Introduction_VLSI

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What is VLSI ?

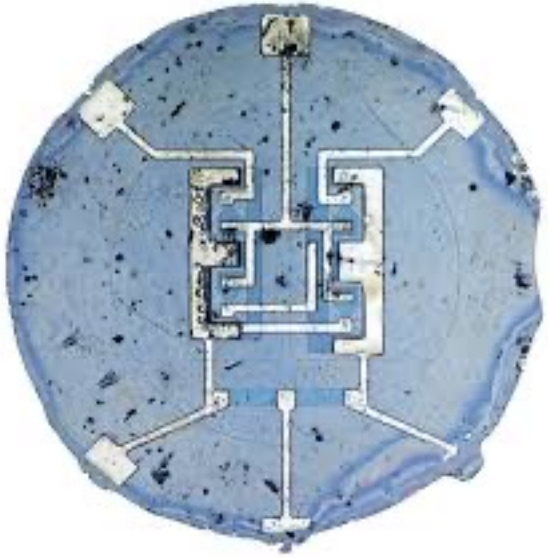
- Very Large Scale Integration Technology
- Enables the production of smaller and more compact devices
- VLSI design allows for the integration of a large number of components onto a single chip
- It has **small power** consumption as compared to discrete components circuit. VLSI can be used i.e.; for different functions in compact size.

