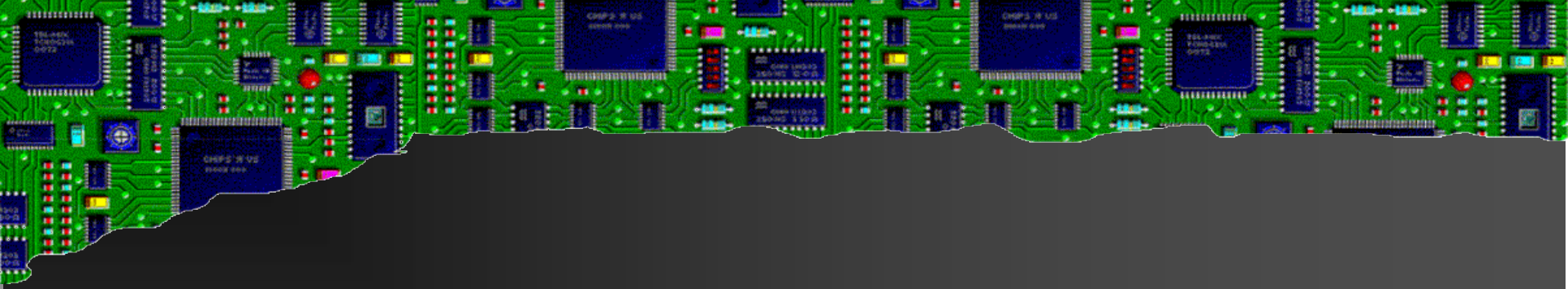


Hardware Modeling

Hardware Description

ECS Group, TU Wien

Content of this course

- Hardware Specification
  - Functional specification
  - High Level Requirements
  - Detailed Design Description
- Realisation
  - Hardware Description
  - Hardware Implementation
- Verification
  - Review
  - Formal verification
  - Simulation

Hardware Description: Outline

- Design entry
  - Levels of abstraction
  - Schematic entry vs. text-based entry

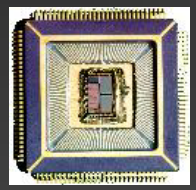
One possible method to describe hardware

- VHDL
  - History
  - Motivation
  - Range of application

Y-Diagram (1)

