- Smart vehicles and autonomous driving technologies.
- Electrification of transportation through semiconductor-based power electronics.
- Integration of AI and machine learning in vehicle safety systems.



https://www.embedded.com/buying-autonomous-electric-vehicles-will-soon-be-just-like-buying-a-laptop/

Wireless Versus Automotive

Figure: Automotive IC requirements versus mobile

PROCESS
RFCMOS, FinFET
SiGe BiCMOS

PROCESS
Bipolar
BiCMOS, BCD
Power BCD
GaN, RFCMOS

Mobile		Automotive
28nm → 7nm	Process	>180nm → 7nm
100M+	Design Sizes(µP/C)	<1M → 1000M+
900MHz → 2.7GHz	Frequencies	30MHz → 5.9GHz
0.5V to 1.8V	Voltages	~1V → >60V
0 → 40°C	Temperatures	-40 → 155°C
1-3 years	Operation Lifetime	~10-15 years
<10%	Target Field Failure Rates	Target Zero Failure

Source: Synopsys, Deloitte analysis

In ATV industry, chips, components, modules and subsystems should **meet stringent specifications on quality, reliability, cost, power and <u>safety</u>**, due to operating conditions in cars

FuSA

Driving AI and High-Performance Computing

- GPUs and TPUs accelerating AI applications.
- Role of semiconductors in data centers and cloud computing.
- Future trends in quantum computing and AI-specific chip designs.

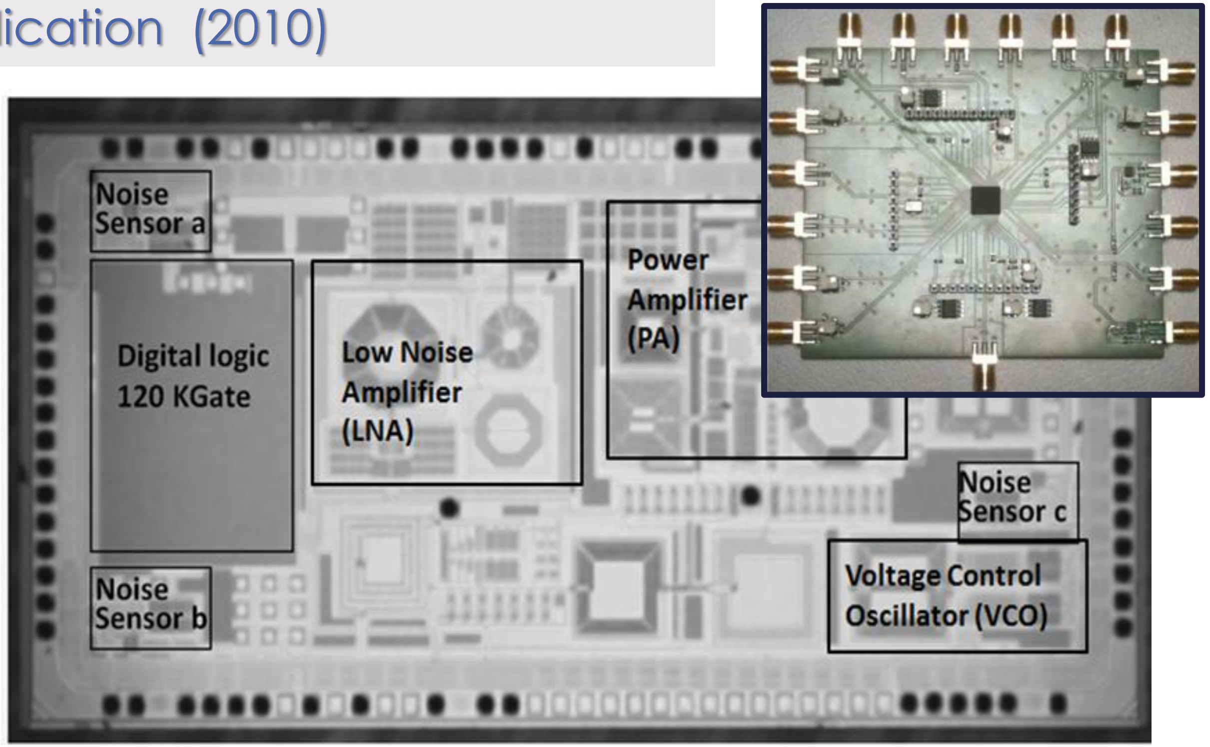
TPUs accelerate both training and inference of large AI models
- perform up to 15– 30x faster than contemporary GPUs and CPUs
– achieve higher energy efficiency, with a 30–80x improvement in one Trillion (Tera) Operations per Second (TOPS)

Semiconductors power the processing units within these servers, enabling them to execute complex tasks and handle massive volumes of data with unparalleled **speed**

Quantum computing can potentially enhance AI's capabilities by **removing the limitations of data size, complexity, and the speed of problem solving**

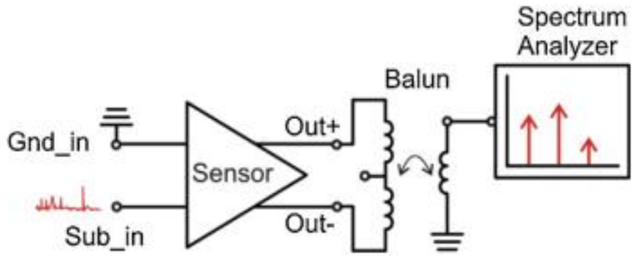
RF Transceiver Case Study (2010)

Wide-band substrate crosstalk sensor and wireless SoC application (2010)



Wireless SoC Vehicle 65nm TSMC

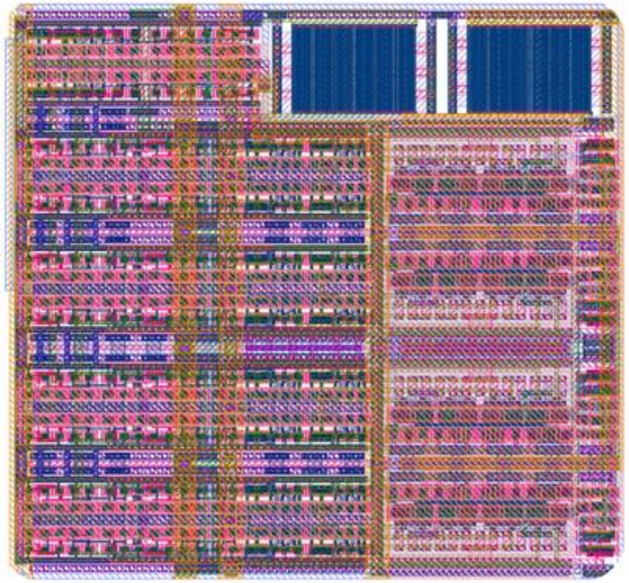
- Mobile Comm's
- Substrate Noise 'on the fly' monitoring
- Substrate Crosstalk Modeling and Simulation Validation



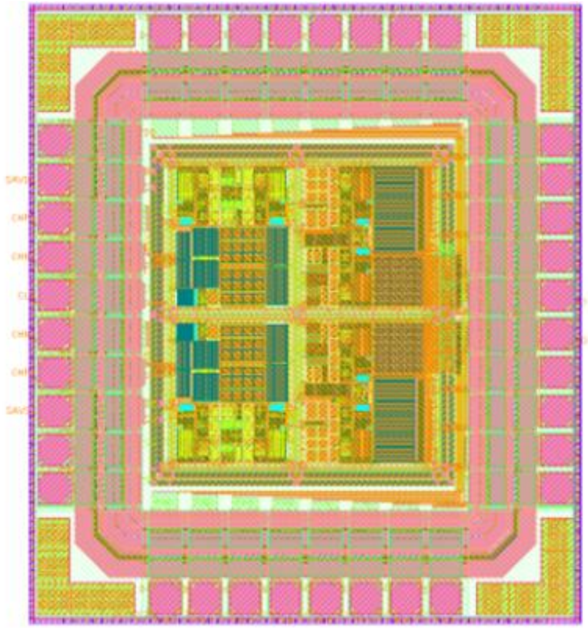
T. Noulis, P. Merakos, E. Lourandakis, S. Stefanou, Y. Moisiadis, "Wide-band substrate crosstalk sensor for wireless SoC applications" Sensors and Actuators A: Physical, Volume 239, 2016, Pages 144-152, ISSN 0924-4247, https://doi.org/10.1016/j.sna.2016.01.014 .

