Challenges for Automating PCB Layout

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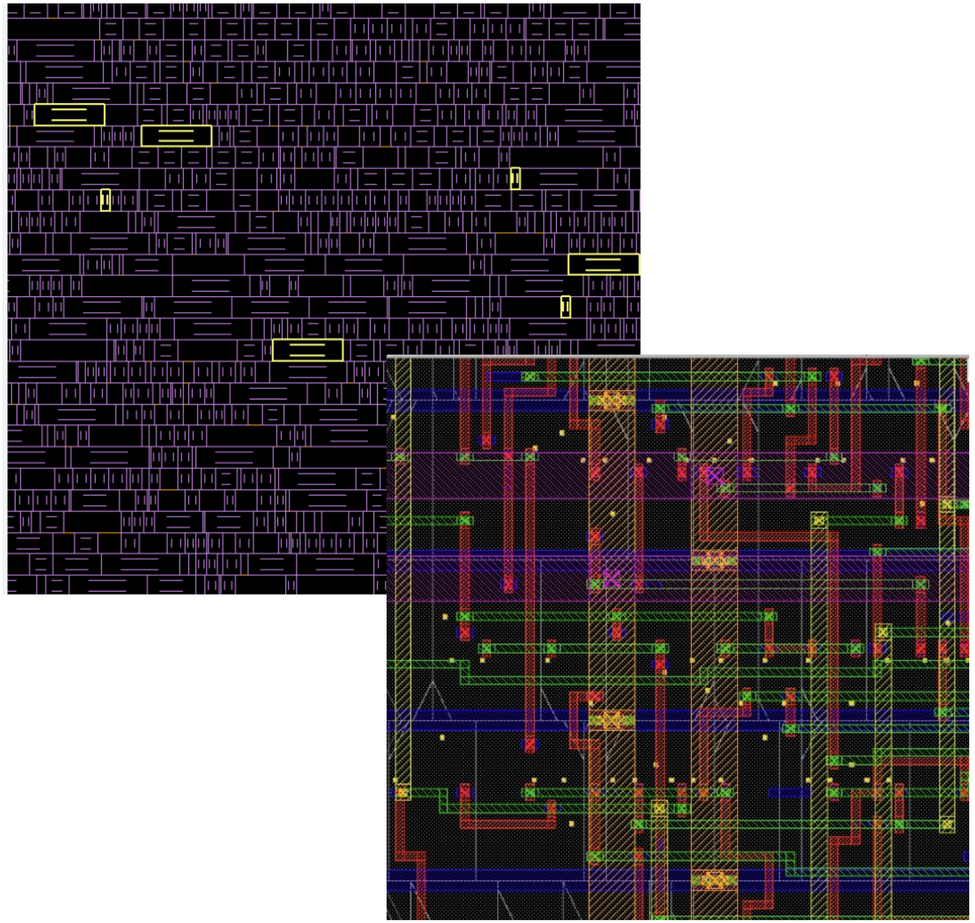
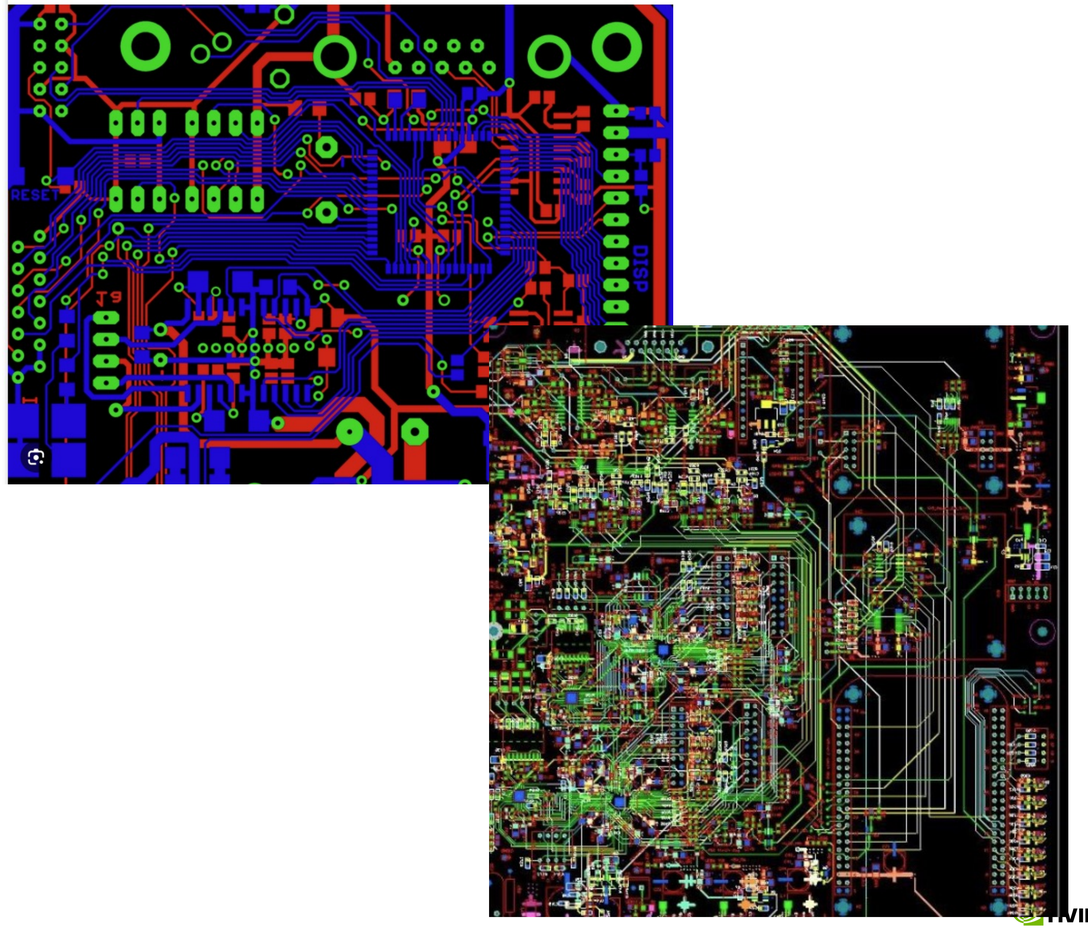
Background