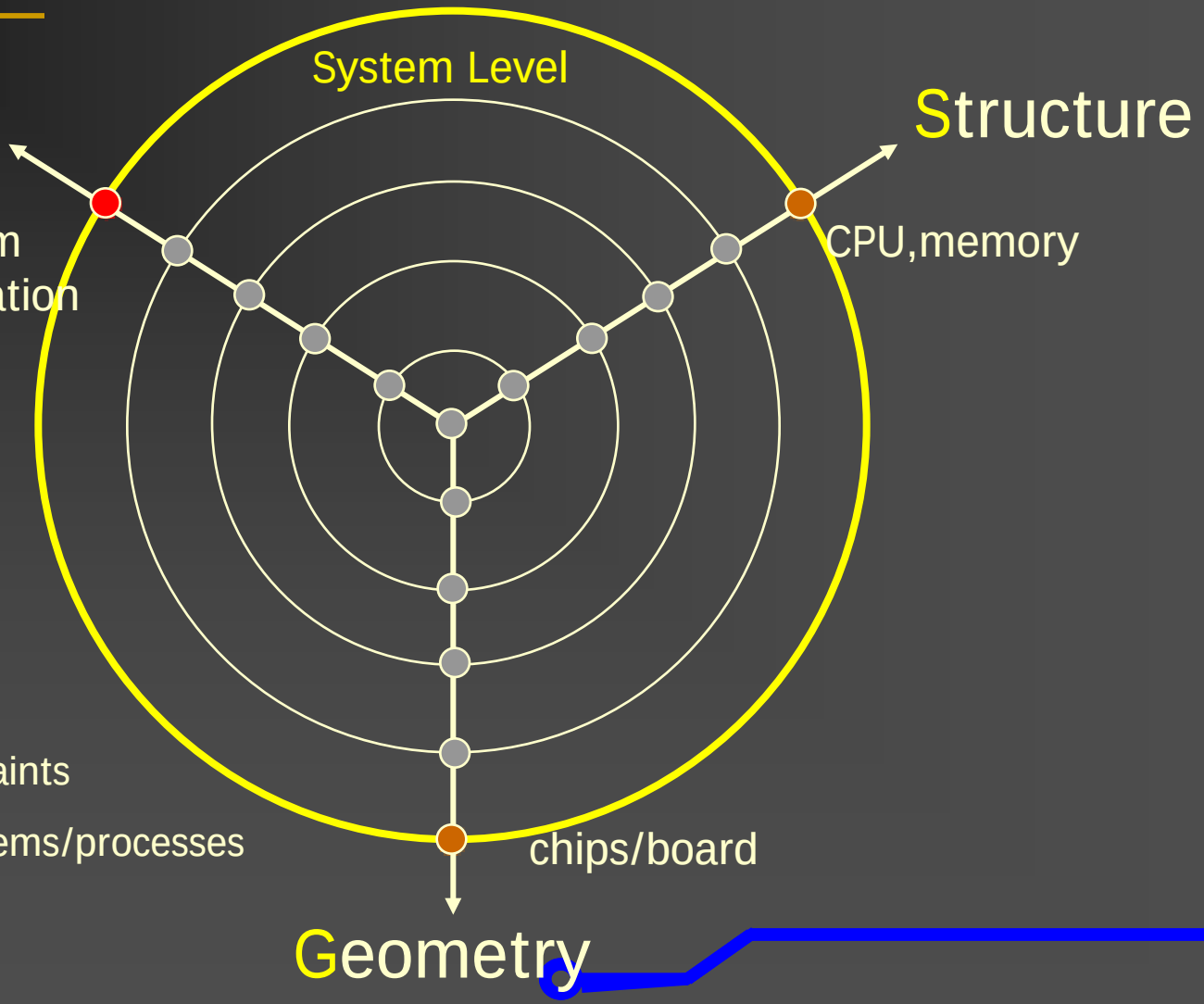
Behaviour of the circuit

Components inside the chip



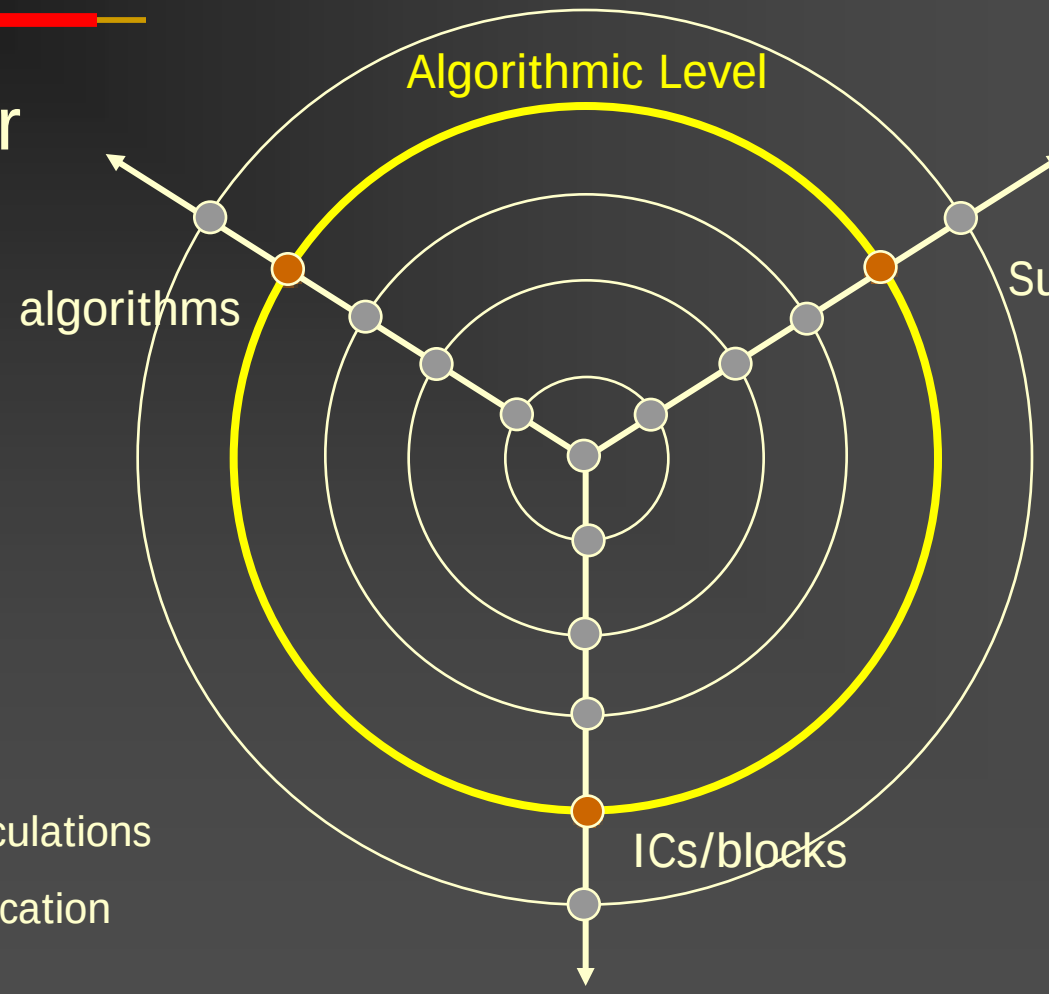
Geometry of the chip

Y-Diagram (2)



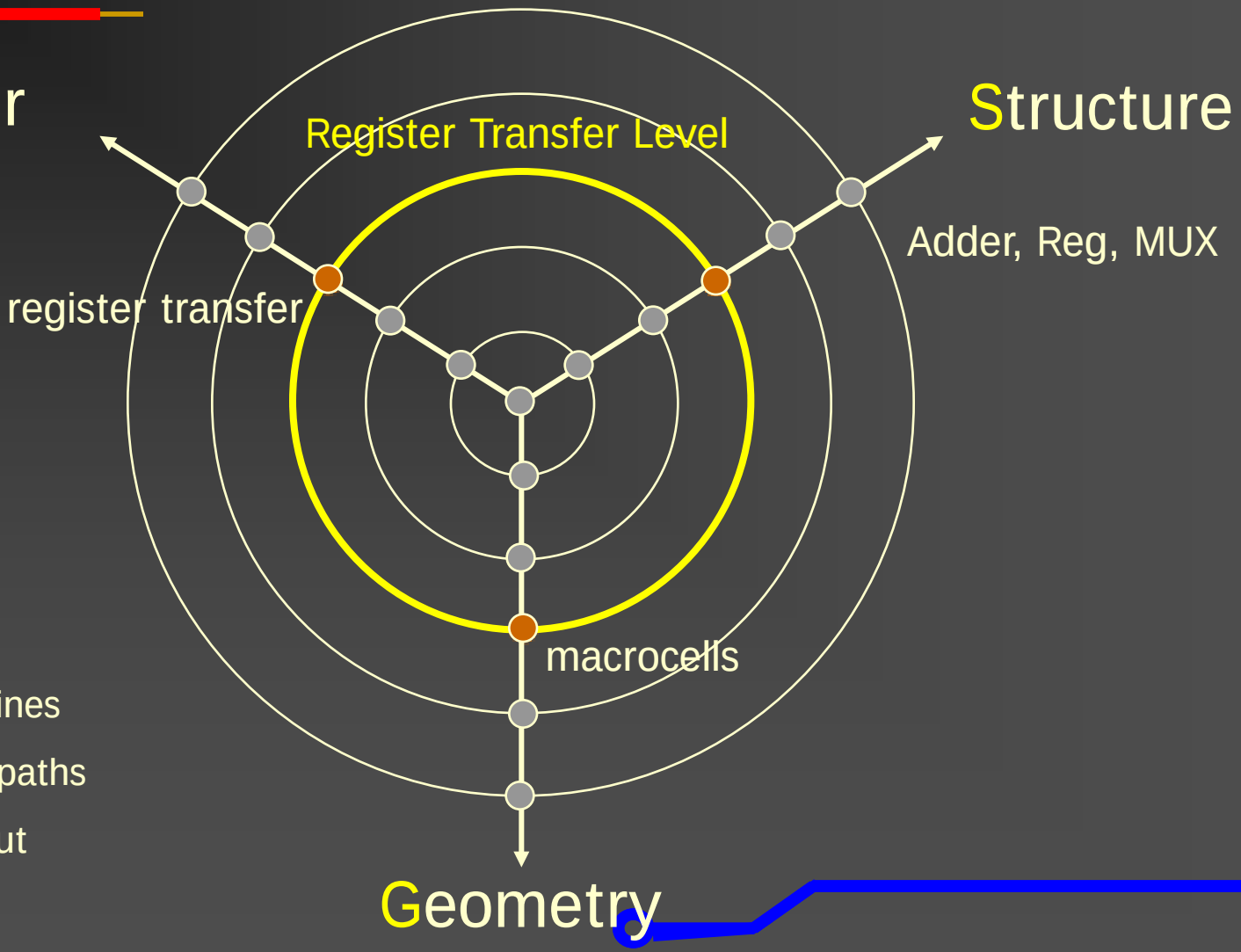
- B: Functionality and constraints
- S: Partitioning into subsystems/processes
- G: (Motherboard-) Layout