Chip Design Vehicles

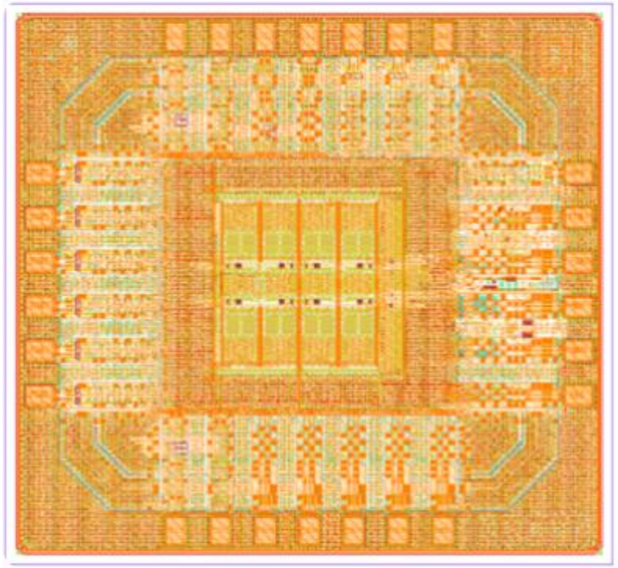
Recent Micro Chip Designs (2024-2025)



mmWave TI DAC 28Gs
22nm RFCMOS SOI

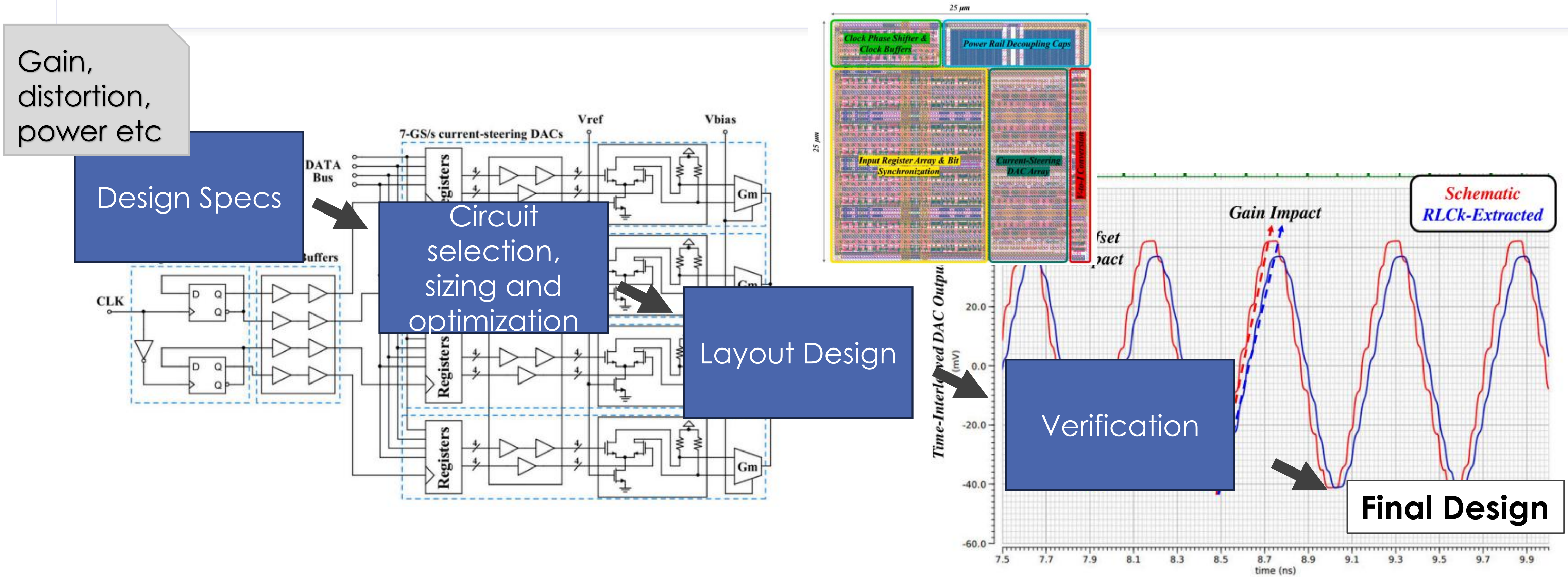


High Speed Readout IC
130nm SiGe BiCMOS



LF high precision ADC
180nm CMOS

AI on Custom IC Design and Design Flow



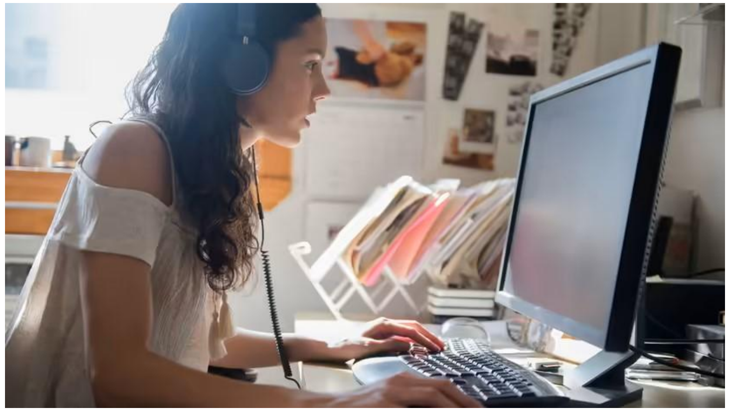
The flow repeated hierarchically for complex blocks - behavioral at higher levels (ie with Verilog A), moving towards transistor level at the bottom (BSIM, PSP level)

How will we design Analog chips in the Future?

https://blog.baruthotels.com/en/the-spectacular-life-story-of-the-famous-artist-salvador-dali

1) The Hand-crafted Artistic Way?