Digital Design
Large size, standardization, fully-automation



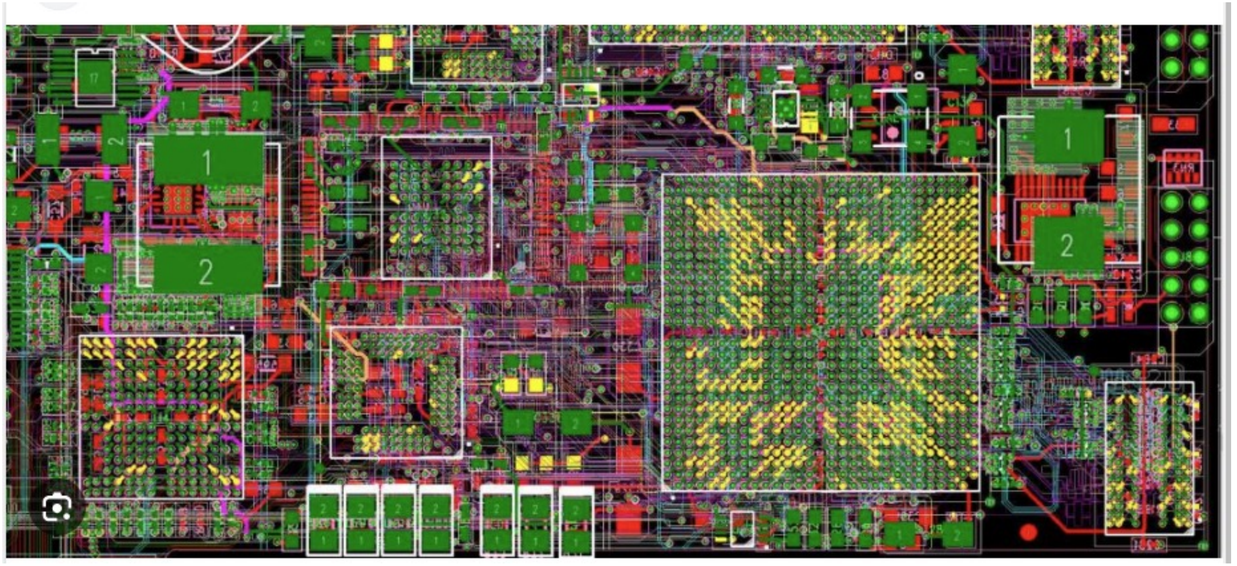
PCB Design
Human-managable size, customization, manual design