Y-Diagram (3)



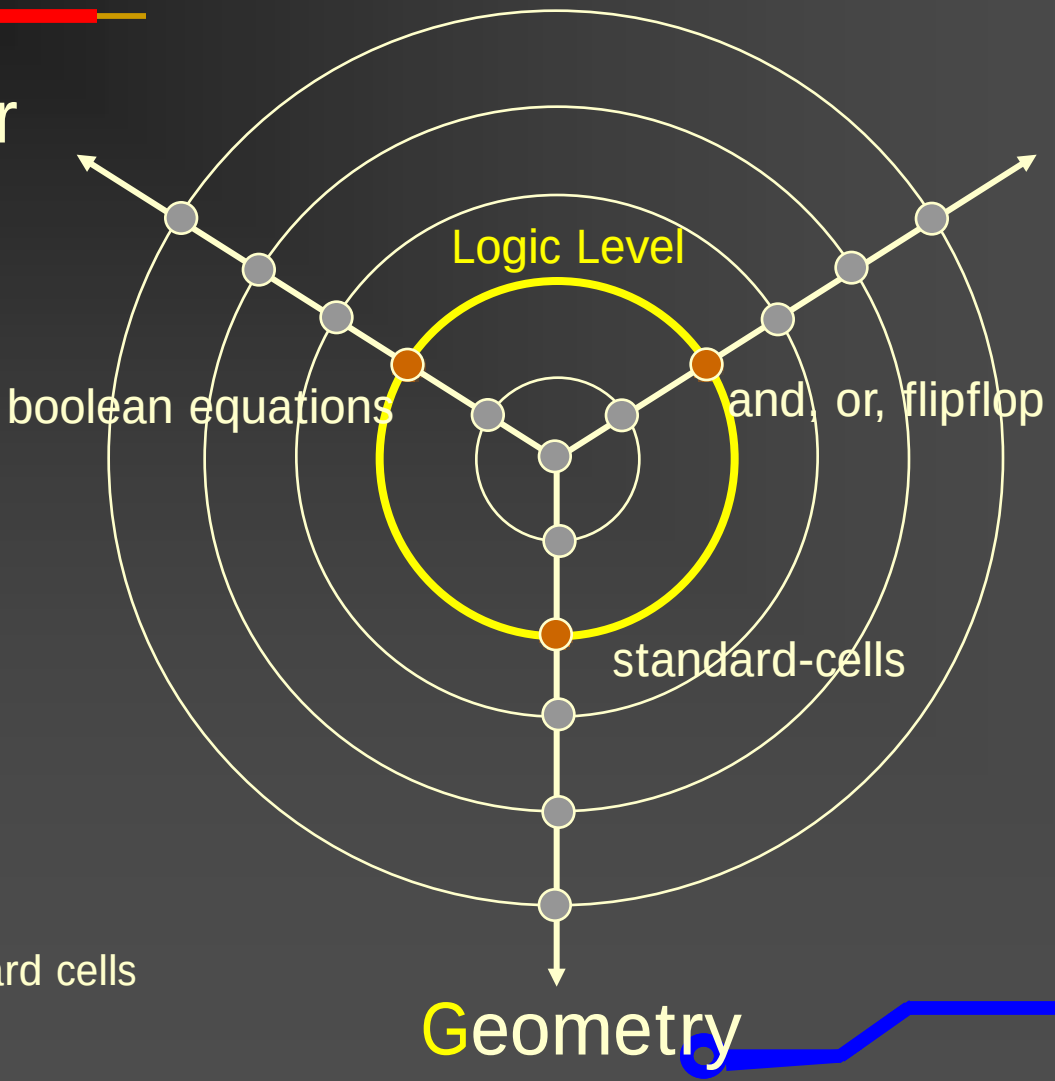
- B: Operations and calculations
- S: Scheduling and allocation
- G: Chip-Layout

Y-Diagram (4)



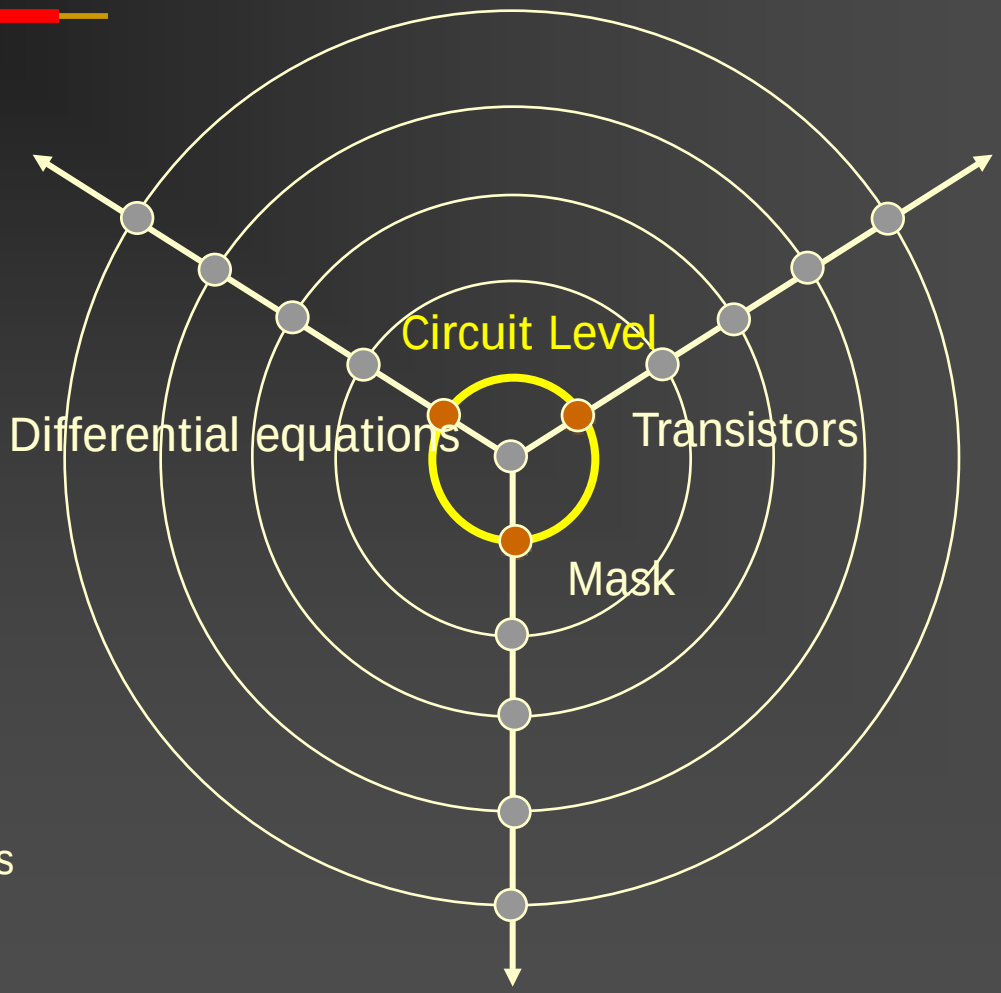
- B: Finite State Machines
- S: Data and control paths
- G: Refined chip layout

