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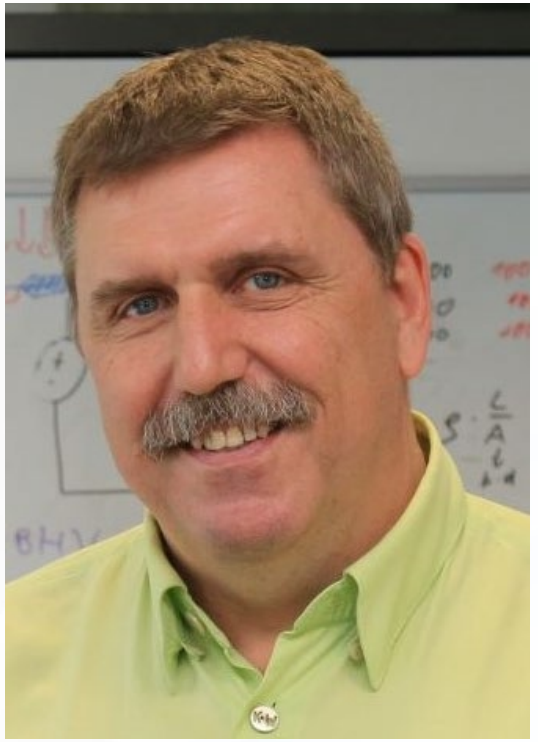
Optimized is not Always Optimal

The Dilemma of Analog Design Automation



Juergen Scheible

Optimized is not Always Optimal
The Dilemma of Analog Design Automation

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- Why is analog design largely done manually?
  - Is it an attitude of the analog designers?
  - Are there technical reasons?
- How can we automate analog design?

Analog designer

Digital designer

- The problem: the analog design gap
- Design automation is mainly based on optimization
- Investigation of
  - basic principles of optimization methods
  - crucial differences between analog and digital design

  → "optimization horizon" → dilemma of optimizing → optimization is not well suited for analog design
- Some thoughts about automation approaches for analog design

System on Chip (SOC)

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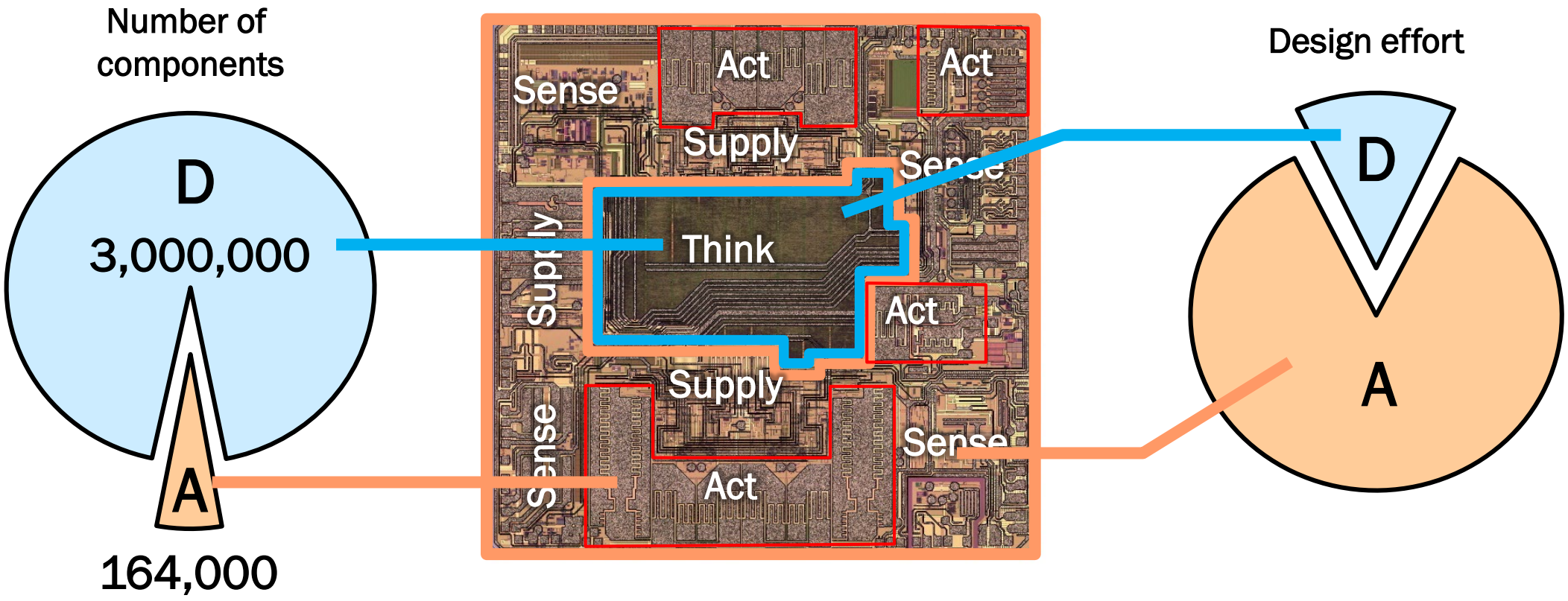

Analog design productivity lags behind digital design productivity by orders of magnitude!