https://computer.howstuffworks.com/10-types-of-computers.htm

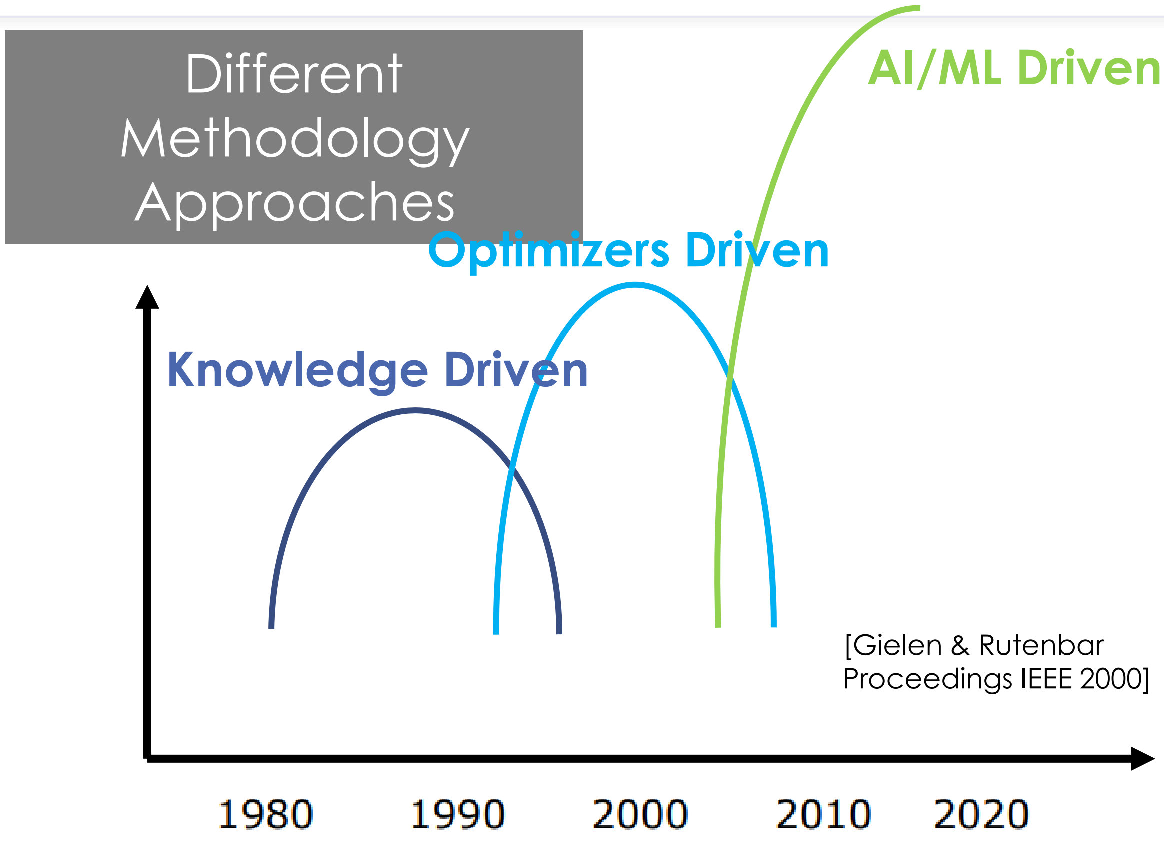


2) Tool Assisted "hand crafted" way?

https://www.fenews.co.uk/wp-content/uploads/2023/03/Canva-AI-digital-1-768x512.jpg

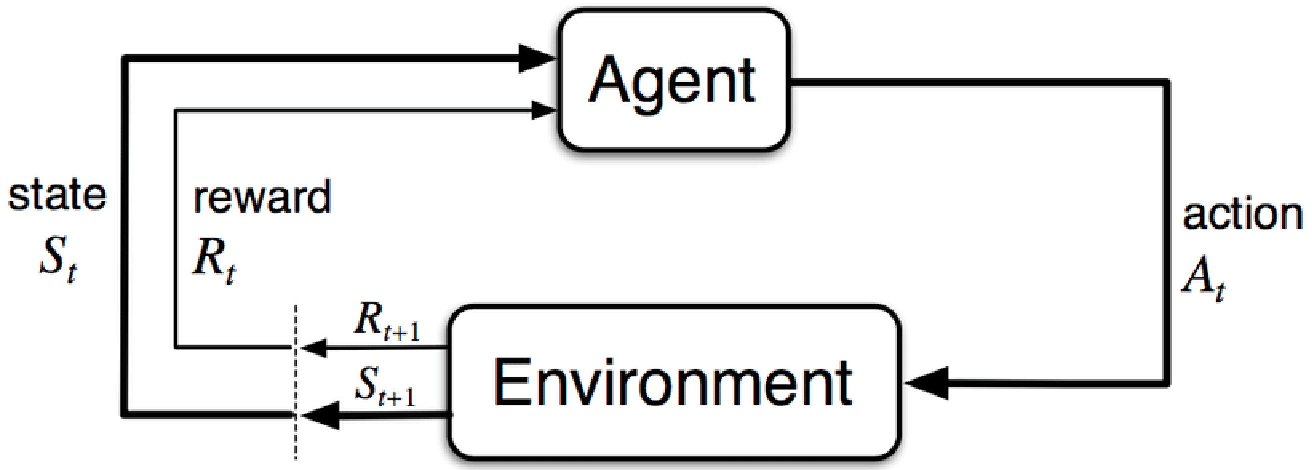
3) AI/ML inspired way?

Three Waves of Analog Synthesis

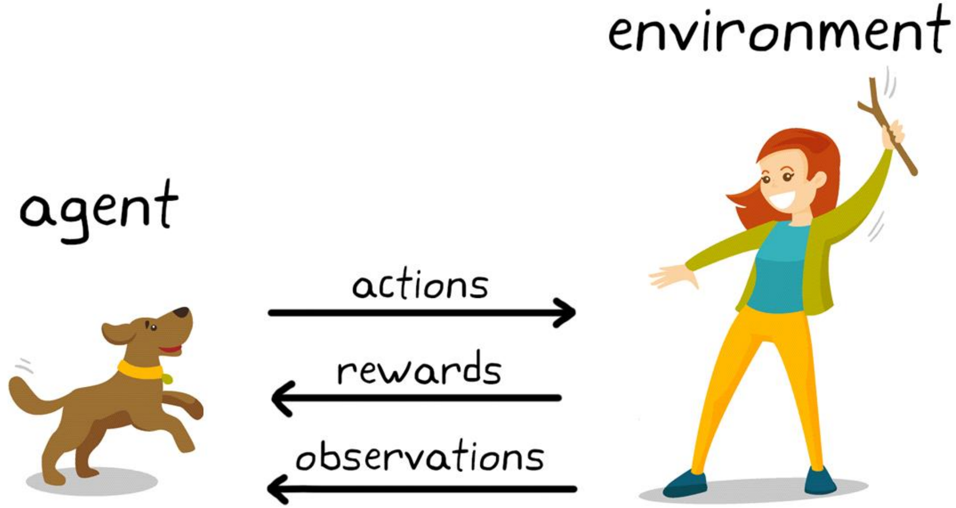


1. **Knowledge Driven**
   Heuristic way of designing circuits, hand calculations based – book driven
2. **Optimizers Driven**
   Gm/Id methodology, ADT toolbox, and many other EDA solutions
3. **AI/ML Based**
   Under development!

Reinforcement Learning

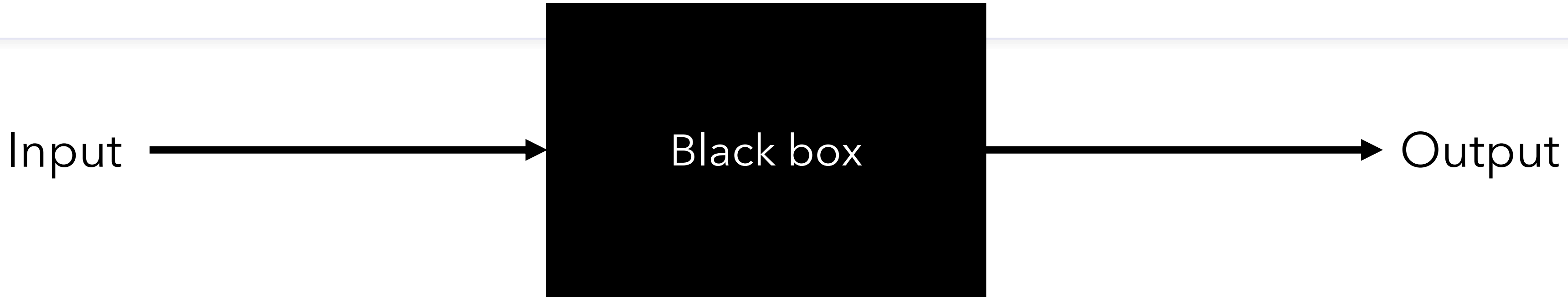


Sutton, R. S., & Barto, A. G. (2018). Reinforcement learning: An introduction (2nd ed.).