Y-Diagram (5)



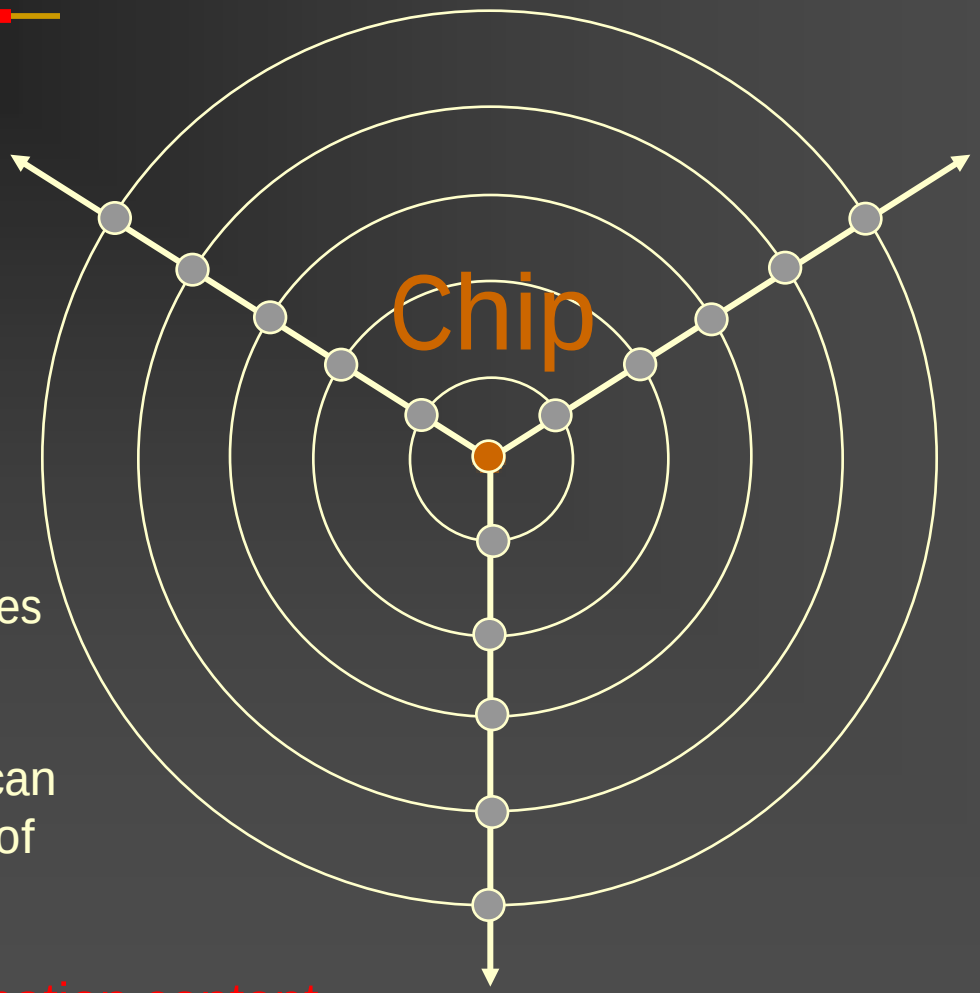
- B: Boolean functions
- S: Gate-level Netlist
- G: Position of standard cells

Y-Diagram (6)



- B: Differential Equations
- S: Transistor network
- G: ASIC Mask

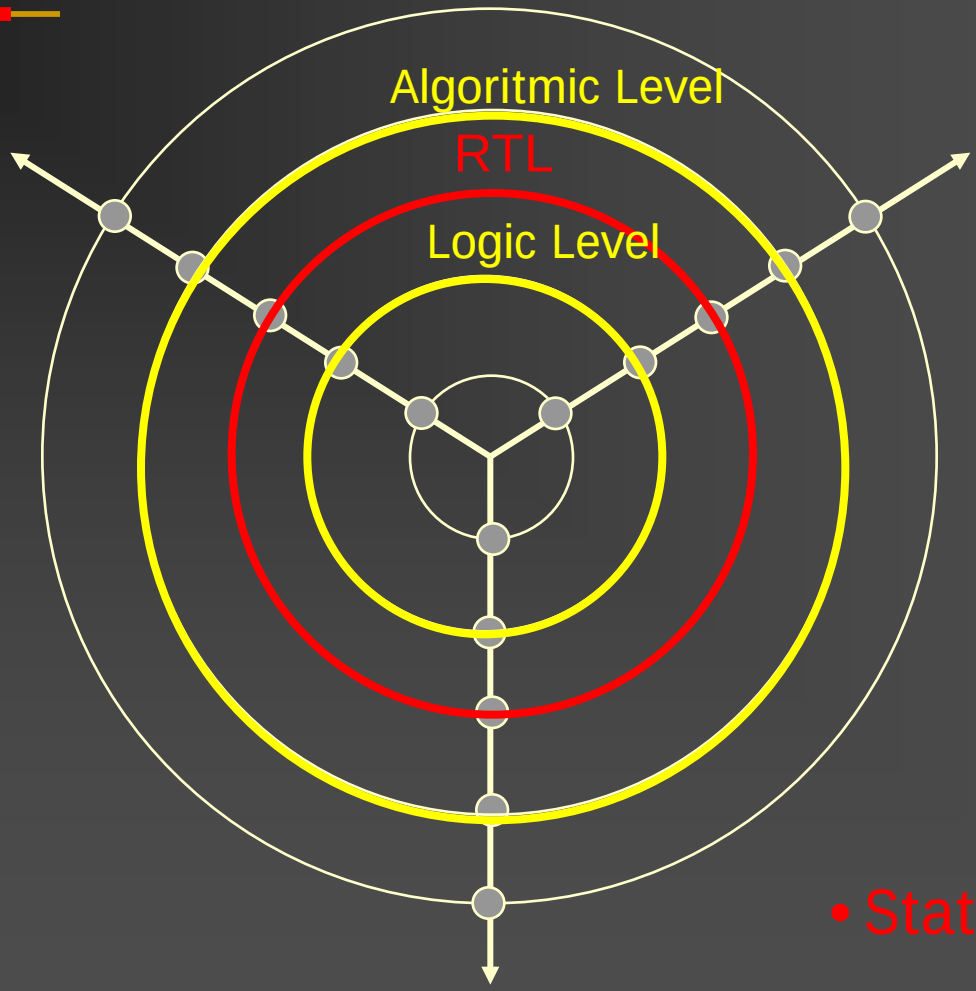
Y-Diagram (7)