Analog vs Digital: Design Gaps

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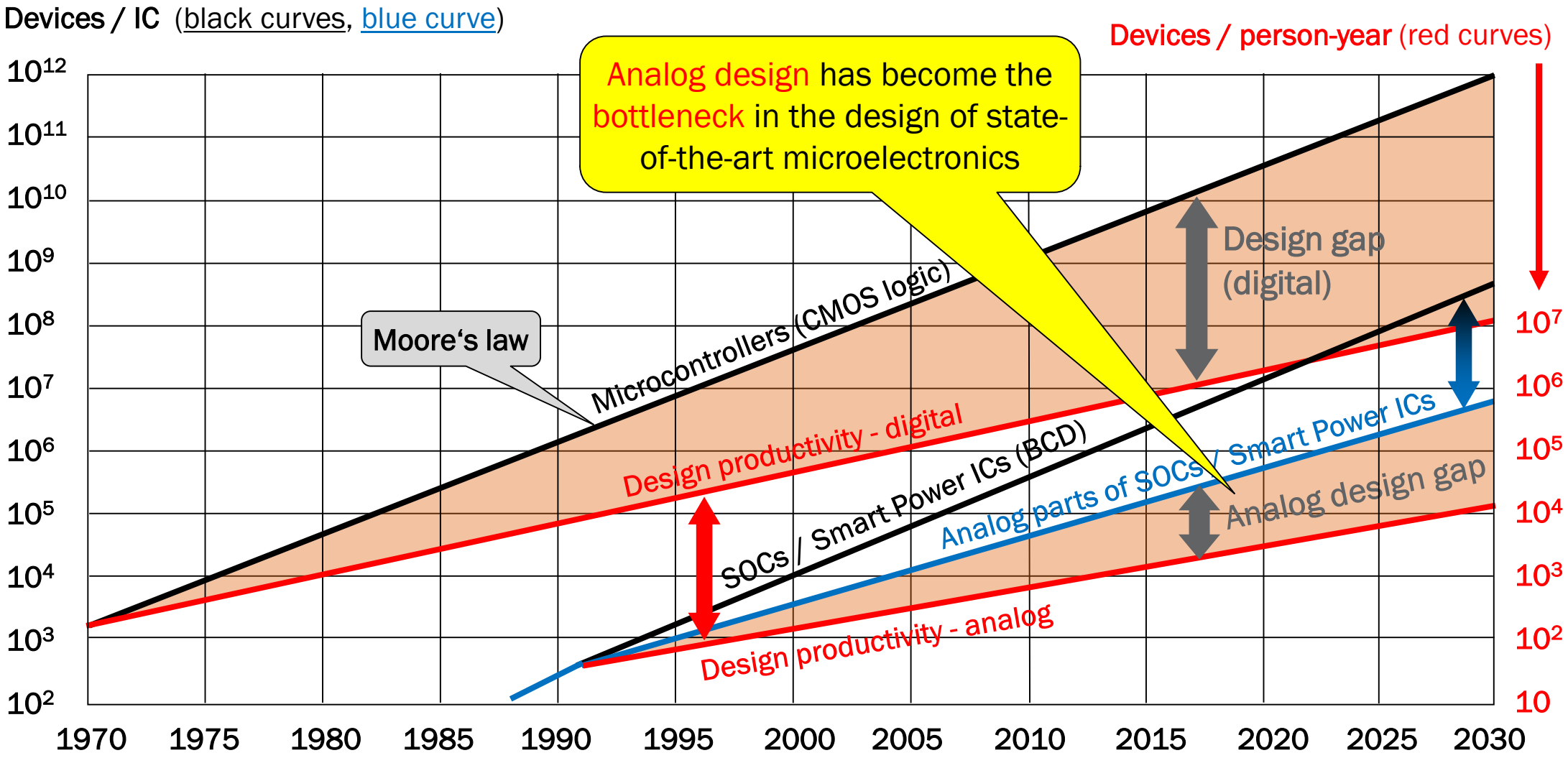
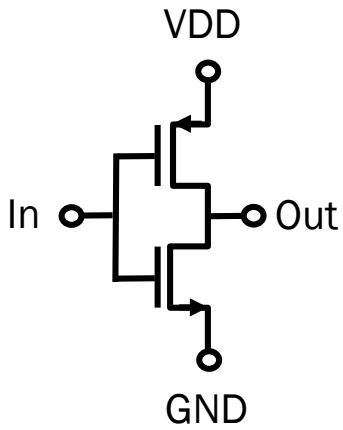
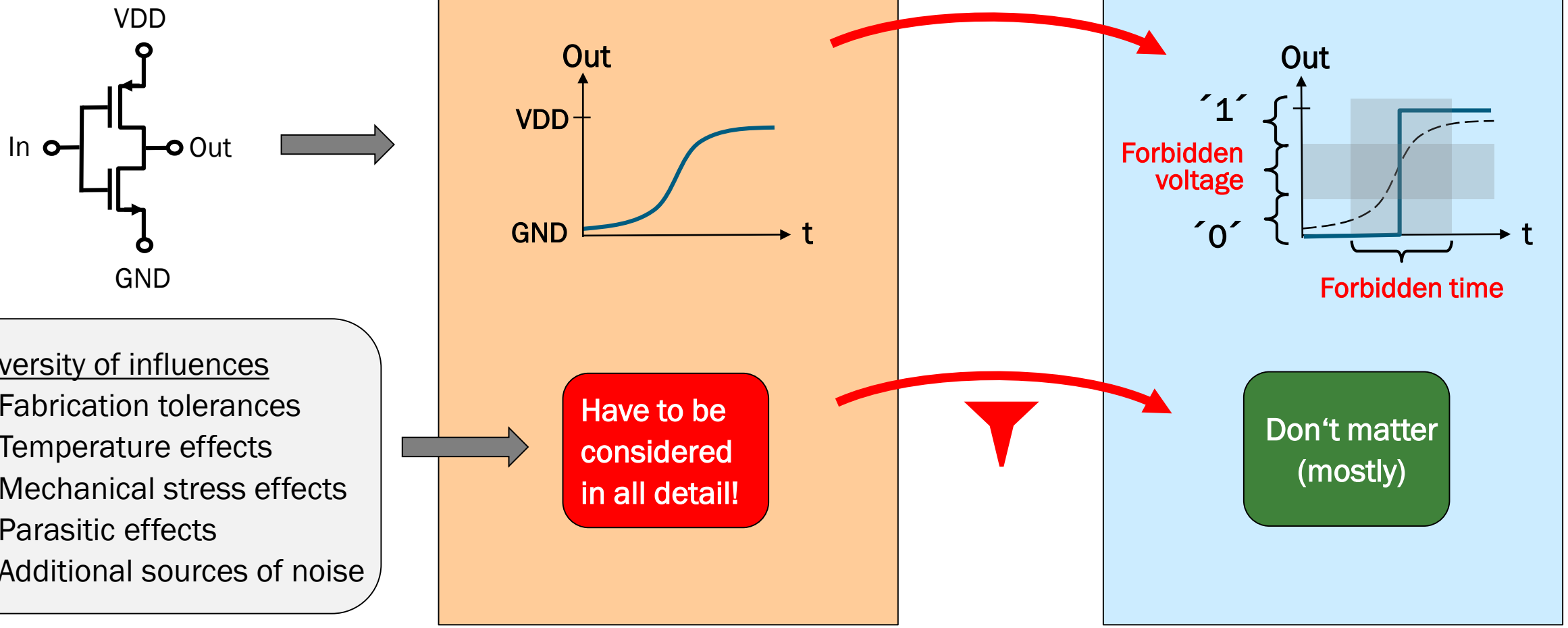


Analog vs Digital: Structural View



Analog		Digital
• Transistors	Same elements	• Transistors
• made of silicon	Same material	• made of silicon
• connected to circuits	Same principle	• connected to circuits
• Many elements (10^4 – 10^5)	Difference	• Many more elements (10^6 – 10^7)

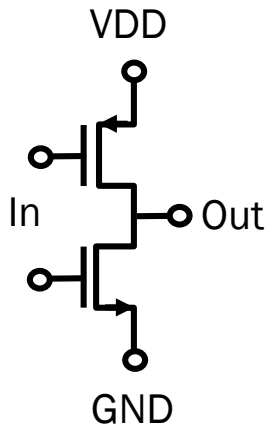
Analog vs Digital: Functional View



Diversity of influences

- Fabrication tolerances
- Temperature effects
- Mechanical stress effects
- Parasitic effects
- Additional sources of noise