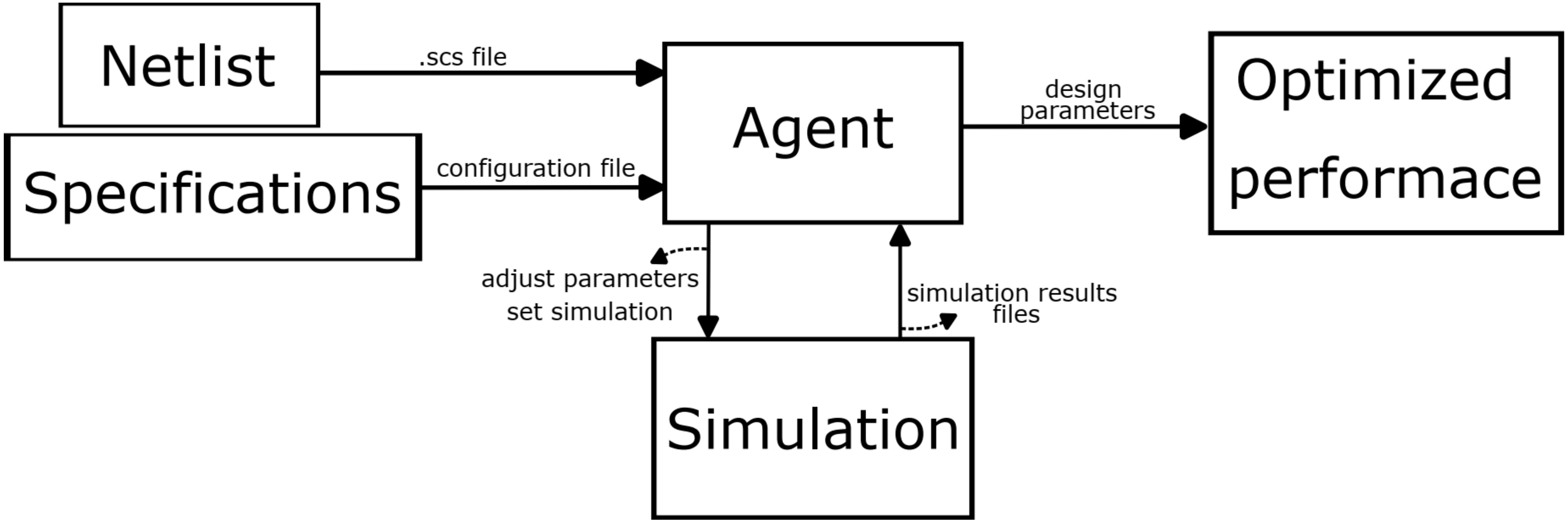
https://www.mathworks.com/discovery/reinforcement-learning.html

Proposed Solution: Black box approach

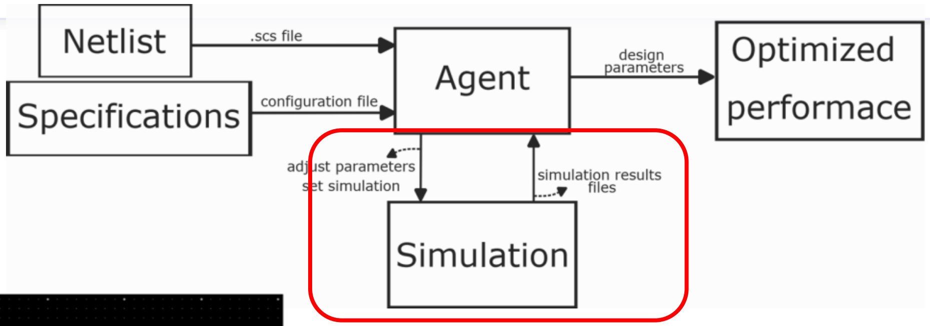


- Main focus on its inputs and outputs, without any knowledge of its internal workings or structure
- The end user interacts only with these
- Eliminating the human in the loop interference – leveraging automation