Motivation

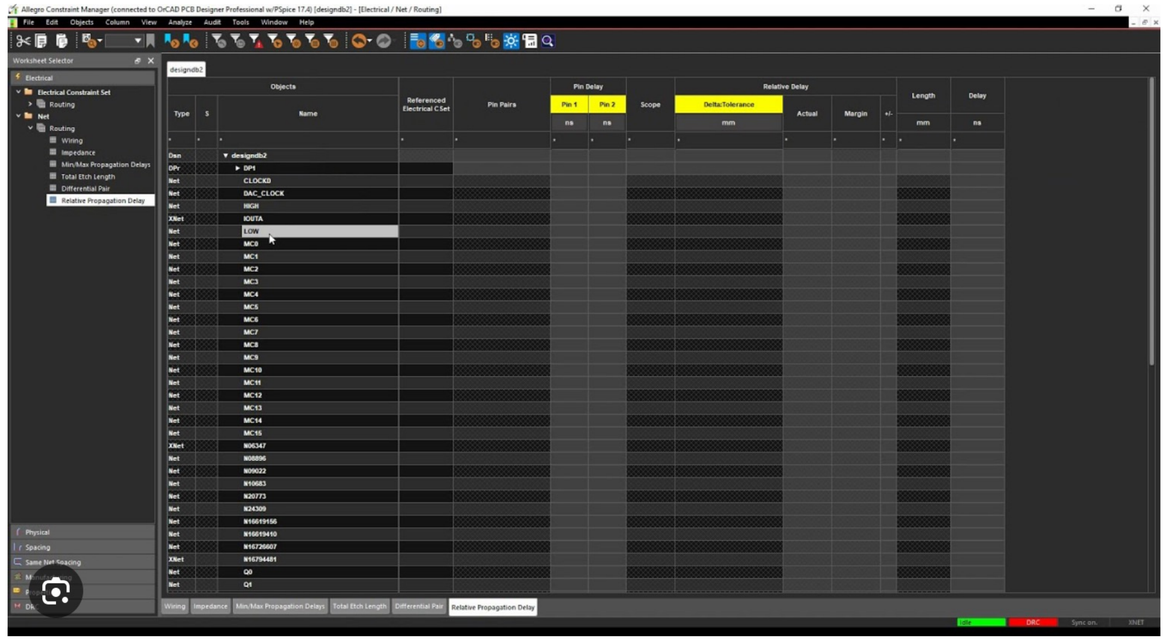
- Printed circuit board (PCB) design is typically done by semi-auto or manual manners in the past
- The scale of PCB designs rapidly enlarges, such that the engineering effort of the manual design increases dramatically.
- PCB houses are looking for the productivity improvement contributed by automation

Big PCB Designs:
>2K components
>200K nets
> 60 metal layers
> 200 routing rules
(40 layout engineers, 1 month effort)



PCB Layout Flow

- At the planning stage, PCB houses rely on experienced engineers to plan the footprint, routing layers, and environment setup for a PCB design.
- Rule setup is labor intensive



Allegro’s constraint manager

Layout Planning and Rule Setup

Component Selection

Schematic Drawing and Simulation

Physical Layout (Place and Route)