Analog vs Digital: Functional View



Diversity of influences
- Fabrication tolerances
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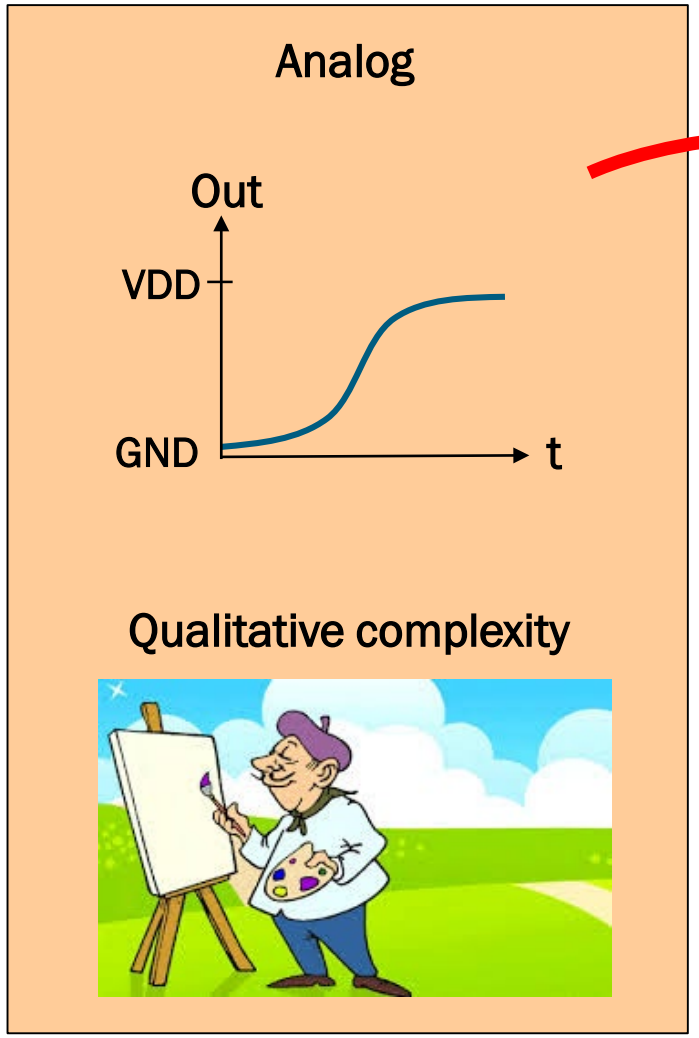
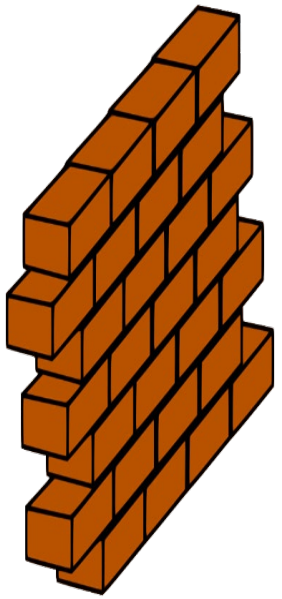
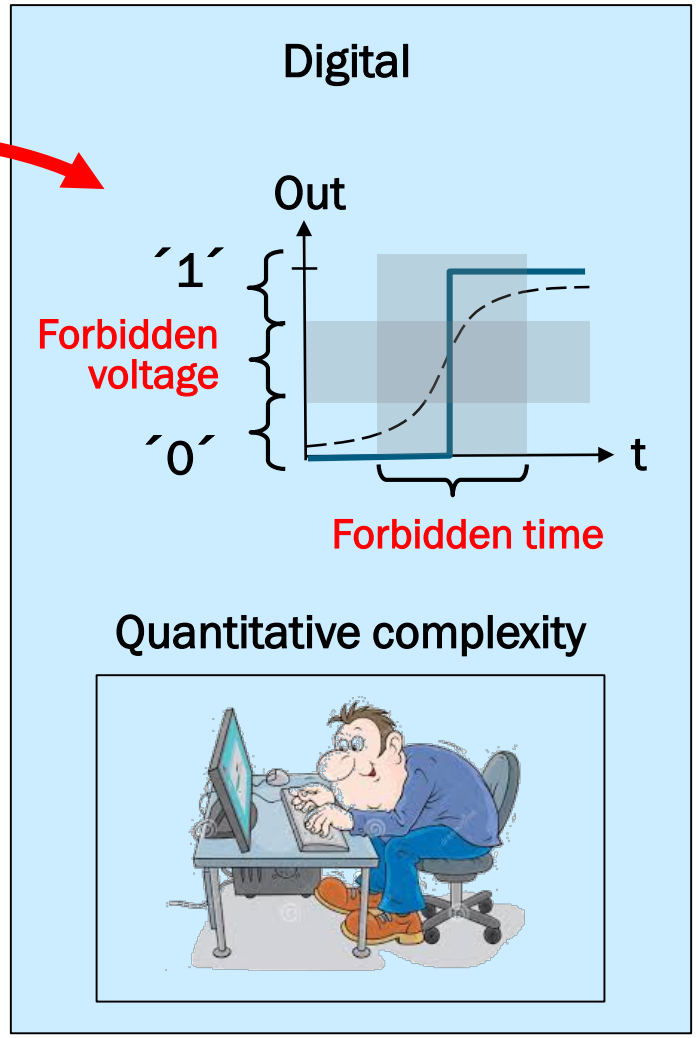
- Additional sources of noise



Abstraction





Design Flow

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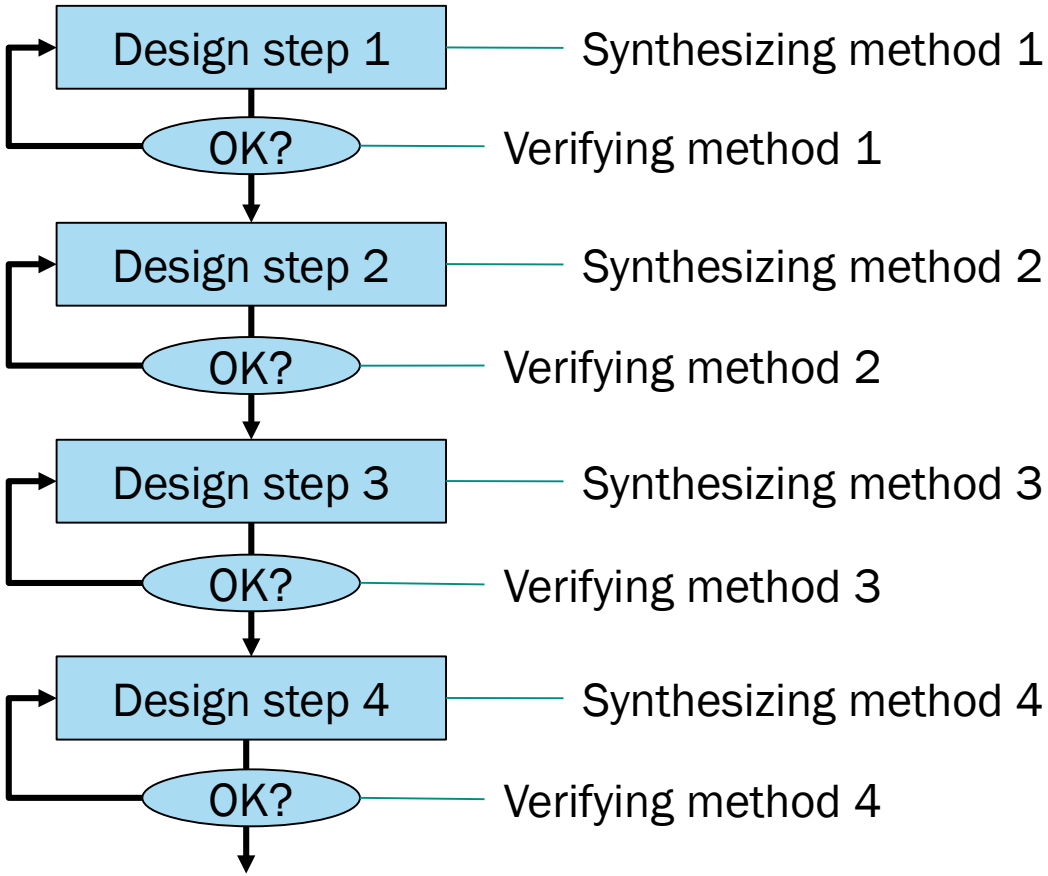
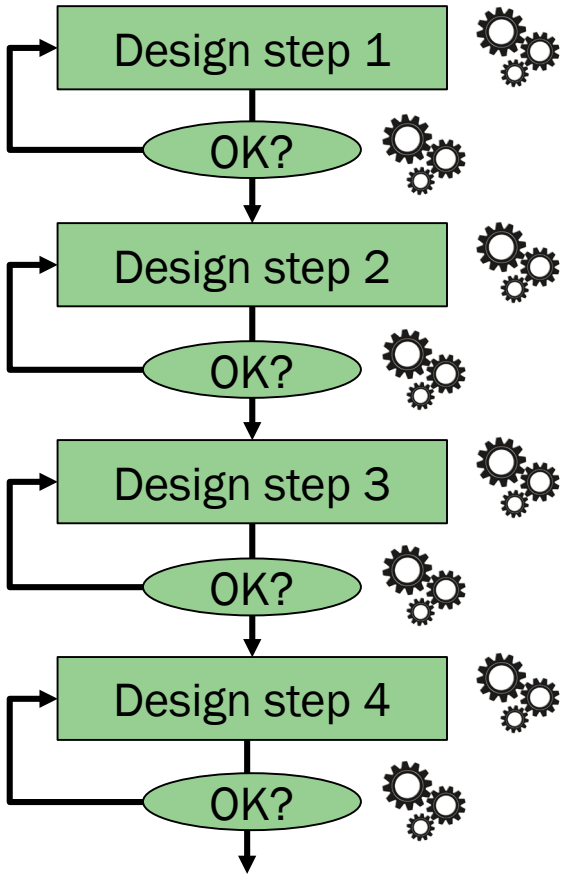
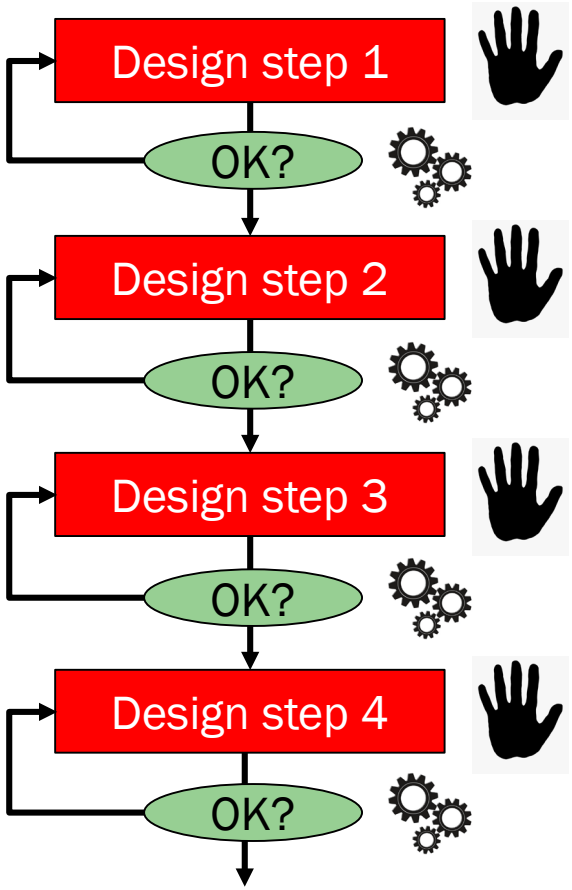