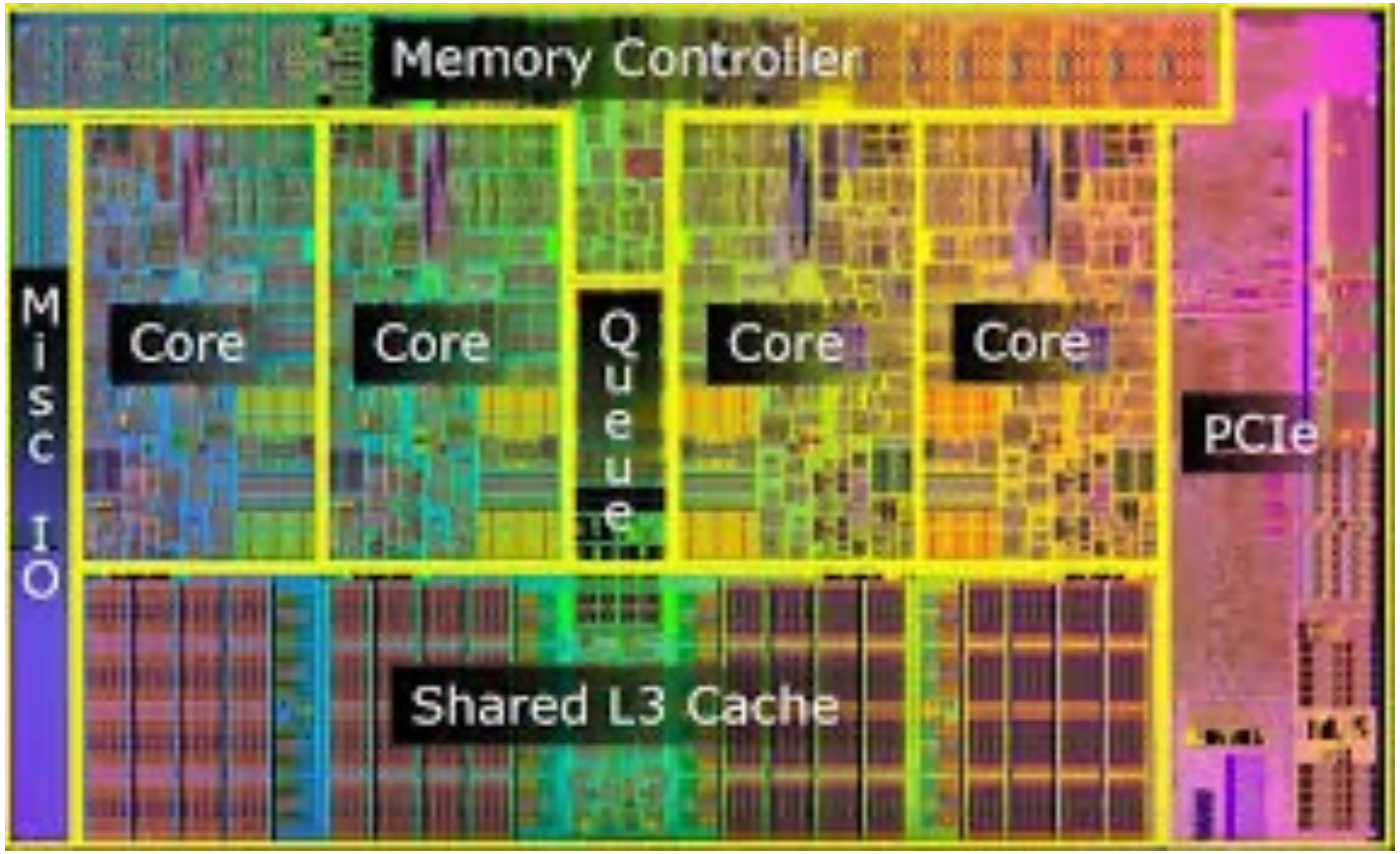
Pros

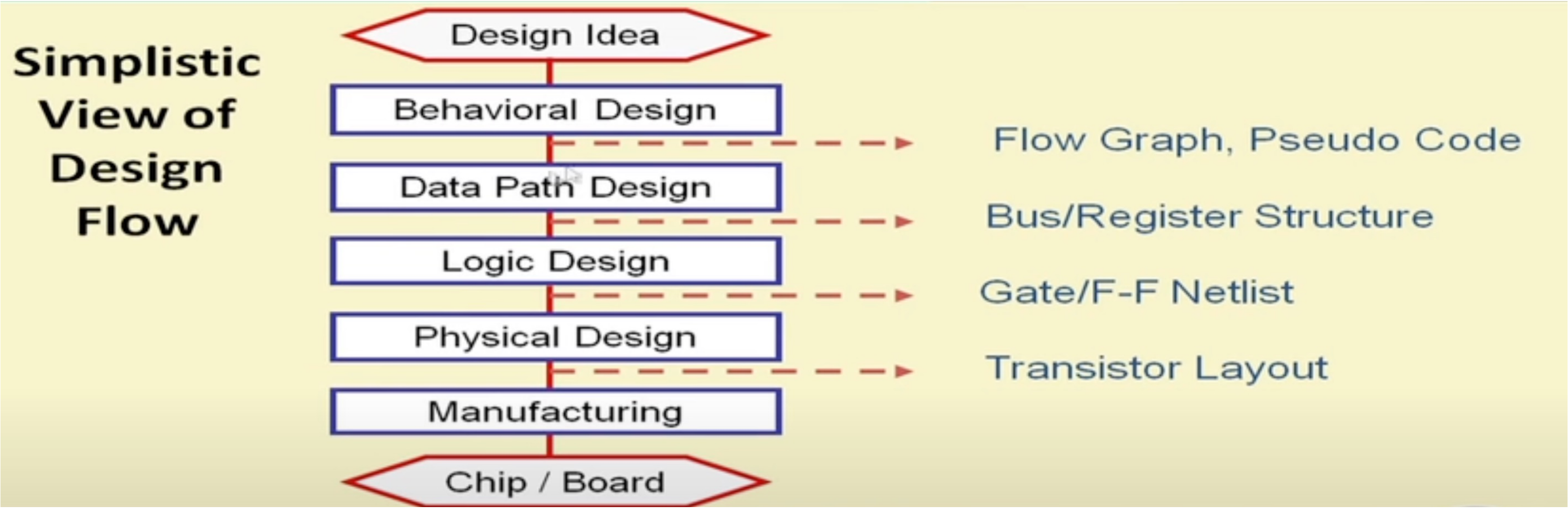
1. High Integration: VLSI technology allows for the integration of a large number of components onto a single chip, leading to smaller, more compact, and more efficient devices.
2. Cost-Effective: VLSI design enables the integration of a large number of components onto a single chip, reducing the cost per component and making electronics more affordable.
3. Increased Performance: VLSI devices can provide increased performance compared to discrete devices, due to the reduced interconnect distances and the increased speed of integrated circuits.
4. Increased Functionality: VLSI technology allows for the integration of multiple functions onto a single chip, providing increased functionality and versatility compared to discrete devices.
5. Improved Reliability: VLSI devices are less susceptible to faults and failures compared to discrete devices, due to the reduced interconnect distances and the improved manufacturing processes used in VLSI design.