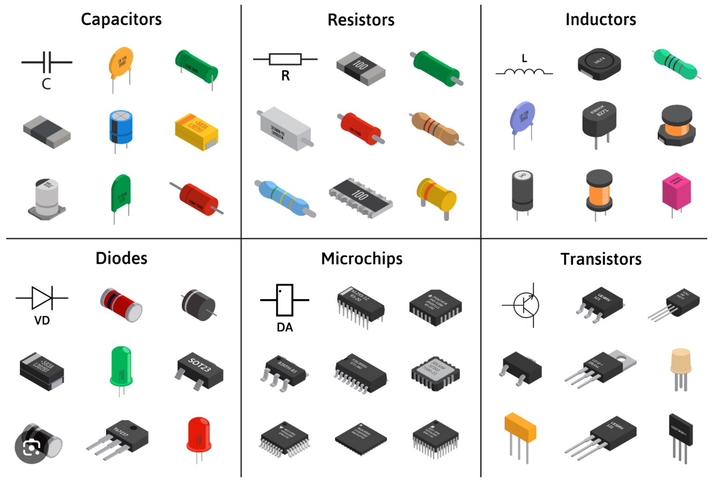
Verification and Validation

PCB Layout Flow (cont.)

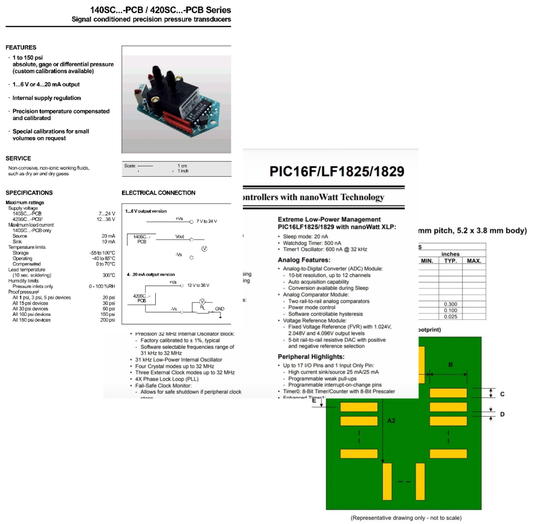
- The functionality of a PCB design is compiled by different combinations of components. Different components have different tradeoff between performance, cost, area, and power. The designers need to select the components wisely to meet the spec with minimal cost.

- Different components have different usage model and limitation specified in a corresponding datasheet or document.

Components



Data Sheet



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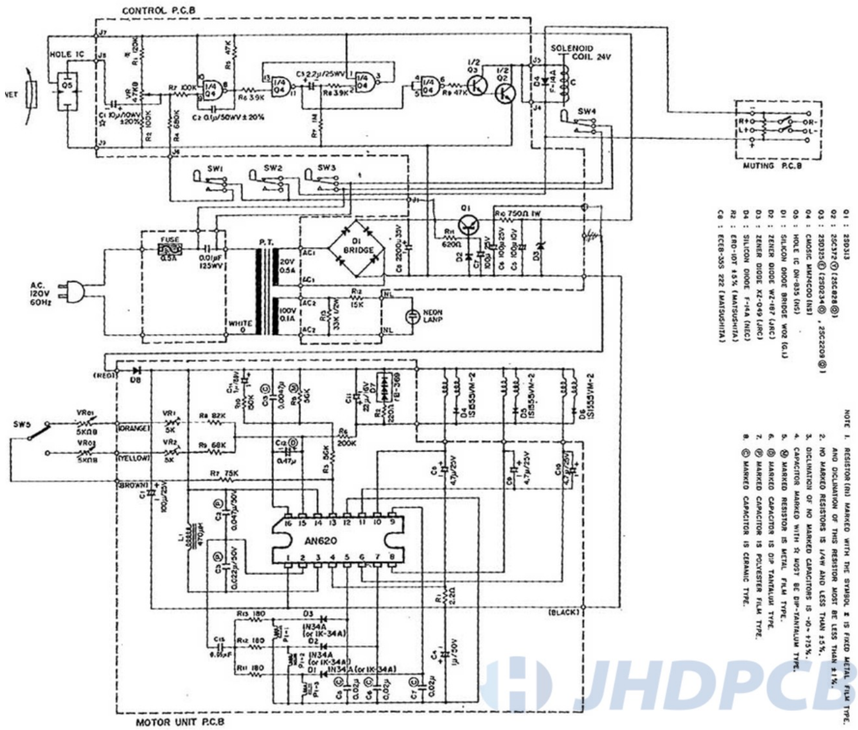
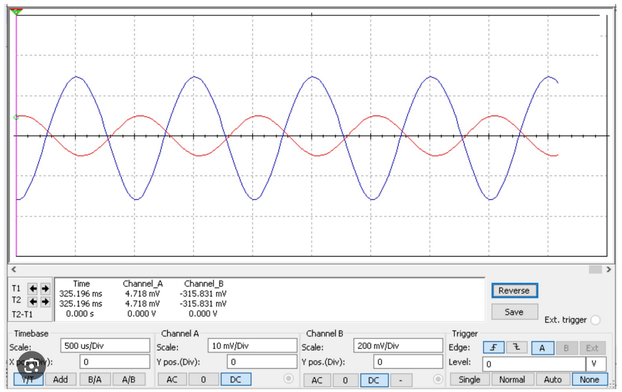
PCB Layout Flow (cont.)