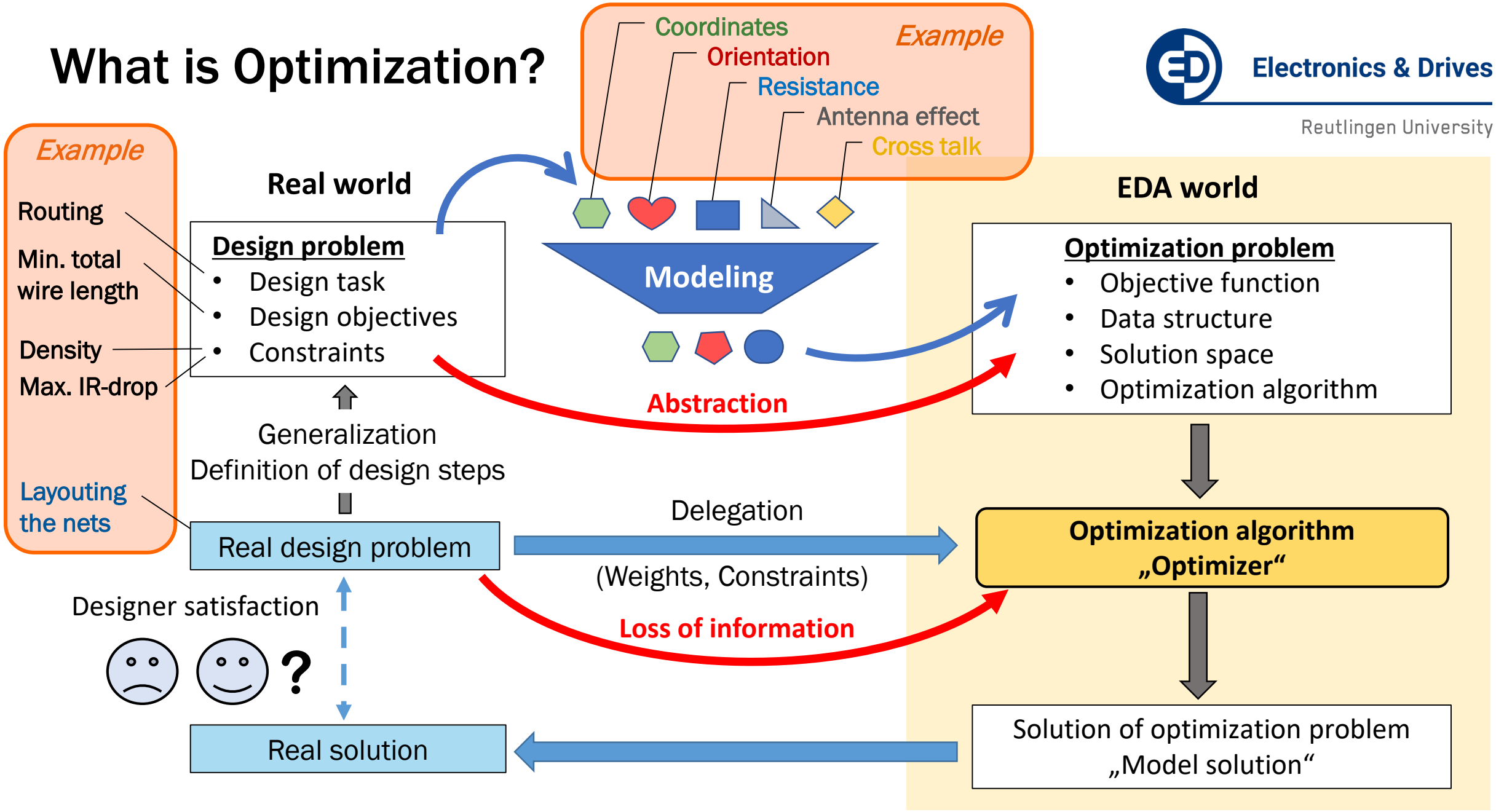
Digital design



Analog design

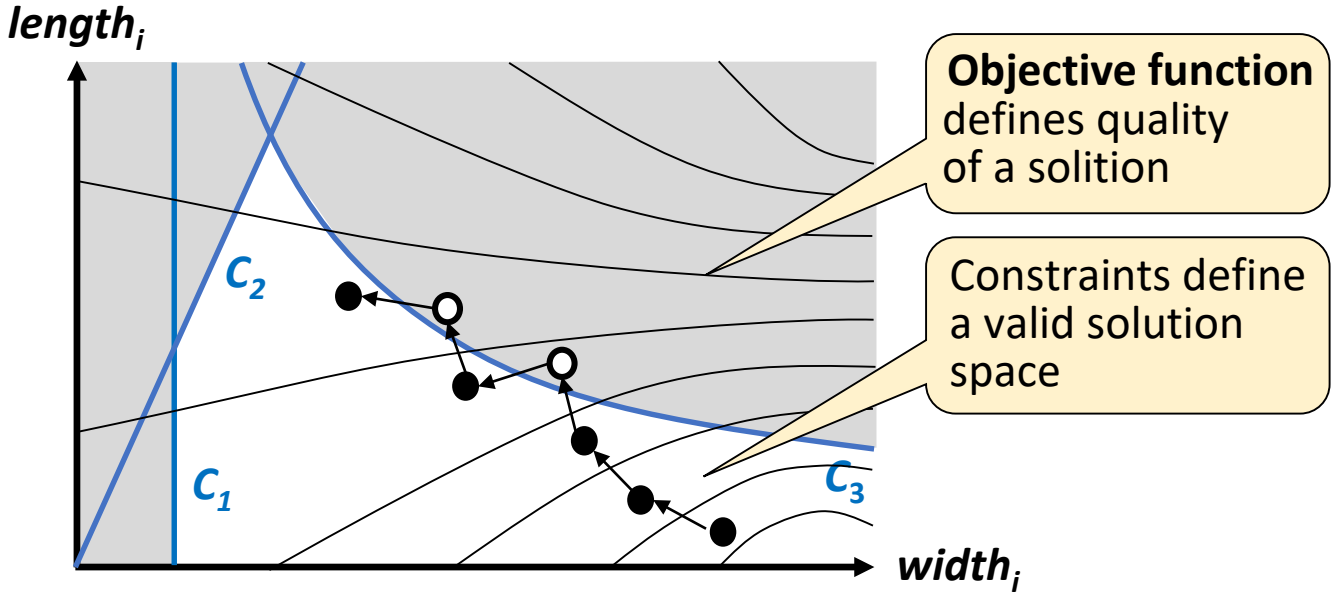


What is Optimization?