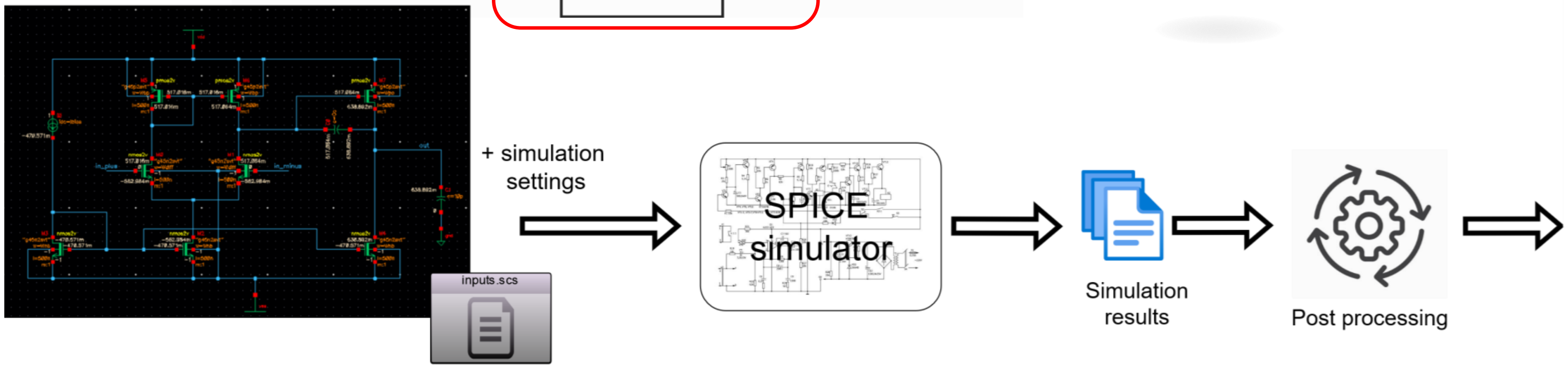
General flowchart

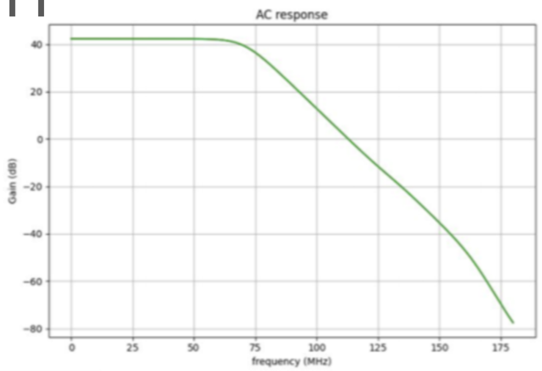


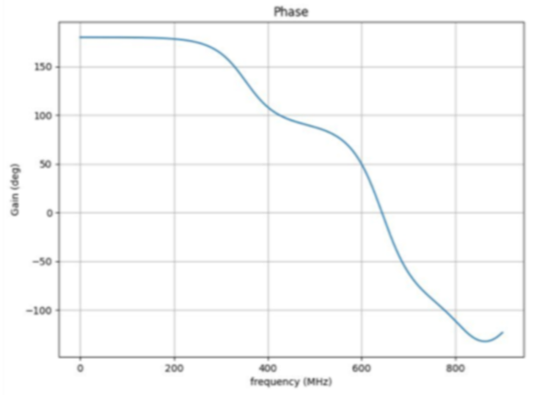
Simulation interface



python

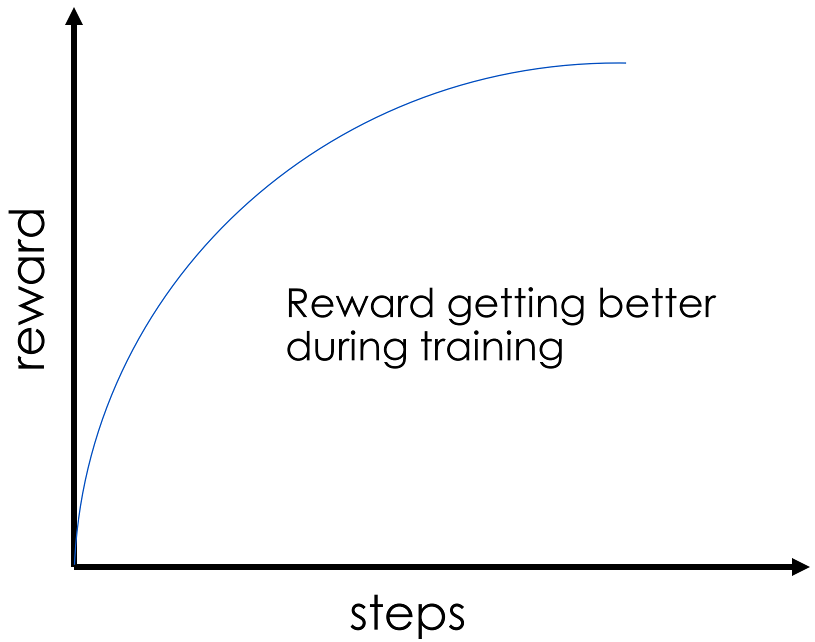


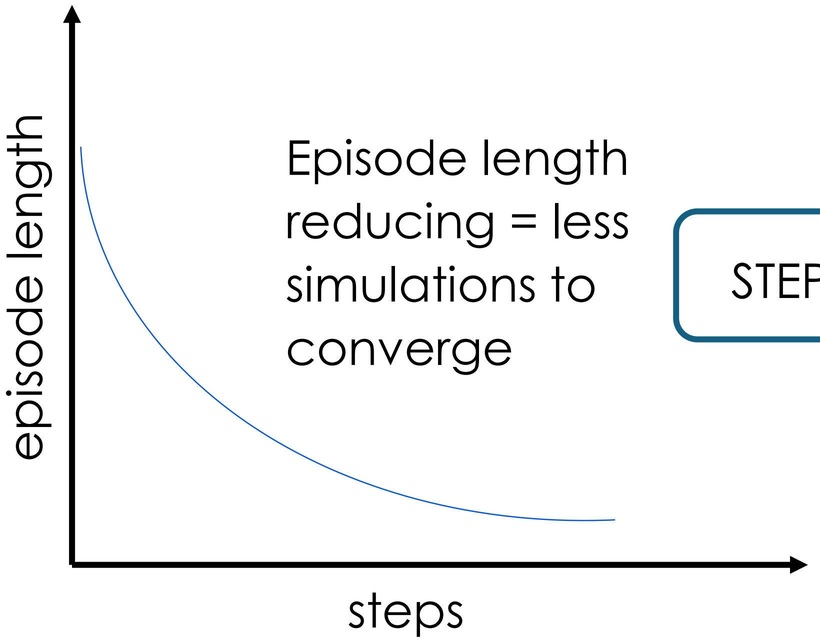




Training

Ideal results for training





STEPS = SIMULATIONS

RL assisted analog design flow

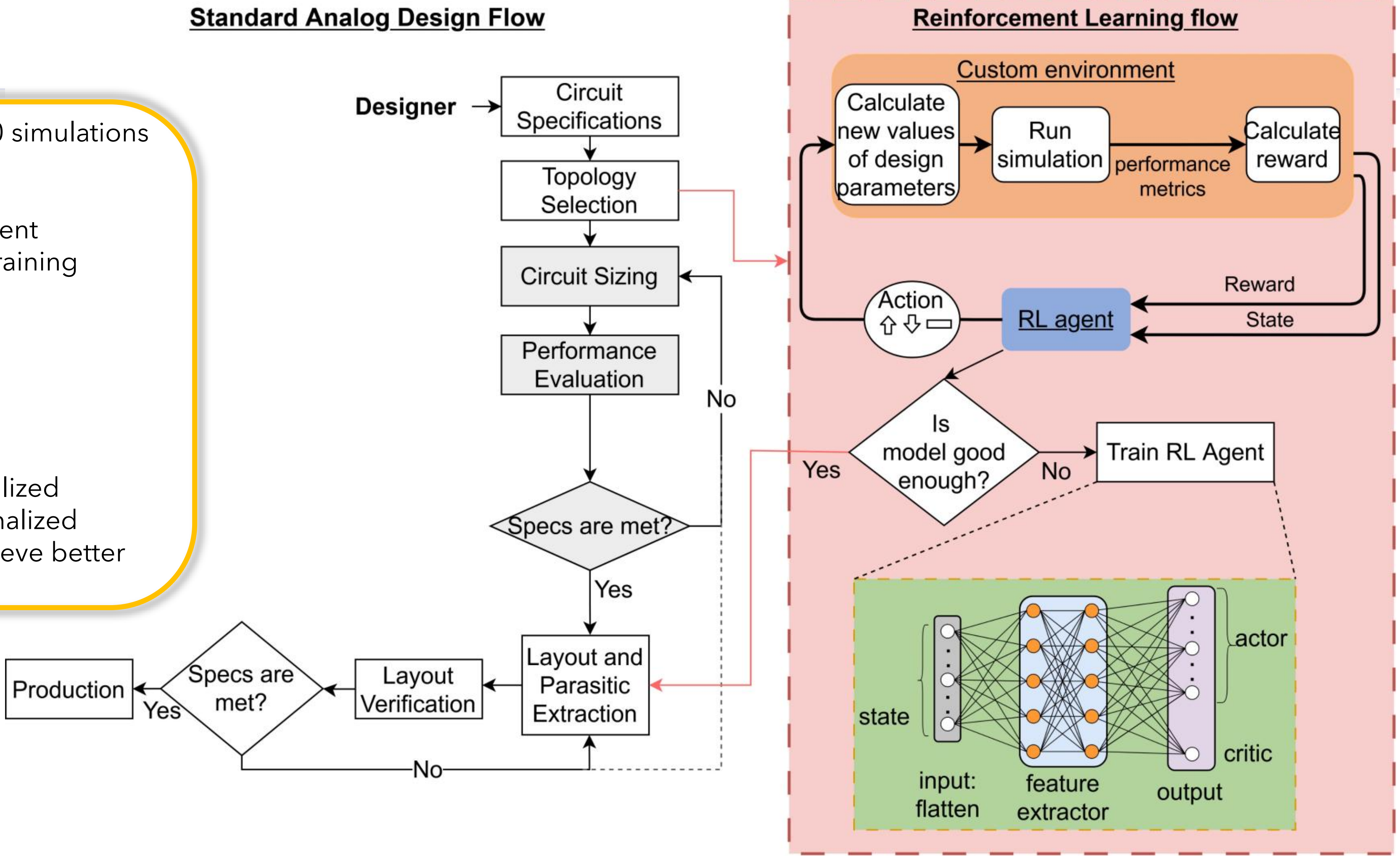
🎯 **Simulation Budget**: 50,000 simulations for training the RL agent