- The three views describes the same system/chip
- The same system/chip can be defined on all levels of abstraction

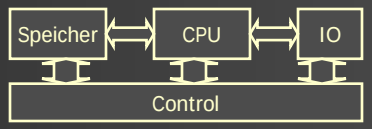
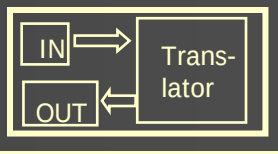
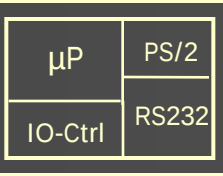
⇒ Level of detail, information content

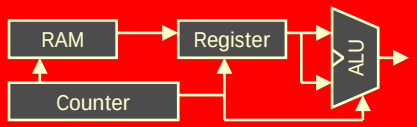
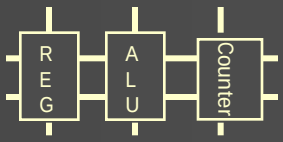
Hardware Description

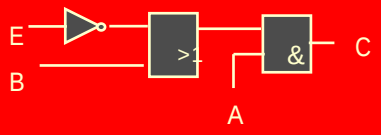
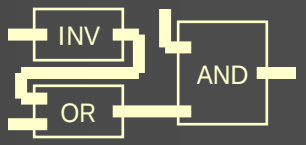
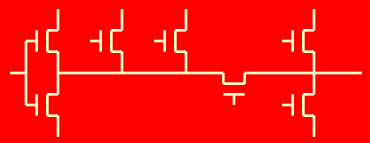


- State of the Art

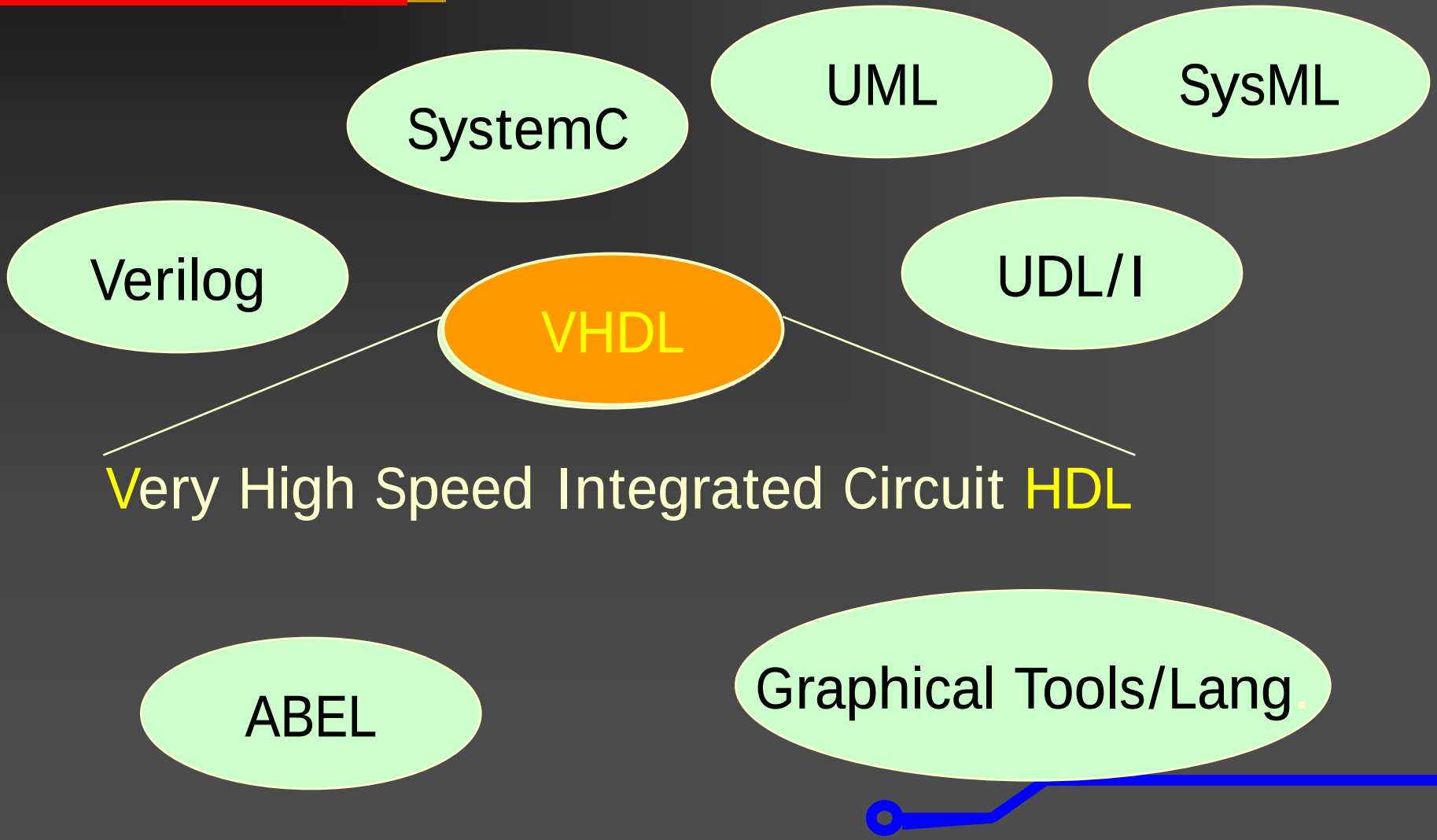
Y-Table

	Behavior	Structure	Geometry
System Level	Inputs : Keyboard Output: Display Funktion:		
Algorithmic Level	while input Read „Schilling“ Ca Euro Dis Euro“		