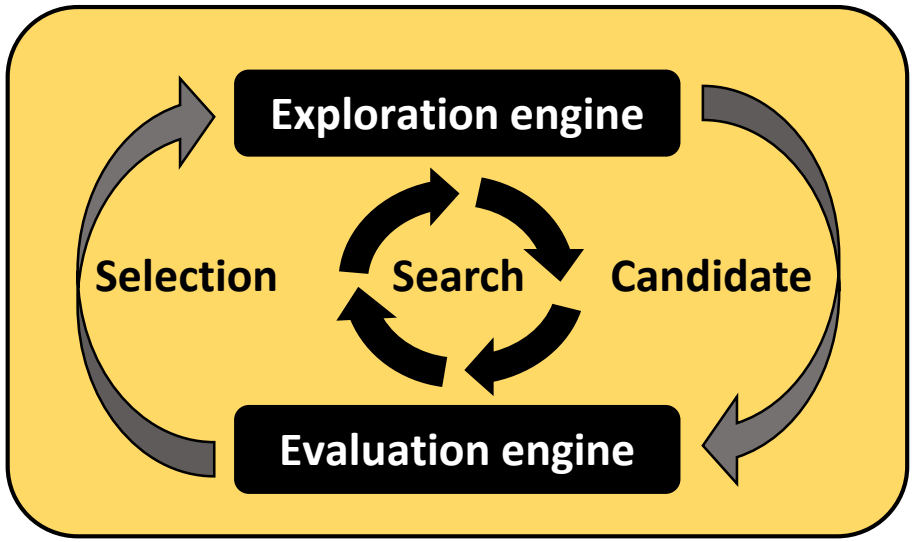


What is Optimization?

Solution space



Optimization algorithm



C_1 : Min. wire width → $width_i \leq w_{min}$

C_2 : Min. IR-drop → $length_i / width_i \leq a$

C_3 : Min. parasitic substrate C → $length_i \cdot width_i \leq b$

Important Properties of an Optimizer

Model complexity *M*

Measure of how many aspects of the reality are modeled.

(The higher *M*, the closer the model is to reality. Low *M* means a „simple“ model.)

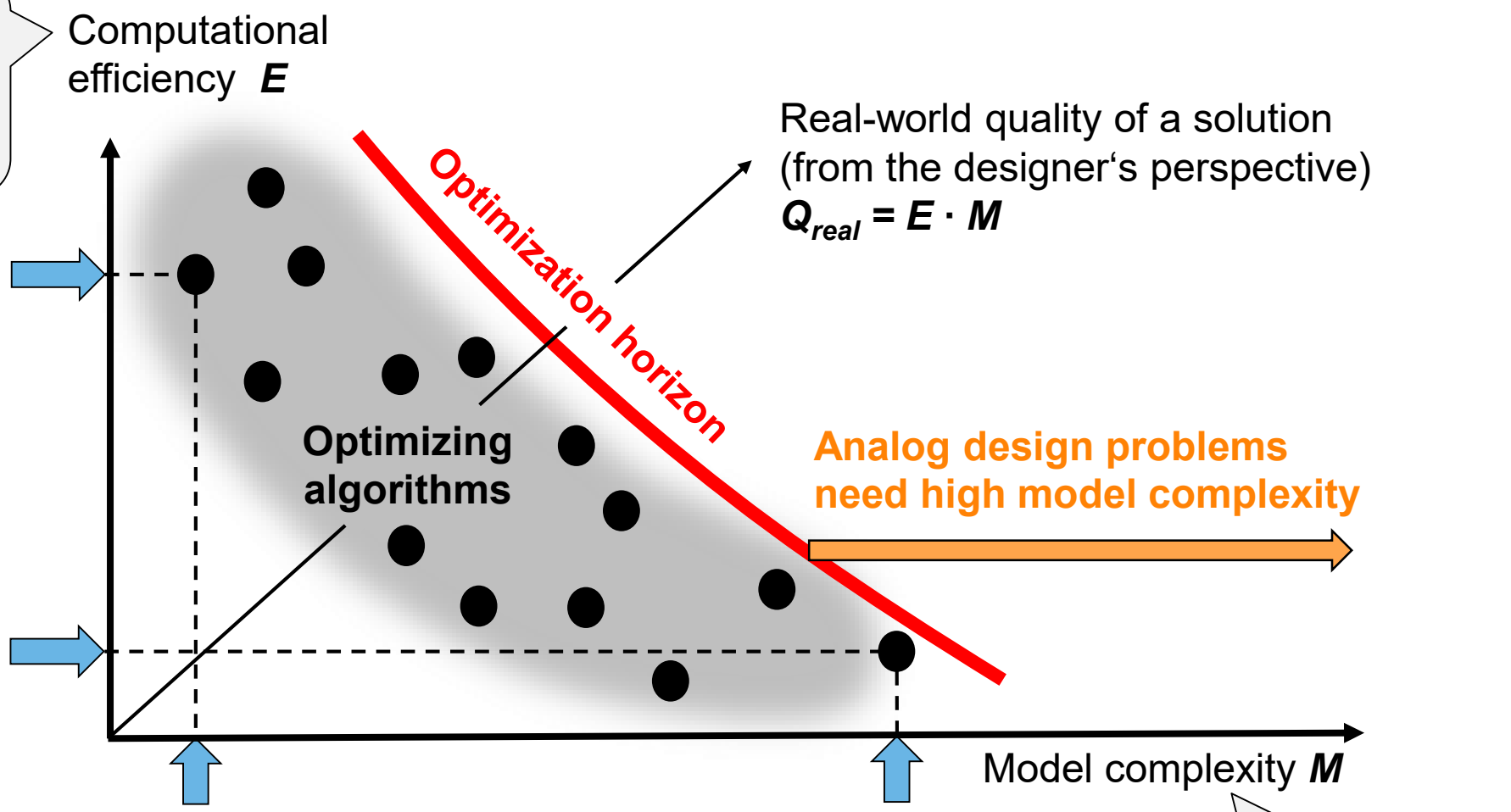
Computational efficiency *E*

How fast does the optimizer approach a „good“ solution in the solution space?