- Designers draw the logical connectivity between components and assign proper voltages for components. Then, run SPICE simulation for the schematic to verify its behavior.

Schematic



Simulation



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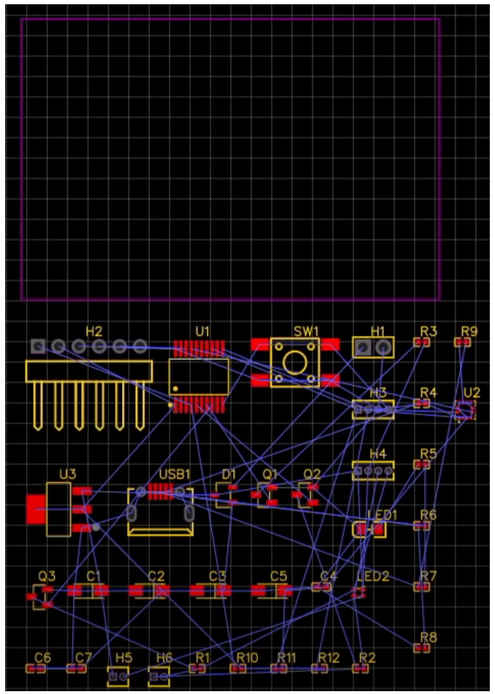
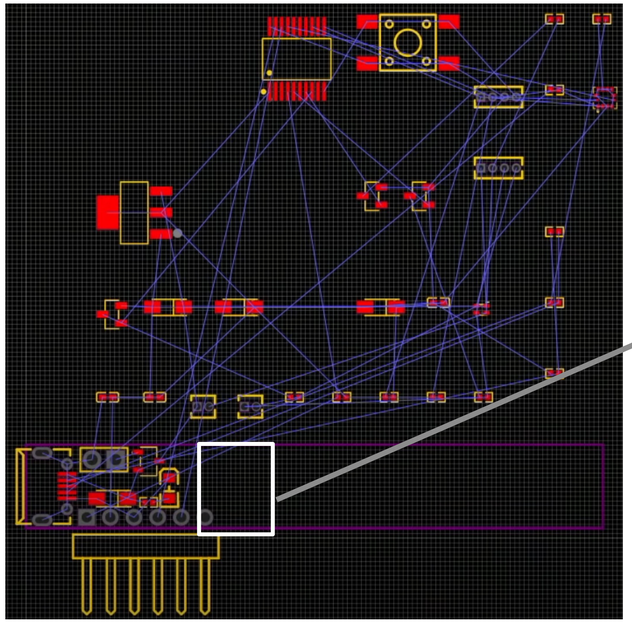
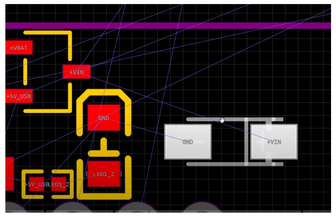
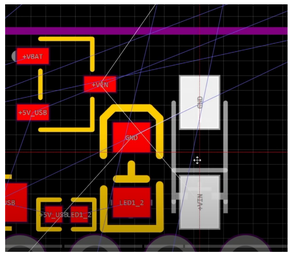
PCB Layout Flow (cont.)