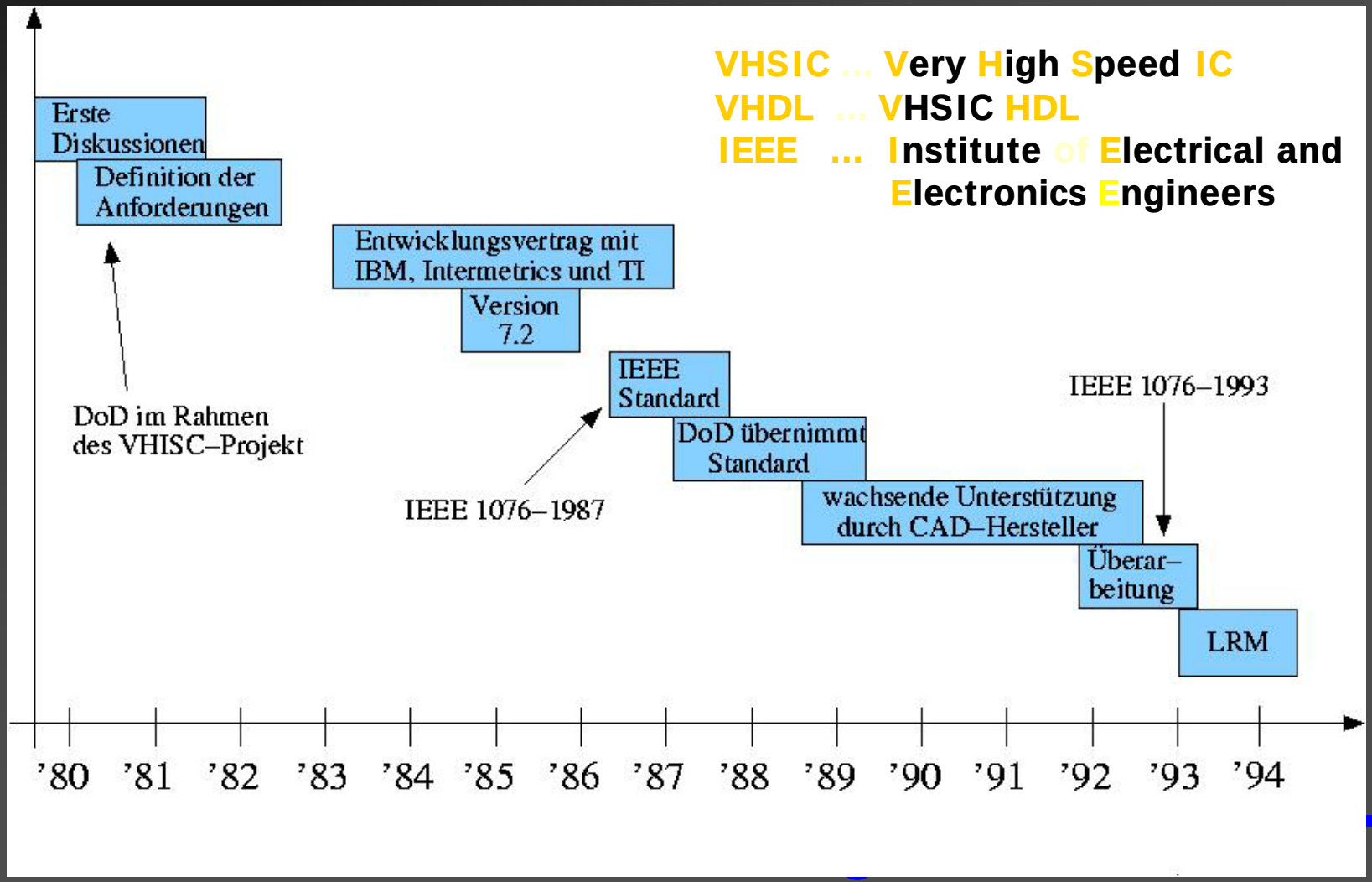
Register Transfer Level (RTL)	if A= `1` then
	B:= B+1
	else
	B:= B
	end if
			

Logic Level	D = NOT E C = (D OR B) AND A		
Circuit Level	$\frac{dU}{dt} = R\frac{dI}{dt} + \frac{I}{C} + L\frac{d^2I}{dt^2}$		

Hardware Description Languages



History of VHDL



Motivation: Documentation

Documentation for :

- Complex systems
- Maintenance
- Reusability
- Different levels of abstraction
- Readable man-machine interface

Motivation: Data exchange

Data exchange between:

- Orderer and contractor
- Developers
- Tools
- Computing systems

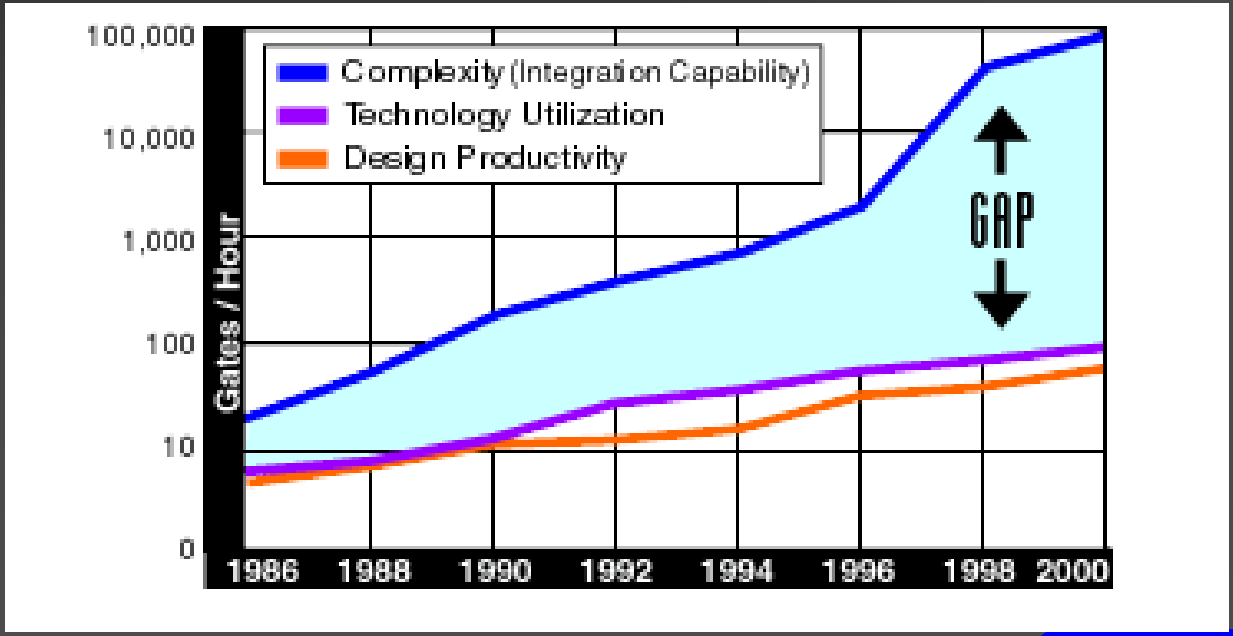
Motivation: Complexity (1)