- Constraint checking: How much computational effort is needed to decide whether a point in the solution space is „valid“?
- How much computational effort does the evaluation engine need to evaluate the goodness of a solution option?
  (Analog design problems require simulation in the loop!)
- How many trials does the exploration engine need to approach a „good“ solution?
  (Search strategy, complexity and texture of solution space)

Optimization Horizon → Dilemma of Optimizing

Depends on:
- Compute effort for checking „validity“
- Compute effort for objective function
- Complexity of solution space
- Search strategy of exporation engine



Optimization Horizon → Dilemma of Optimizing

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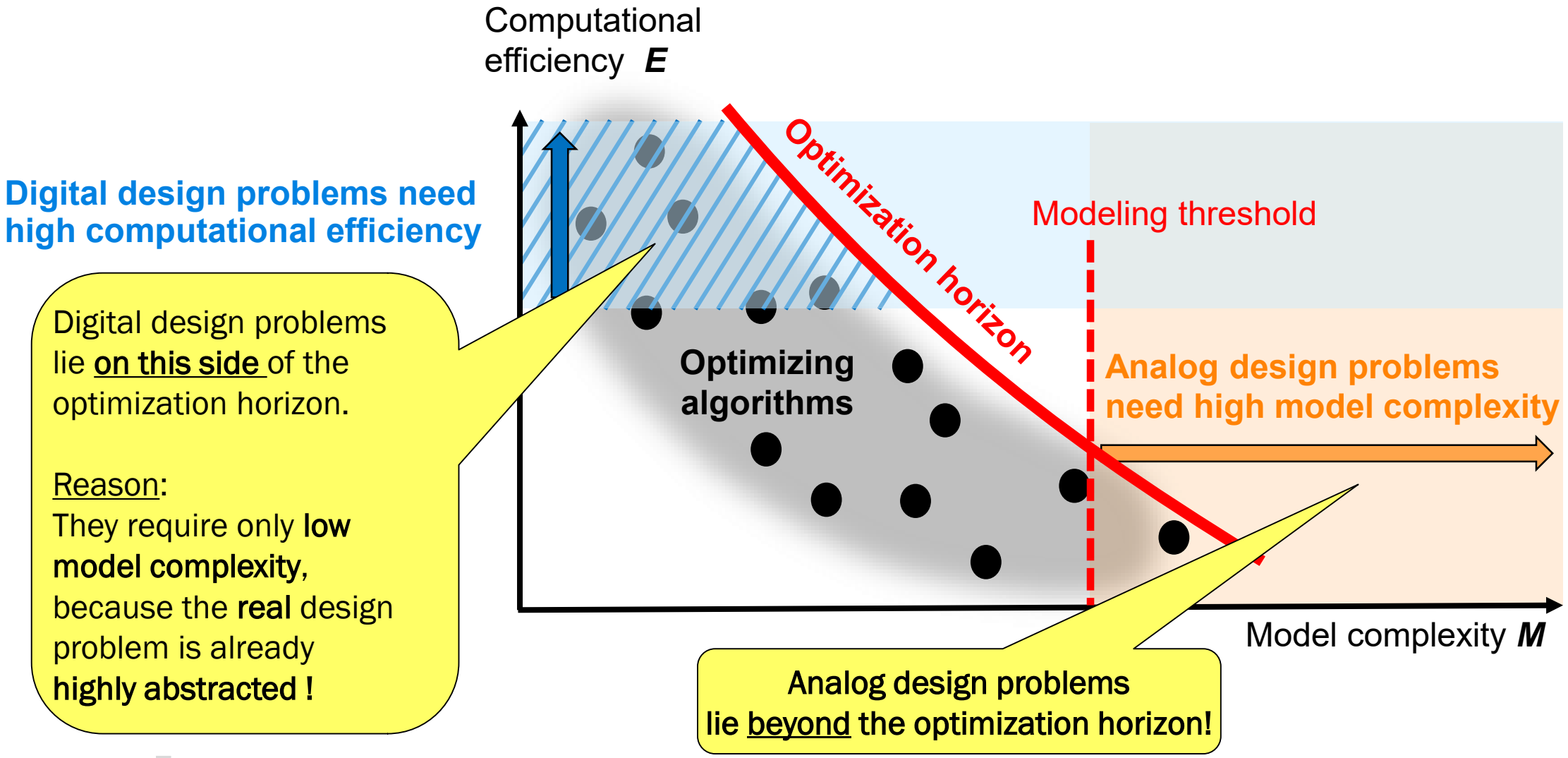
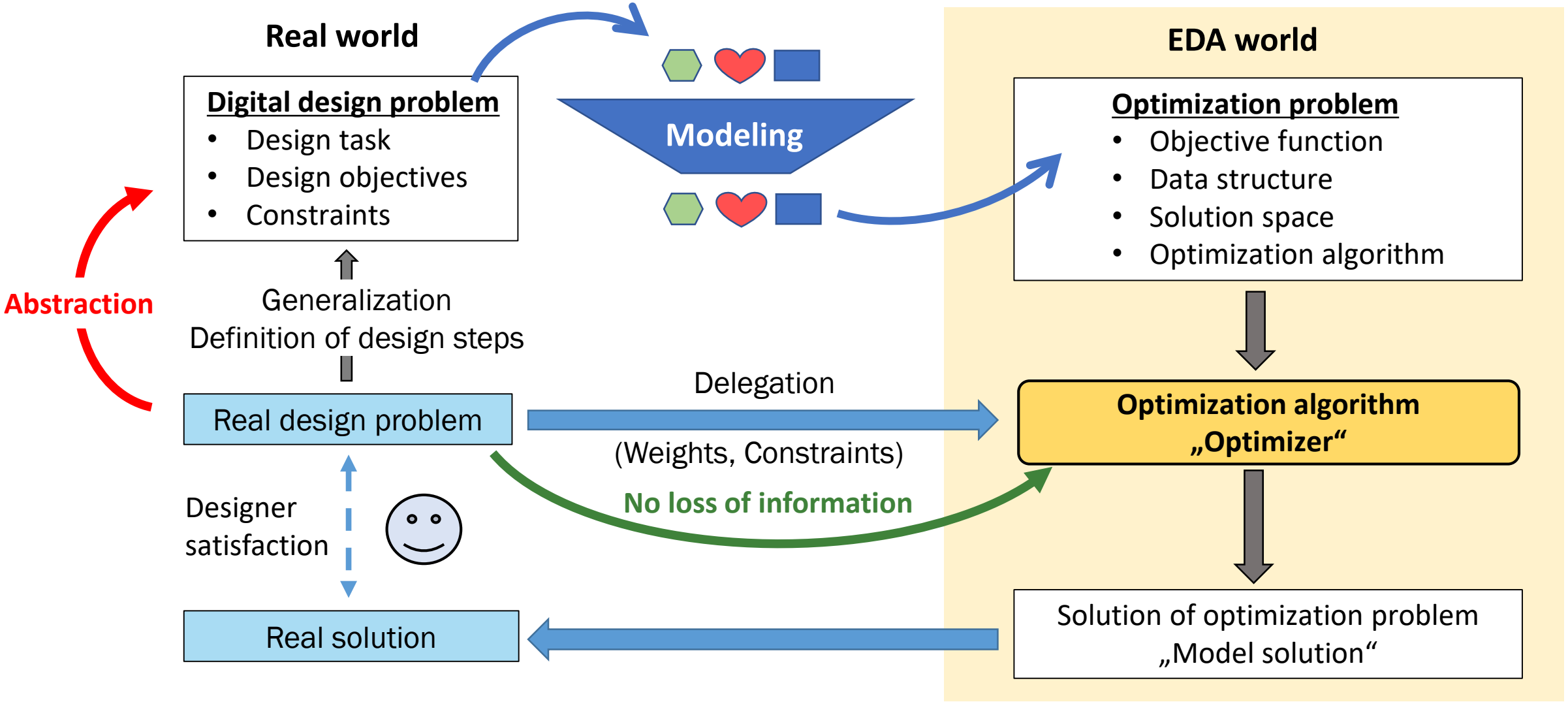


Optimization in digital design



An alternative approach: Generators

- A generator is basically a script that captures the design strategy for a specific design task.
- When executed it replicates the work of a designer in a straight-forward manner.
- Generators are parametrized to cover a certain range of applications.