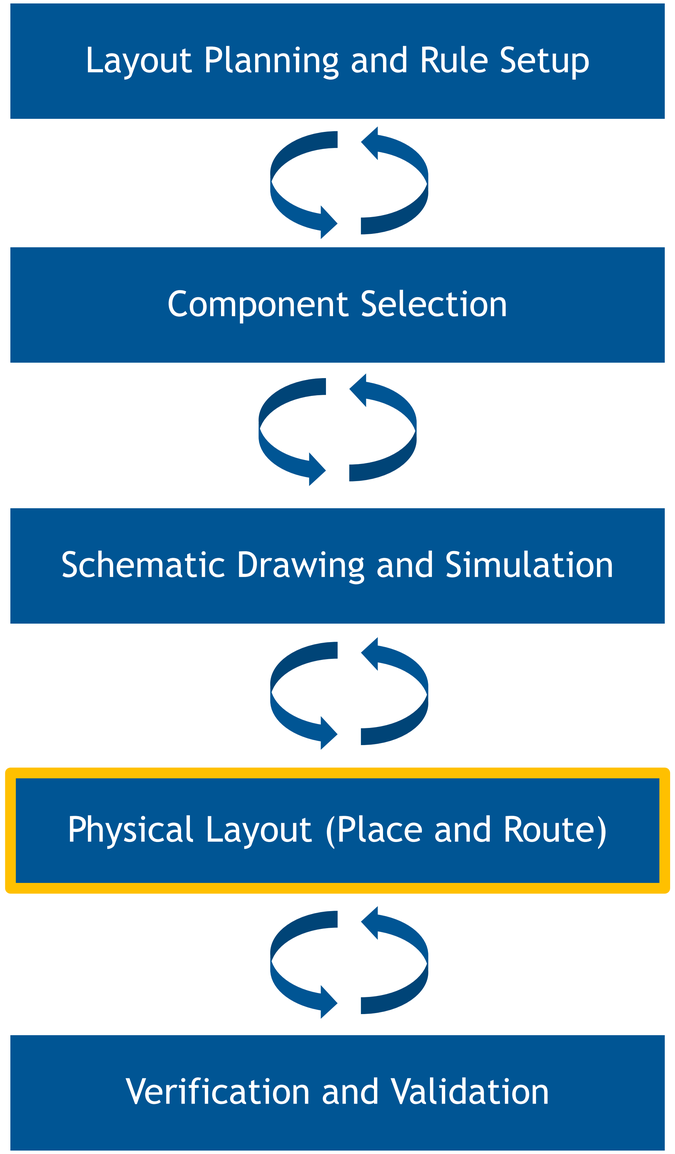
- Placement stage puts components in PCB outlines using the following operations
  - Move components
  - Rotate components
  - Enlarge or shrink outline
  - Re-select component





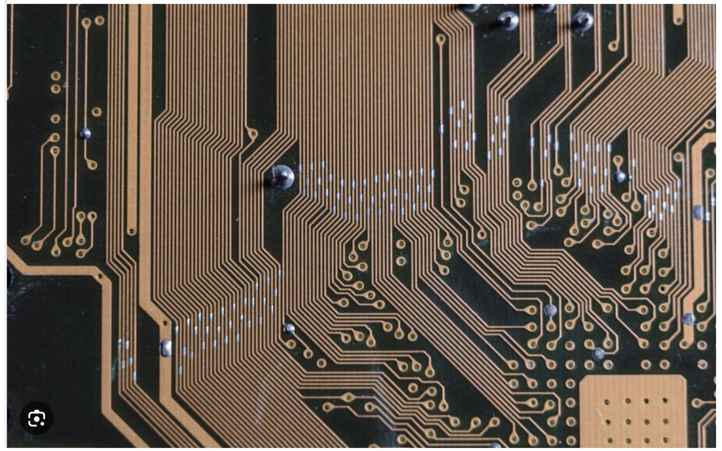




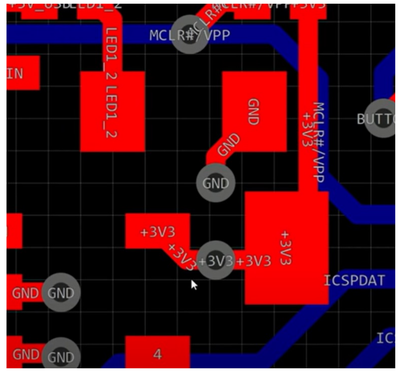


PCB Layout Flow (cont.)