Cons

1. Complexity: Complex design
2. High Cost of Development: Developing VLSI devices is a costly and time-consuming process, design tools
3. Manufacturing Challenges: Subject to various manufacturing challenges, such as yield loss, variability, and reliability issues, which can impact the quality and performance of the final product.
4. Time to Market: The development cycle for VLSI devices can be long, with multiple stages of design, verification, and manufacturing, leading to longer time to market for new products.
5. Short Product Life Cycle: The rapid pace of technological advancement in VLSI design can lead to short product life cycles, with new products and technologies becoming obsolete quickly.




Memory Controller
Core
Core
Queue
Core
Core
Misc
IO
PCIe
Shared L3 Cache


Simplistic View of Design Flow
Design Idea
Behavioral Design
Data Path Design
Logic Design
Physical Design
Manufacturing
Chip / Board
Flow Graph, Pseudo Code
Bus/Register Structure
Gate/F-F Netlist
Transistor Layout

Behavioral design

- Specify the functionality of the design in terms of its behavior.
    - Various ways of specifying:
    - Boolean expression or truth table.
    - Finite-state machine behavior (e.g. state transition diagram or table).
    - In the form of a high-level algorithm.
- Needs to be synthesized into more detailed specifications for hardware realization.

Data path design

- Generate a netlist of register transfer level components, like registers, adders, multipliers, multiplexers, decoders, etc.
- A netlist is a directed graph, where the vertices indicate components, and the edges indicate interconnections.
- A netlist specification is also referred to as structural design.
  - Netlist may be specified at various levels, where the components may be functional modules, gates or transistors.
  - Systematically transformed from one level to the next.