Design Productivity Gap

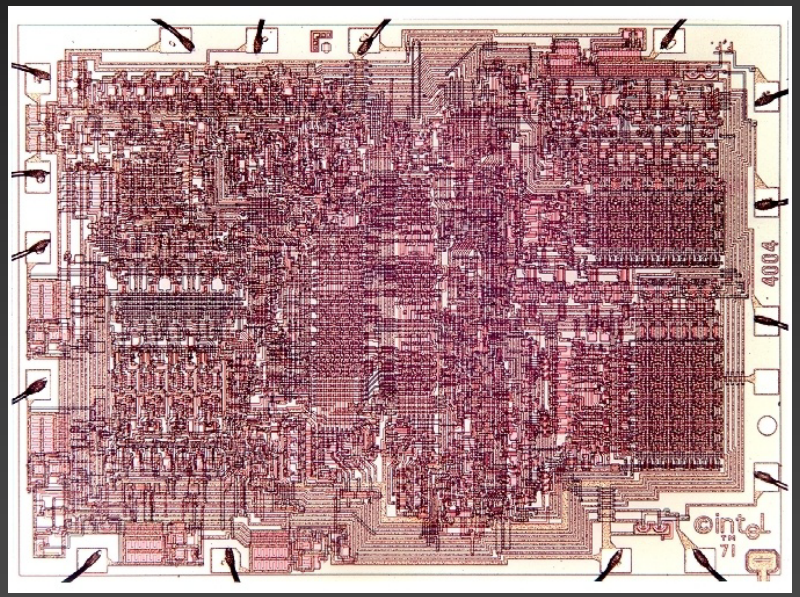
21%/Yr.
Productivity growth rate

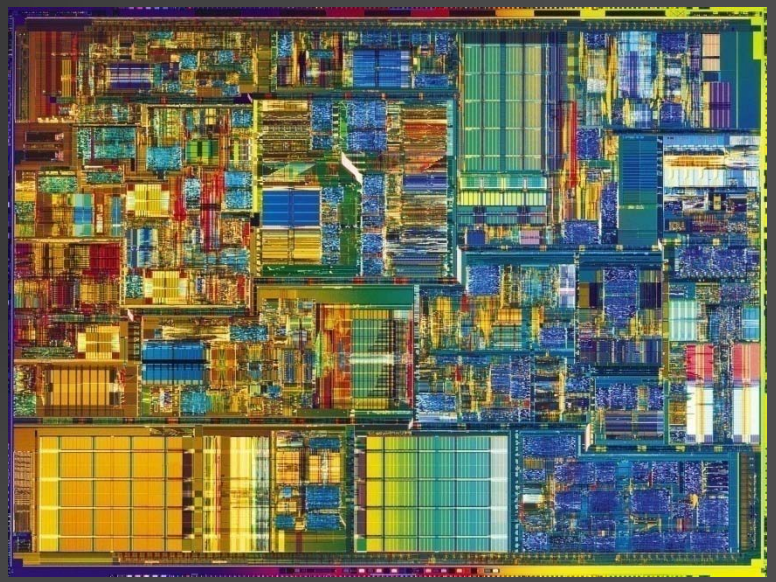
vs.

58%/Yr.
Complexity growth rate



Motivation: Complexity (2)





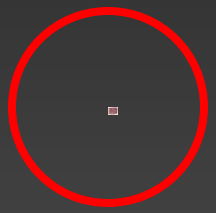
Intel 4004 (1971)

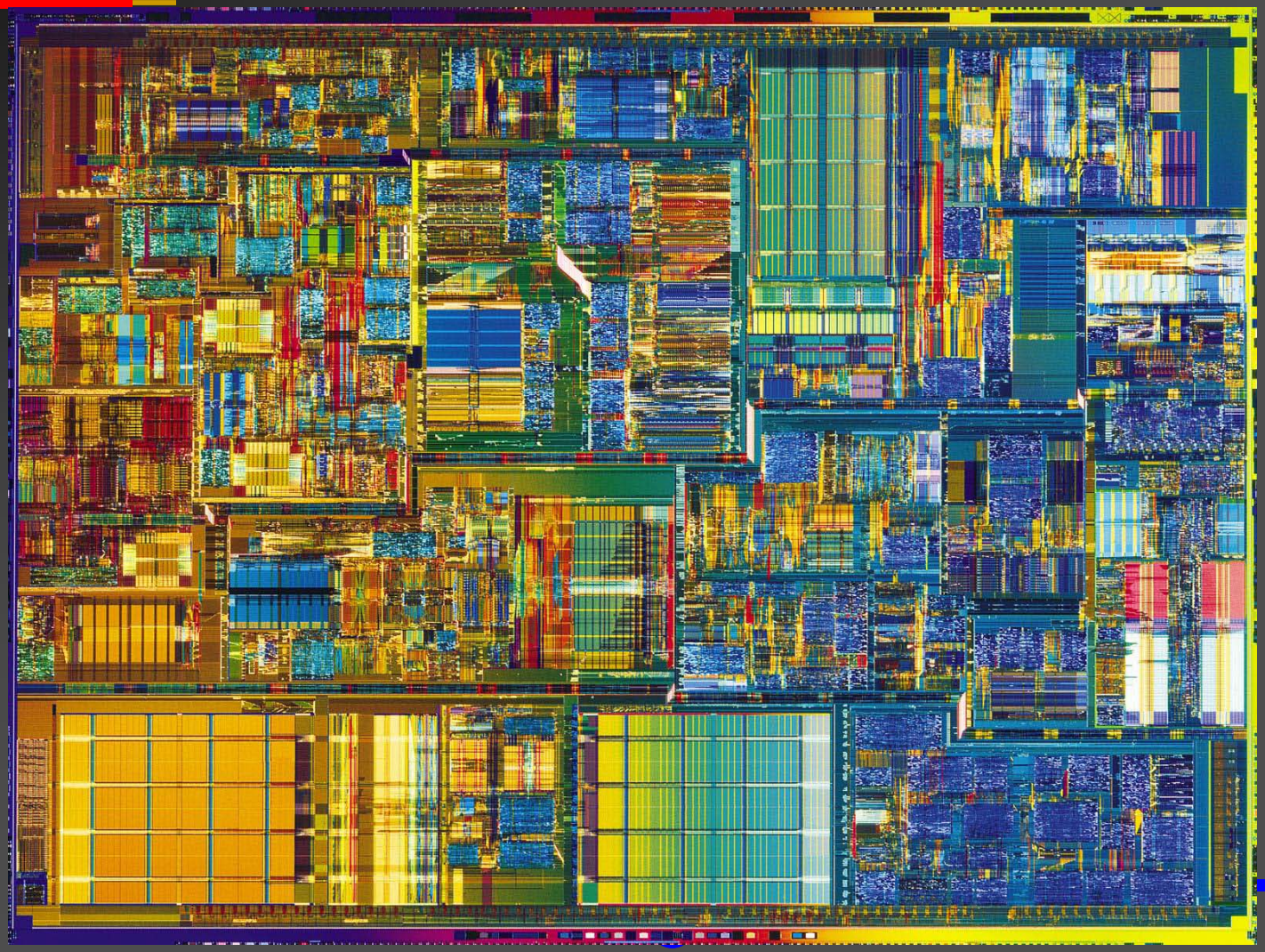
- 2300 Transistors
- 12 mm² / 10µm
- 108 kHz