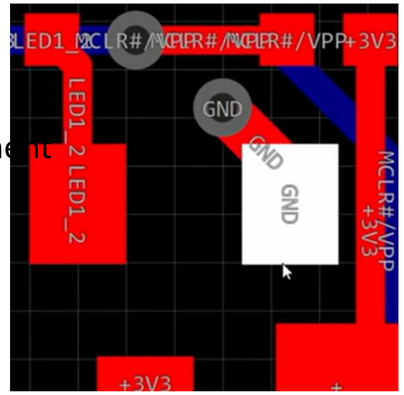
- Routing stage creates wires and vias using semi-auto or manual solutions
- Co-optimize routing and placement for routability
- Post refinement is involved to spread and size wires to improve yield and performance.

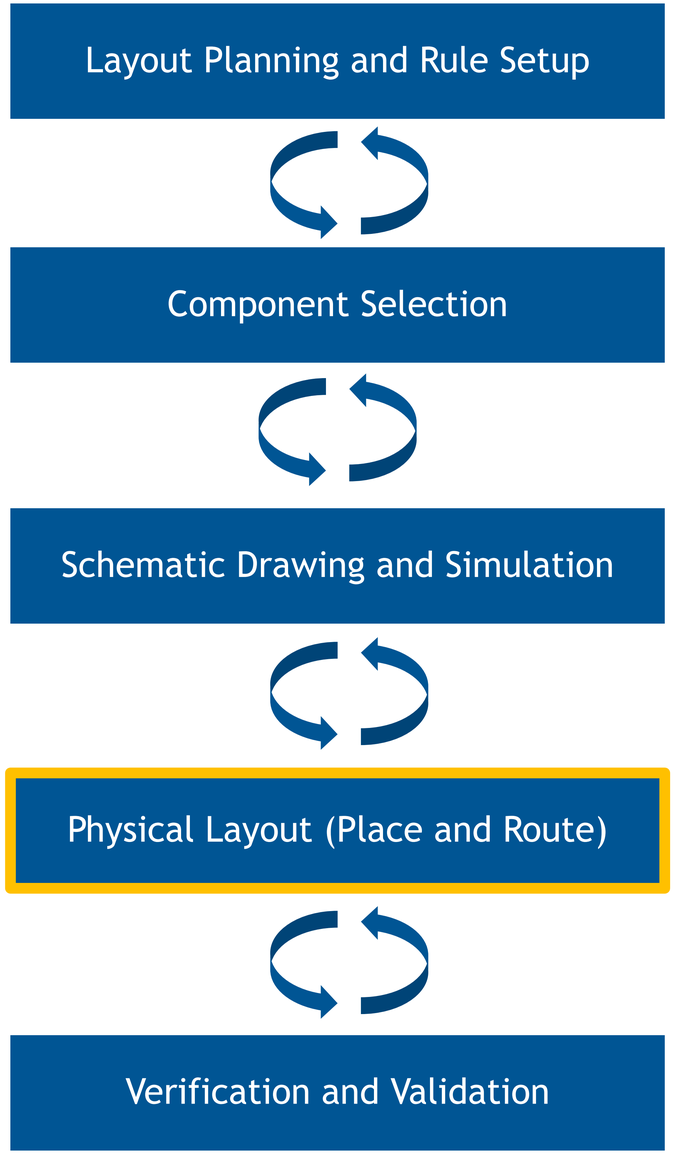


Before post refinement



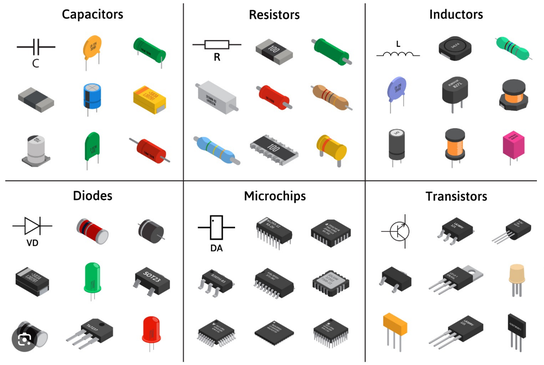
After post refinement

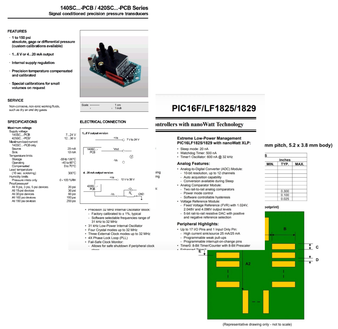


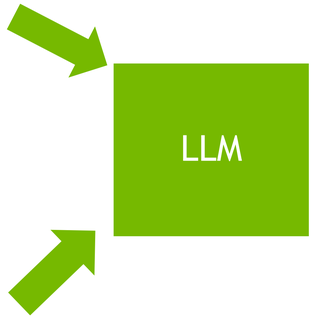


Automation Opportunity – Component Selection

- Use Large Language Model to select components [1] and rule setup

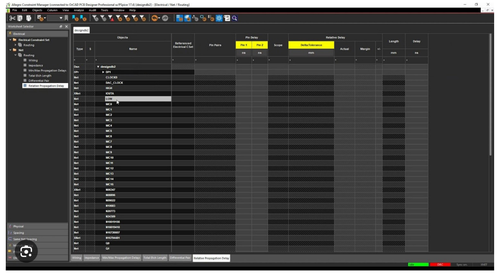






Component Selection

Rule Setup



Layout Planning and Rule Setup

Component Selection

Schematic Drawing and Simulation

Physical Layout (Place and Route)

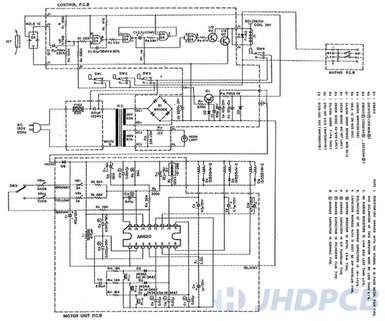
Verification and Validation