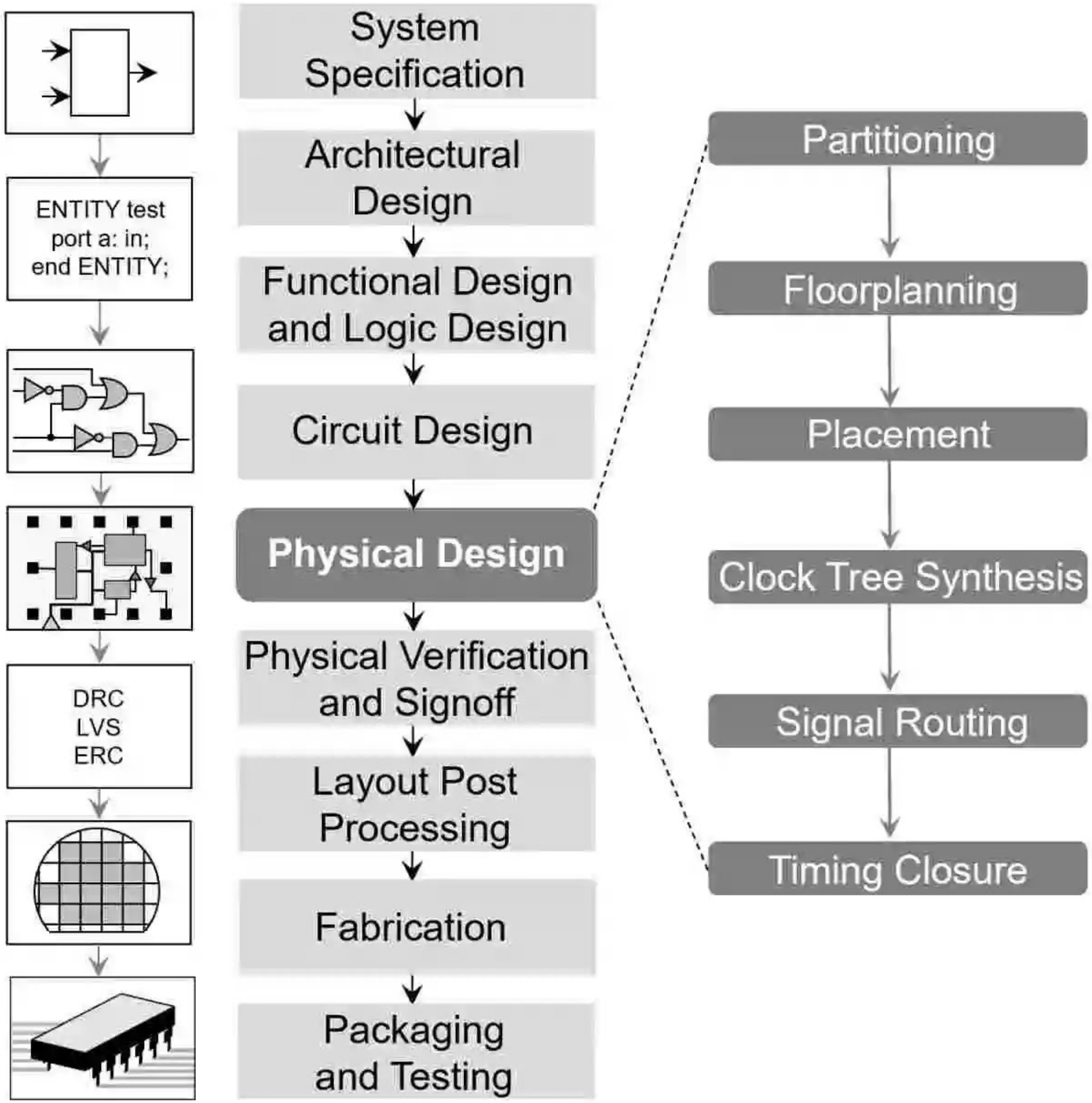
Logic design

- Generate a netlist of gates/flip-flops or standard cells.
- A standard cell is a pre-designed circuit module (like gates, flip-flops, multiplexer, etc.) at the layout level.
- Various logic optimization techniques are used to obtain a cost effective design.
- There may be conflicting requirements during optimization:
    - Minimize number of gates.
    - Minimize number of gate levels (i.e. delay).
    - Minimize signal transition activities (i.e. dynamic power).

Physical design and Manufacturing

- Generate the final layout that can be sent for fabrication
- The lầyout contains a large number of regular geometric shapes corresponding to the different fabrication layers
- Alternatively, the final target may be Field Programmable Gate Array (FPGA), where technology mapping from the gate level netlist is used.
  - Can be programmed in-field.
  - Much greater flexibility, but less speed.

VLSI Design Flow



System Specification: (Behavioral Design)

- Defining the overall goals and requirements of the system
- Chip Architects, circuit Designers, Product Marketers, Production Managers, and Layout and Library designers
- Goals include functionality, performance, physical dimensions, and production technology of the system
- The system specifications are used to create a design plan that outlines the different stages of the design process

Architectural Design: Datapath Design

- Decides the overall architecture of the IC to meet the goals
- Includes deciding the blocks of IC line analog and mix signal block, Memory management, deciding no of cores, digital signal processors (DSPs), internal-external communications, standard protocols like CAN, UART, I2C, etc, pinout and packages like BGA, PGA, etc.
- It ensures that the chip or system is designed to meet the required specifications.

Functional and Logic Design:

- Defined the connectivity and functionality can be defined in this step
- Each module has an input-output and timing behavior.
- Logic design is performed at the register transfer level (RTL) using a hardware description Language (HDL) eg the software programs that define the functional and timing behavior of a chip

Circuit Design: Physical design

- Critical and low-level elements that must be designed at the transistor level this is called circuit design
- The circuit design phase is where the RTL description is translated into a circuit-level implementation
- Gate-level netlist, which is a low-level description of the circuit in terms of logic gates.
- The gate-level netlist is then optimized to improve performance, power consumption, and area utilization.
- The gate-level netlist is also verified through simulation to ensure that it functions correctly. This involves the creation of test benches

Physical Design

- In physical design, all components like macros, cells, gates, transistors, etc with fixed sizes and shapes are placed at the location in the fabrication layer to perform appropriate routing
- Physical design is performed according to DRC (Design Rule Check) which depends on the capabilities of fabrication technology.
- For example, wires must be kept at a proper distance between them. Physical design directly impacts circuit performance, area, reliability, power, and manufacturing yield.