⚙️ **Environments**: 4 independent environments used for parallel training

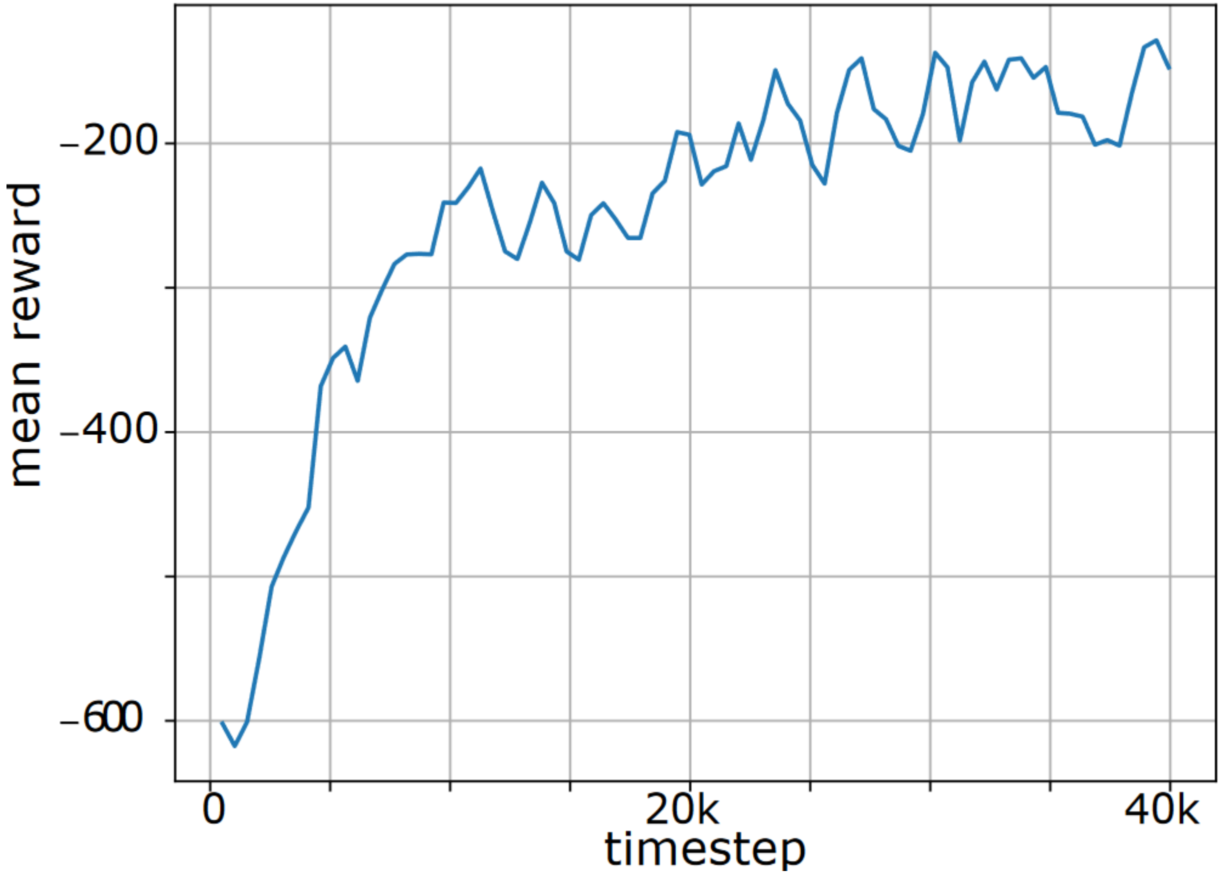
📦 **Batch Size**: 64

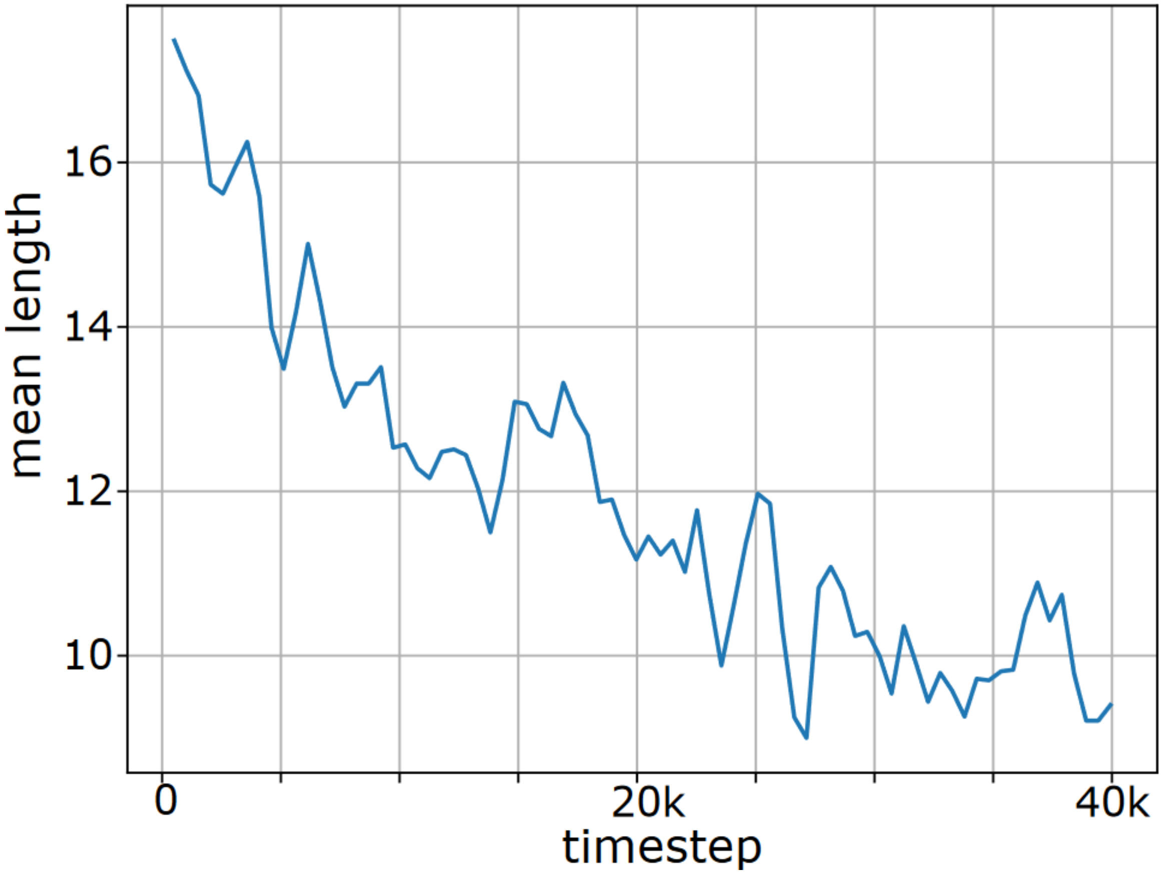
🔁 **Update Step Size**: 256

📊 **Normalization**:
Design parameters are normalized
Performance metrics are normalized
Helps the neural network achieve better results



Training (65nm)