Intel P4 (2001)

- 42 Millionen Transistors
- 217 mm² / 0,18µm
- 2 Ghz

Motivation: Complexity (3)

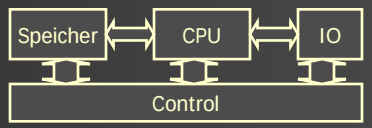
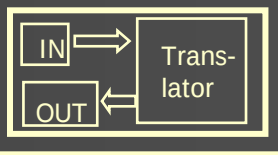
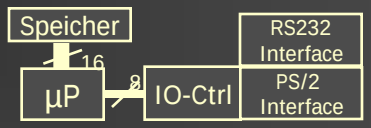
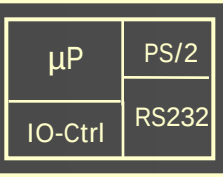


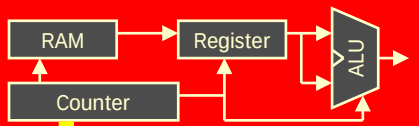
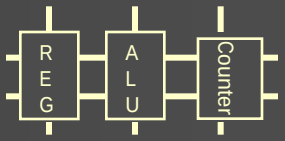


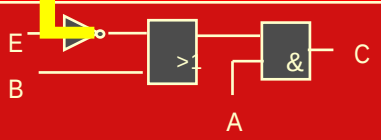
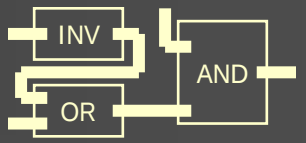
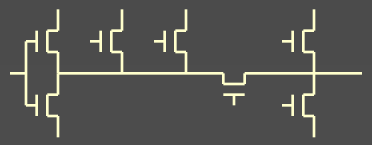
Trans. count ratio:

1: 18261

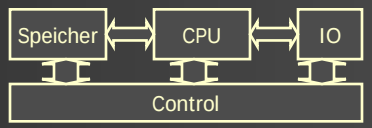
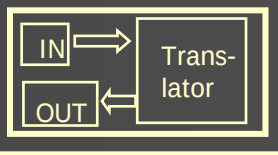
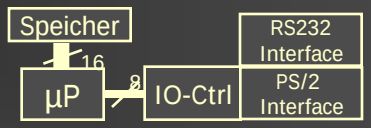
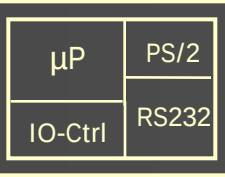
Range application of VHDL

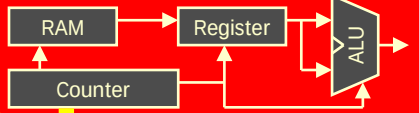
	Behavior	Structure	Geometry
System Level	Inputs : Keyboard Output: Display Funktion:		
Algorithmic Level	while input Read „Schilling“ Calulate Euro Display „Euro“ **Testbench (VHDL)**		

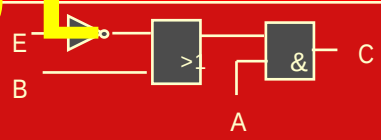
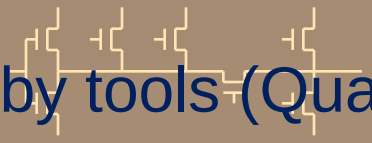
Register Transfer Level (RTL)	if A=`1` then
	B:= B+1
	else
	B:= B
	end if
	V H D L
			

Logic Level	D = NOT E C = (D OR B) AND A		
Circuit Level	$\frac{dU}{dt} = R\frac{dI}{dt} + \frac{I}{C} + L\frac{d^2I}{dt^2}$		

Range application of VHDL

	Behavior	Structure	Geometry
System Level	Inputs : Keyboard Output: Display Funktion:		
Algorithmic Level	while input Read „Schilling“ Calulate Euro Display „Euro“		

Register Transfer Level (RTL)	if A=`1` then
	B:= B+1
	else
	B:= B
	end if
			

Logic Level	D = NOT E C = (D OR B) AND A		
Circuit Level	$\frac{dU}{dt} = R\frac{dI}{dt} + \frac{I}{C} + L\frac{d^2I}{dt^2}$		

Testbench (VHDL)

V H D L

Generated by Tools (Synplify, Synopsys)

Generated by tools (Quartus, e.g.)

Summary

- Hardware can be described from different view: Behavioral, Structural and Geometrical
- Hardware can be described on different Levels of Abstraction
- VHDL is one approach to describe hardware on RTL and Boolean Level