Physical design steps

- Partitioning
- Floorplanning
- Power and Ground Routing
- Placement
- Clock Network Synthesis
- Global Routing
- Detailed Routing
- Timing Closure

Physical Verification:

- Designed layout must be verified to ensure correct functionality
- After verification, some problems found can be neglected if they cause a nominal impact on performance but if causing major impact

1) Design Rule Check (DRC)
2) Layout vs Schematic(LVS)
3) Parasitic Extraction
4) Antenna Rule Checking
5) Electrical Rule Checking (ERC)

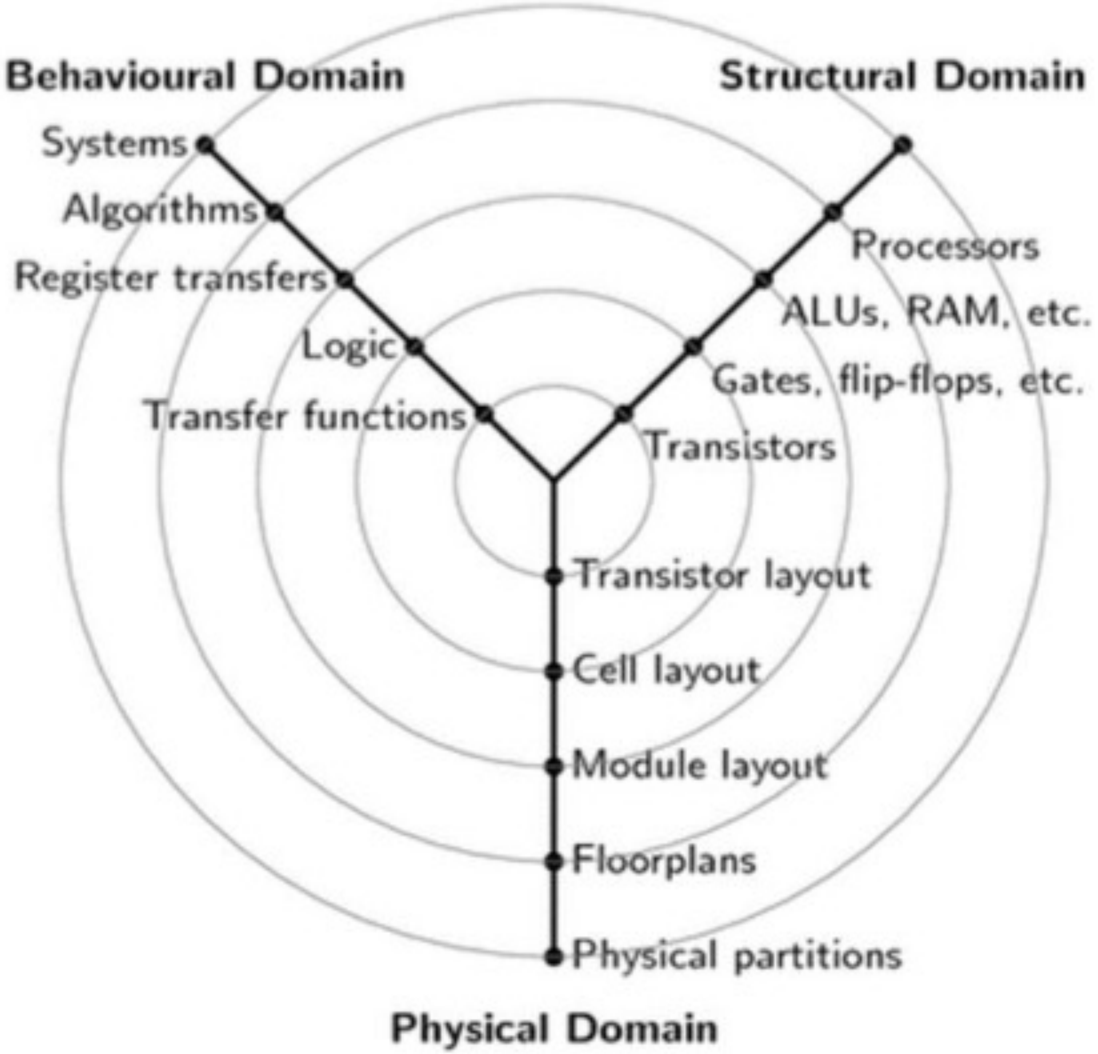
Fabrication:

- GDSII stream format is sent for manufacturing at a dedicated silicon foundry(Fab)
- The handoff of the design to the manufacturing process is called tape out
- The generation of data for manufacturing is sometimes referred to as streaming out. At fab, the design pattern is printed on different layers using photolithography
- The fabrication process is a complex and expensive process that requires specialized equipment and facilities

Packaging and Testing:

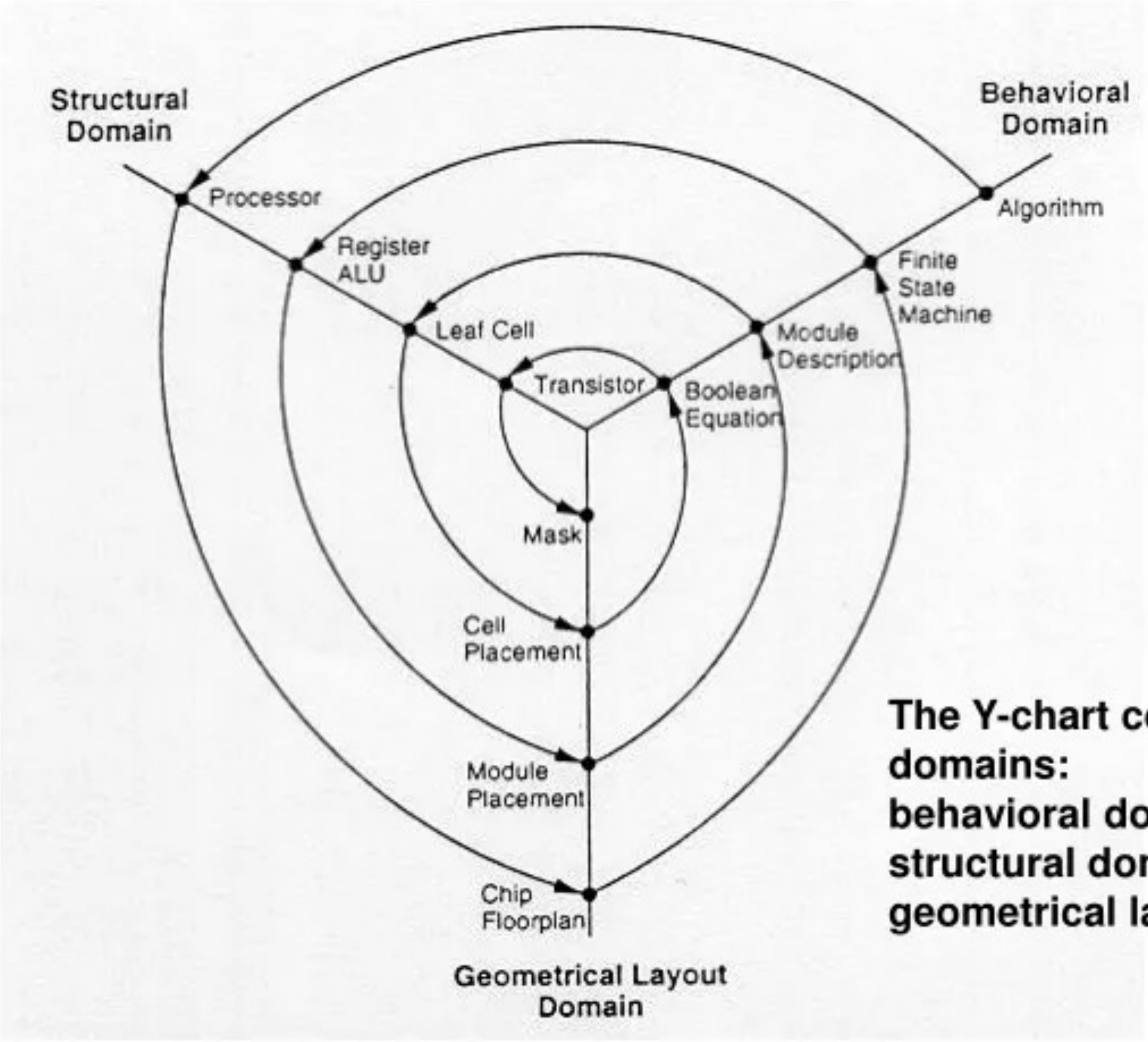
- Chip package types like dual in-line packages (DIPs), pin grid arrays (PGAs), and ball grid arrays (BGA). After the chip is placed in the die cavity the pins are connected to the pins of the package and then it is sealed.

EDA Tools?



Gajski-Kuhn Y-chart

VLSI Design Flow



The Y-chart consists of three major domains:
behavioral domain,
structural domain,
geometrical layout domain.