	Optimizer	Generator (Procedure)
Design flow	top-down	bottom-up
Handling of goals, constraints, problem aspects …	explicitly	implicitly
Solution / result	found by algorithm, repeatedly „re-invented“	conceived by human expert, re-use of experience-based design strategy
„Real-world“ quality of solution	intrinsic quality loss (due to optimization horizon)	full-custom (handmade)
Industrial acceptance for analog design	low	high

Today‘s design flows in the Y-model

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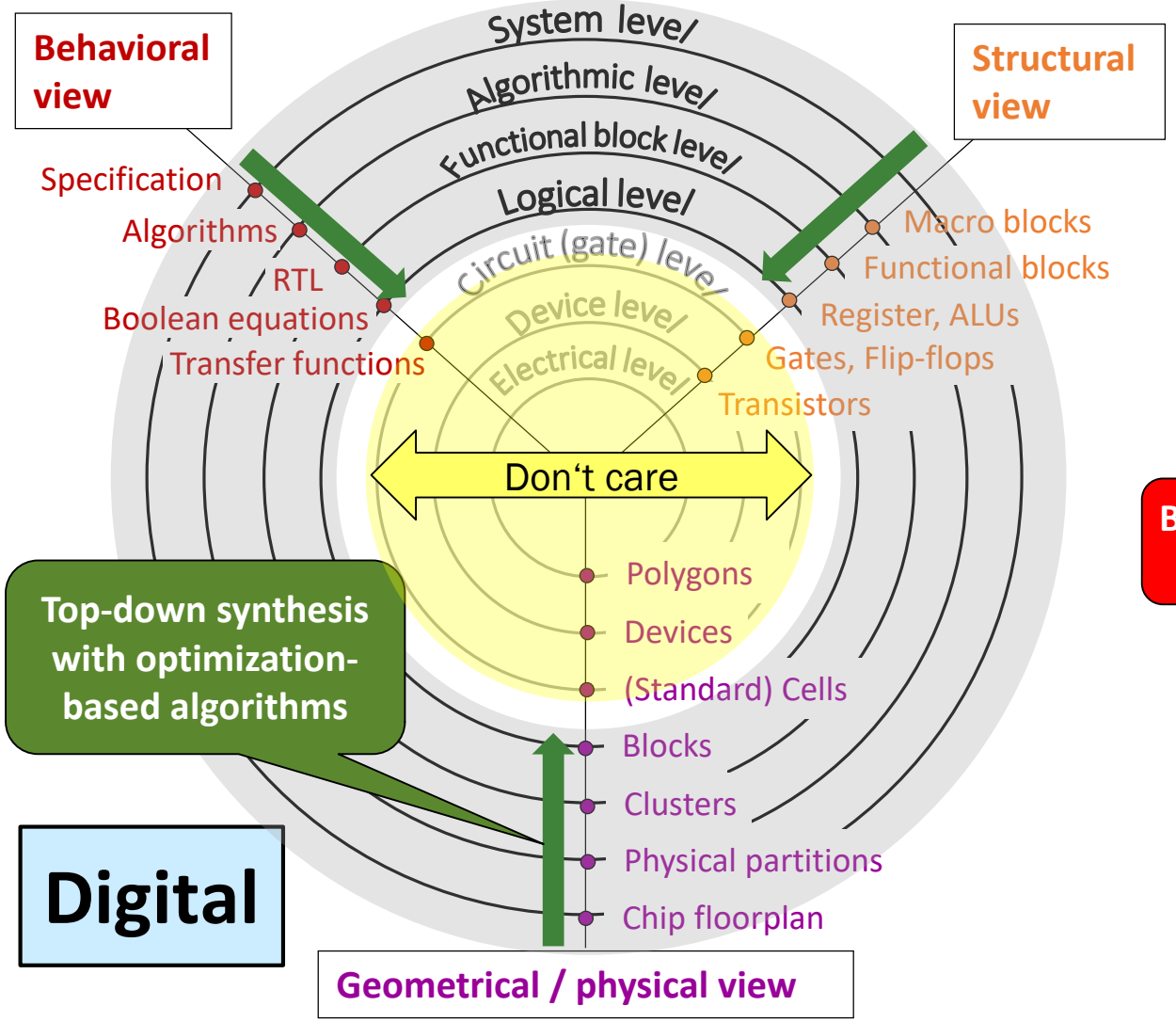