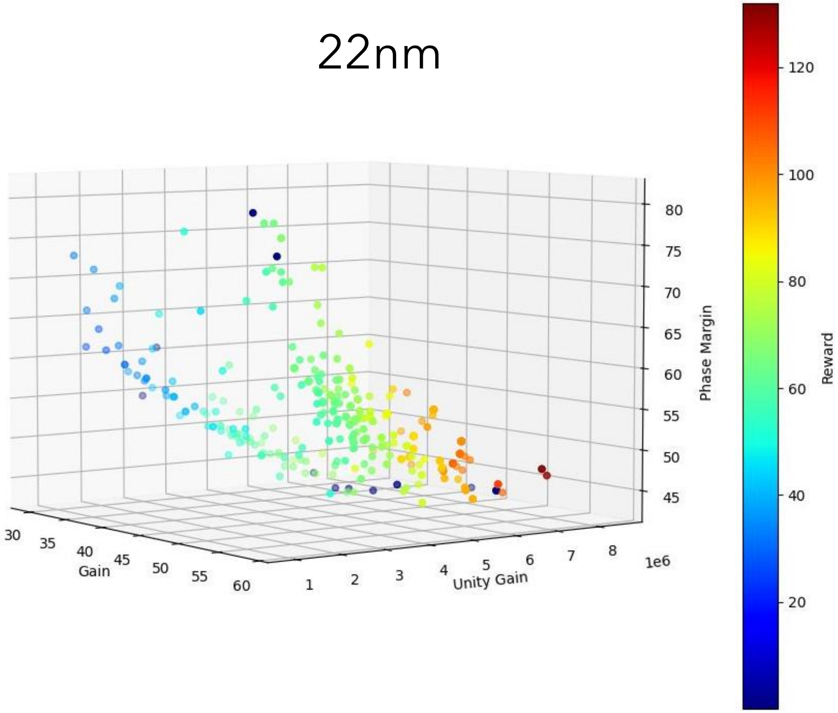
Training the same agent on multiple process nodes

- Utilized the same agent on multiple process nodes
- Why?
  - Verifying the functionality of the agent
  - Evaluating how general the model is
  - Transfer learning potential