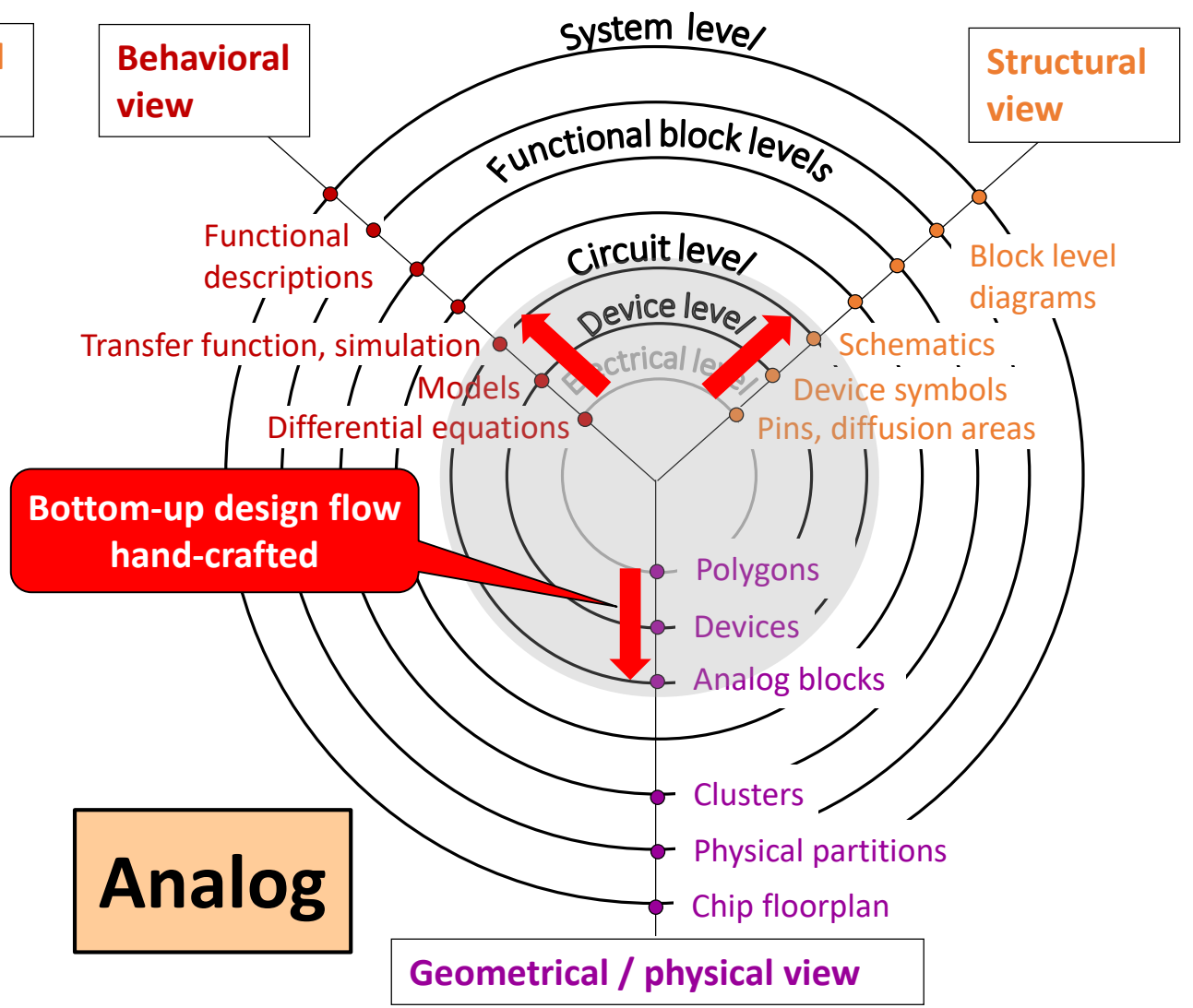

Future design flows in the Y-model

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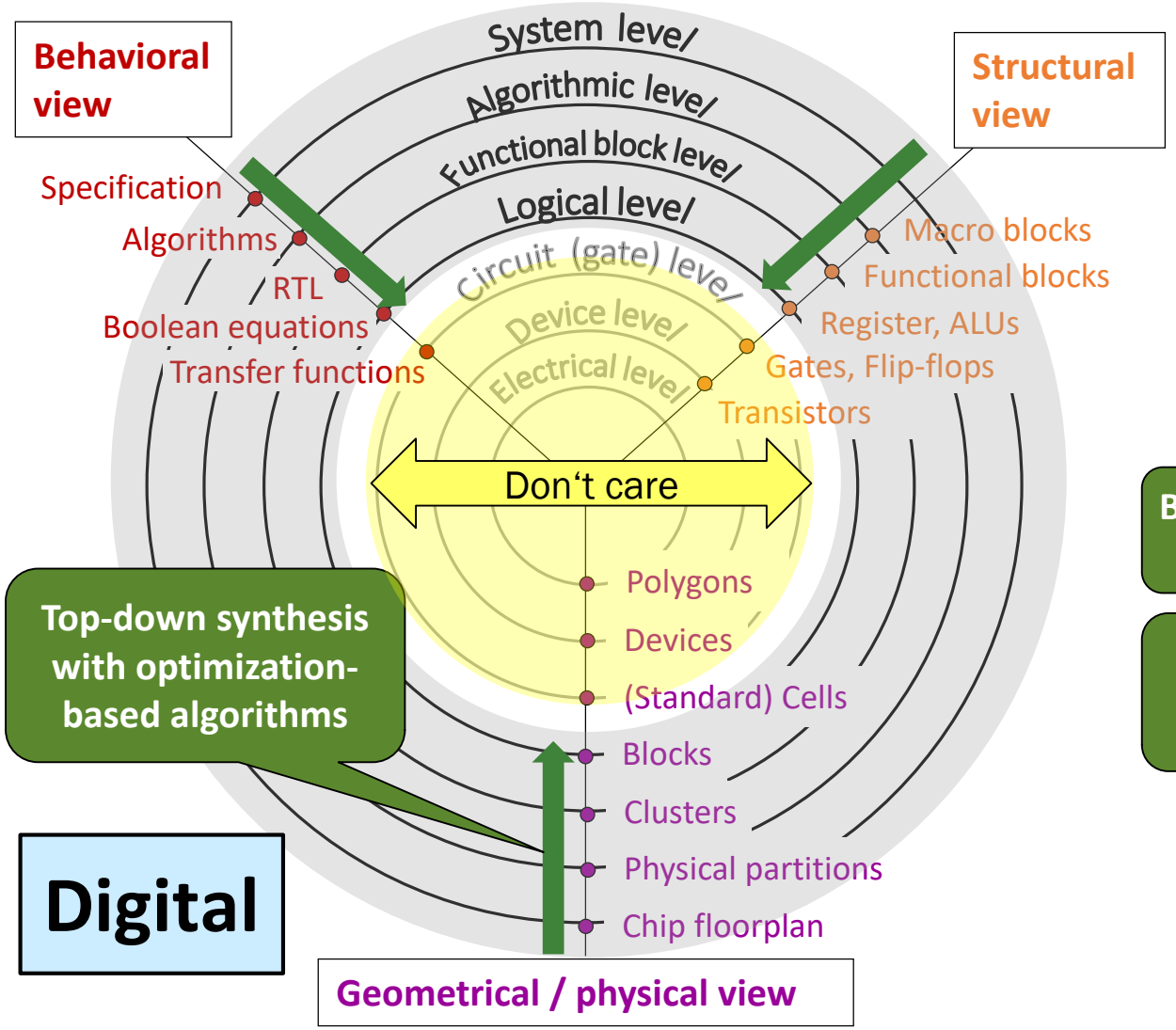

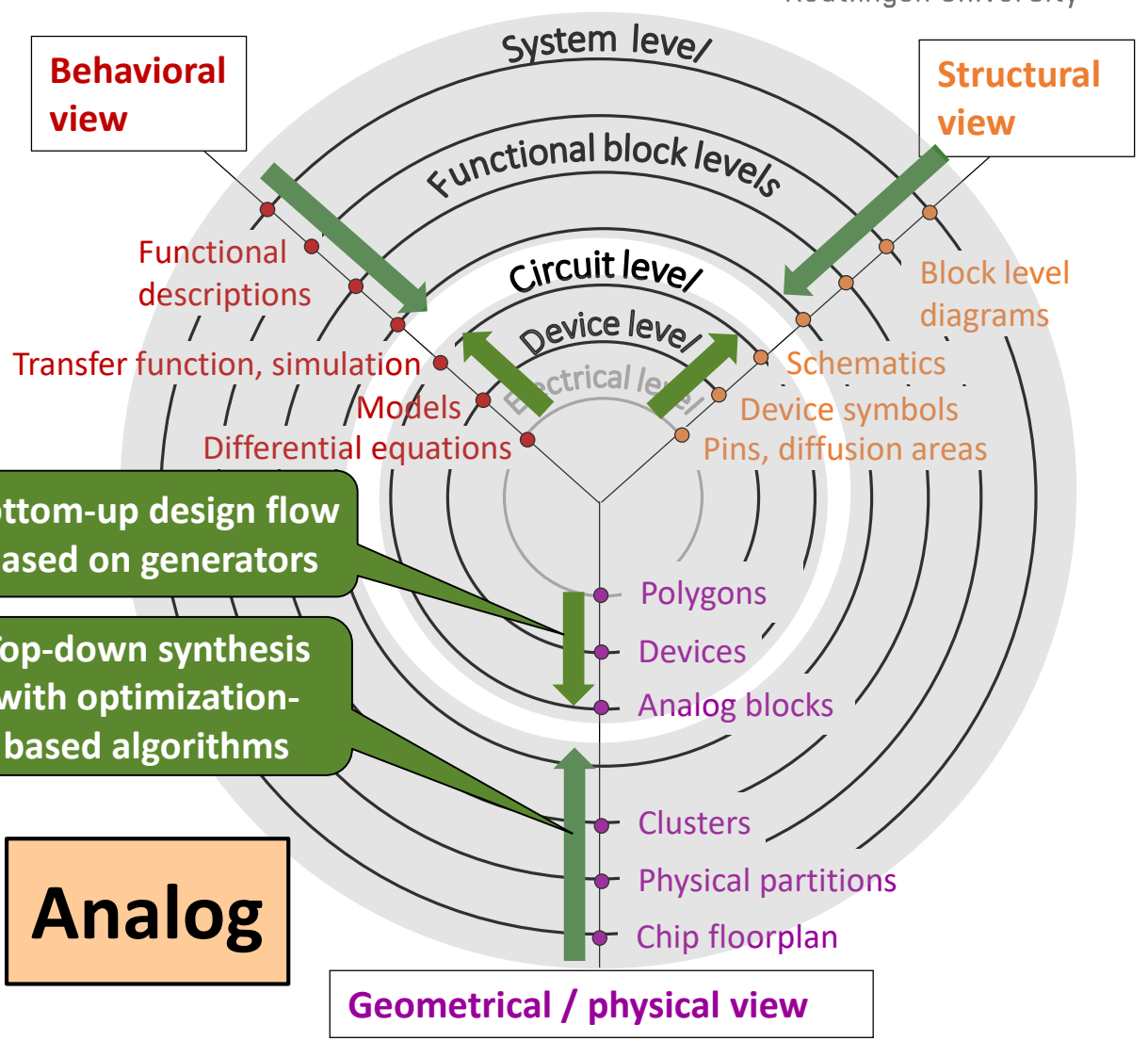

Summary and Conclusion

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- Analog design productivity is the bottleneck in AMS design
- Due to the optimization horizon, optimization techniques cannot be the sole solution to the problem
- For successful automation of analog design, optimization techniques must be supplemented by other techniques. Procedural approaches (generators) are promising here.
- Proposal: a top-down-meets-bottom-up design flow