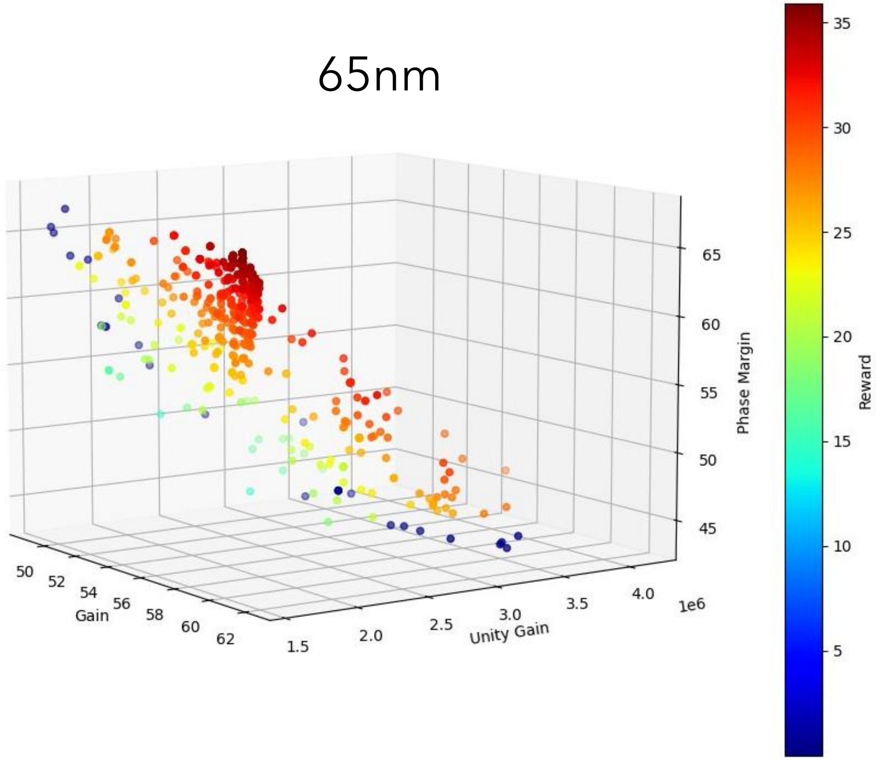
22nm -> 65nm -> 180nm

3D scatter plot for the three process nodes

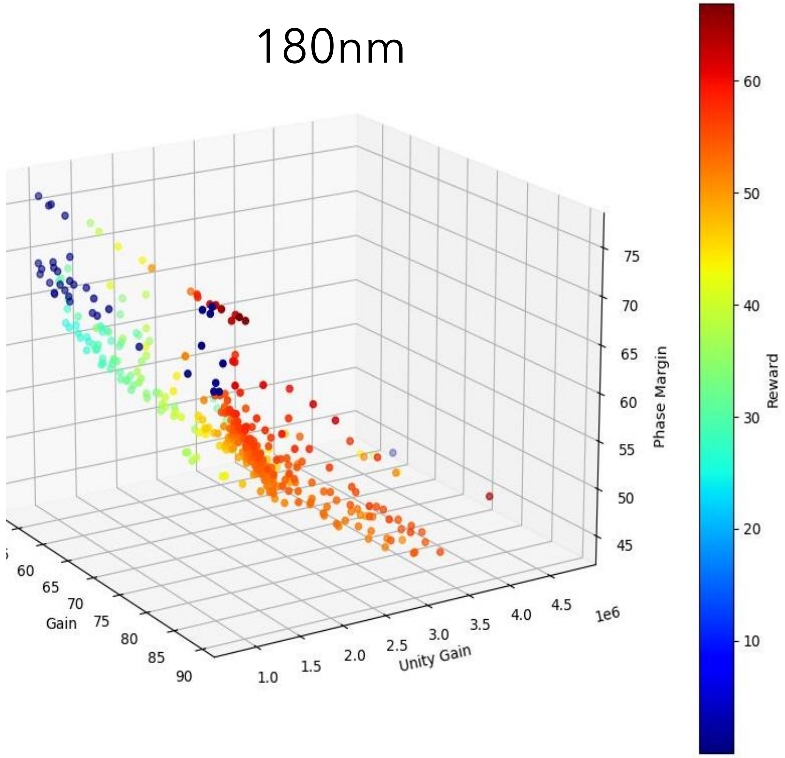
22nm



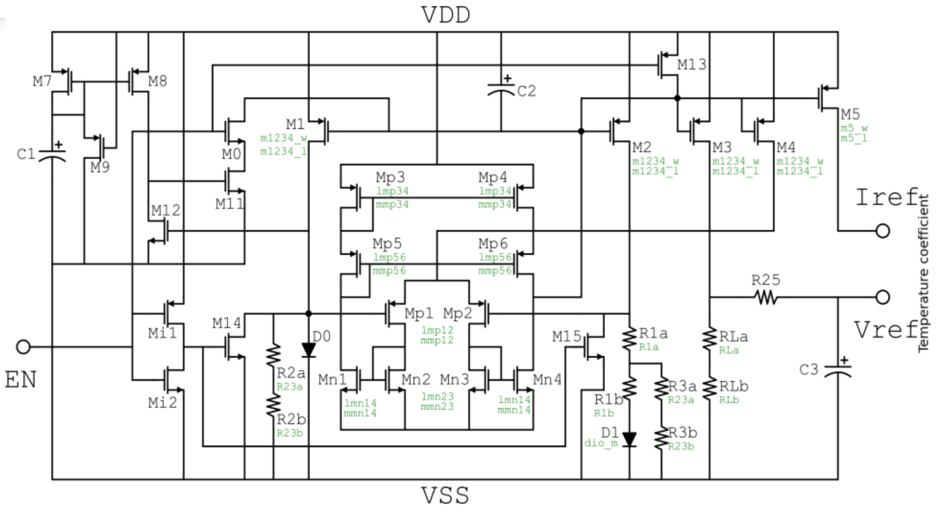
65nm

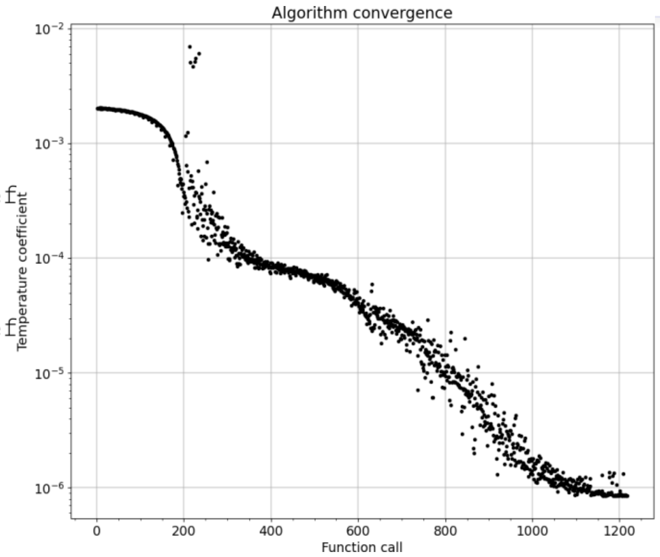


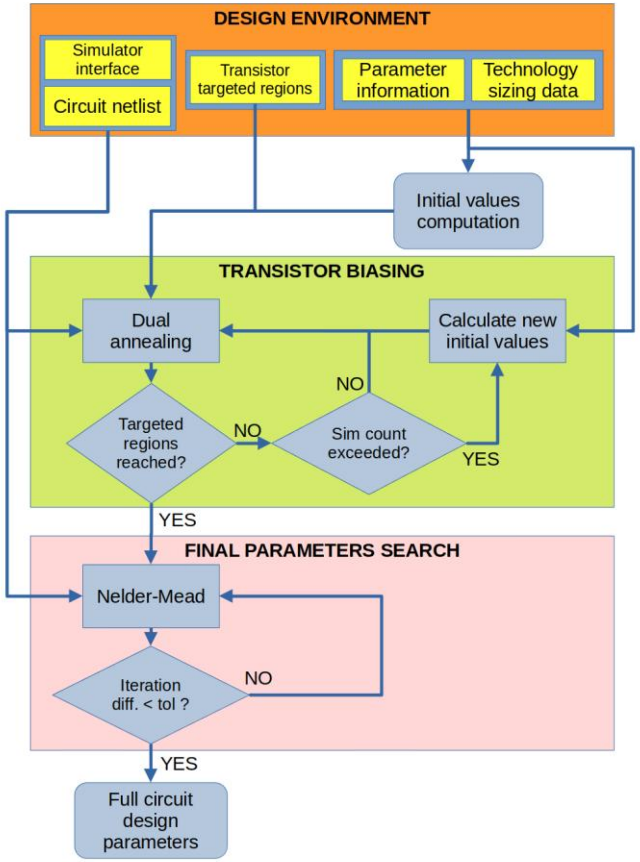
180nm



Bandgap AI Design using EA



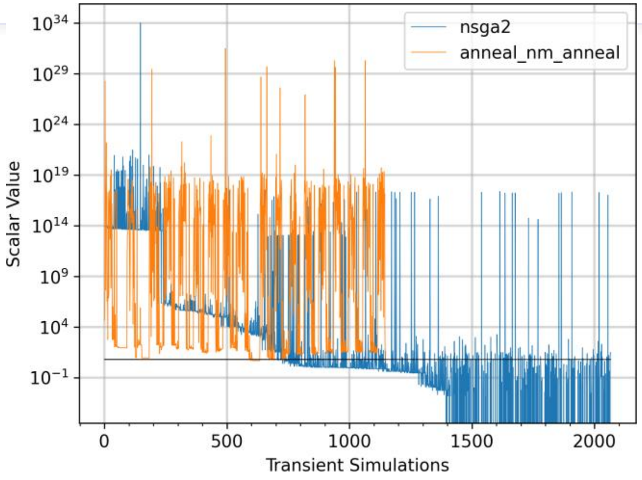


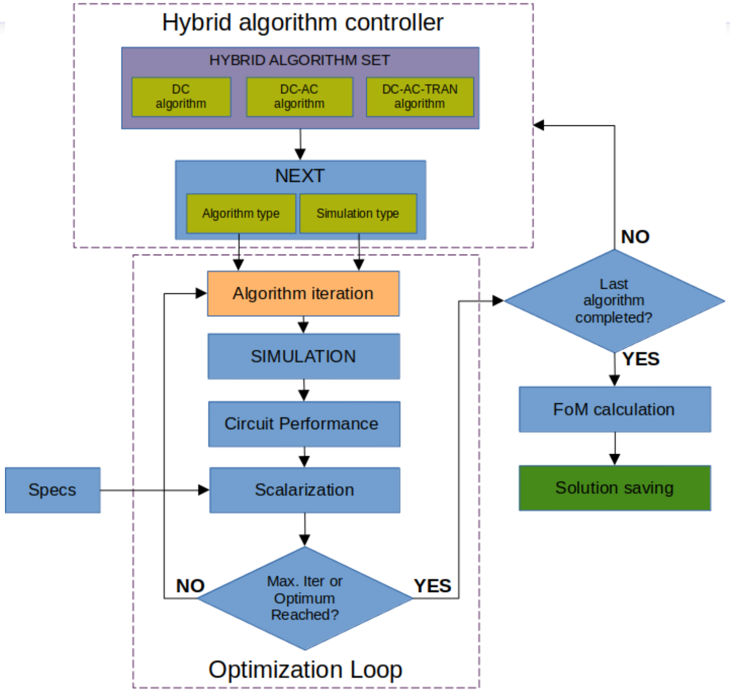


- 21 parameters
- 0.84 ppm final temperature coefficient (instead of 10)
- 12 μW power (instead of 20)
- 1260 simulations (~26 minutes)

LDO AI Design using EA

- 30 free parameters
- full complexity LDO design [1]
- 10 outputs
- 14 hybrid algorithm setups (including transient analysis!)
- 31% savings in transient analysis (~1150 sims on avg) compared to state-of-the art NSGA-II optimizer (~1660)
- State of the art specs (table below)





METRIC NAME	DESCRIPTION	[1]	Algorithm result	Improvement [%]
OTA_DC_GAIN	Gain of the Error amplifier	80	80.96	+1.19
PSRR	PSRR at zero frequency [dB]	-70	-78.01	+11.42
PHASE_MARGIN	Phase margin [deg]	45	77.74	+76
LNR	Line regulation [mV/V]	0.01992	0.01543	+22.85
LDR	Load regulation [μV/mA]	0.25	0.1437	+42.52
QUESC_CUR	Quiescent current [μA]	6.3	36.30	-476
LNR_LOW_RECTIME	LNR rec. time from low [μs]	22	1.635	+92.00
LDR_LOW_RECTIME	LDR rec. time from low [μs]	10	1.668	+83.33
LNR_HIGH_RECTIME	LNR rec. time from high [μs]	22	12.83	+41.68
LDR_HIGH_RECTIME	LDR rec. time from high [μs]	10	7.640	+23.00

[1] Nikolaos Zachos, Vasiliki Gogolou, and Thomas Noulis. A fully integrated 1.8 v low-power ldo regulator with dynamic transient control for soc applications. Electronics, 13(23), 2024.

DRL vs EA Summary

- Two AI methodologies DRL and Numeric Algorithm based - both enabling designers to rapidly implement schematic designs of commonly used design blocks.
- DRL methodology uses a “**brute force” simulation design space scanning** (110k sims. in 22nm for 6 params) providing results/data for the full design space and for any OpAmp spec. **The training and data generation is done only once.**
- Numeric Algorithm method runs **way less simulations (1k for 21params)** and converge to a specific solution – resources wise is way more efficient but it **has to re-run again if specification is updated.**

Conclusions

Semiconductors continue to be at the heart of technological progress.

Their influence spans multiple industries, from communications and automotive to AI.

The future holds even more innovation with emerging semiconductor technologies.

Thank You!

Questions and discussions!

tnoul@physics.auth.gr, tnoulis@auth.gr