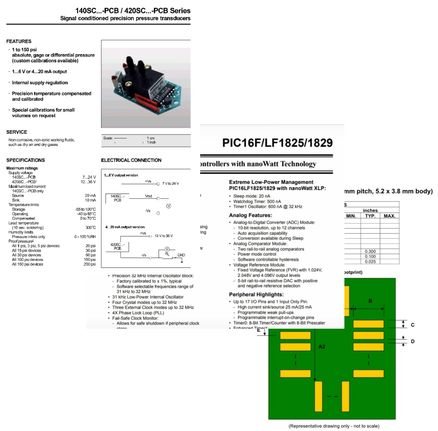
[1] https://resources.altium.com/p/can-you-use-chatgpt-pcb-design

Automation Opportunity – Schematic Verification

- Designers usually need to check the datasheet time to time during schematic drawing stage to verify the correctness of the schematic.

- The work [3] uses machine learning (ML) model to parse the datasheet and schematic diagram to verify its correctness.





ML Model

Debugging Information

Layout Planning and Rule Setup

Component Selection

Schematic Drawing and Simulation

Physical Layout (Place and Route)

Verification and Validation

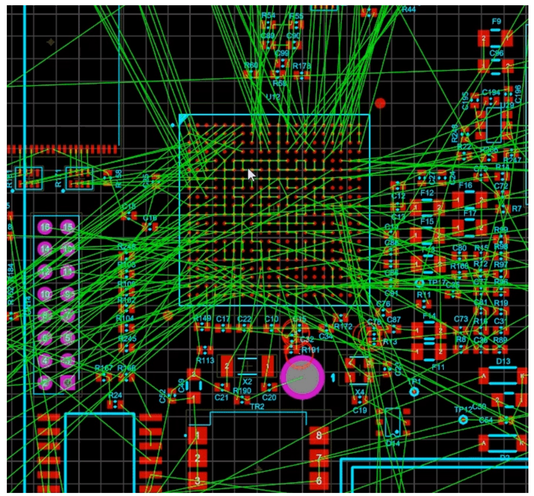
[3] K.-C. Chen et al, “Massive Figure Extraction and Classification in Electronic Component Datasheets for Accelerating PCB Design Preparation,” *in Proc. of MLCAD, 2021.*

Automation Opportunity – Auto Layout

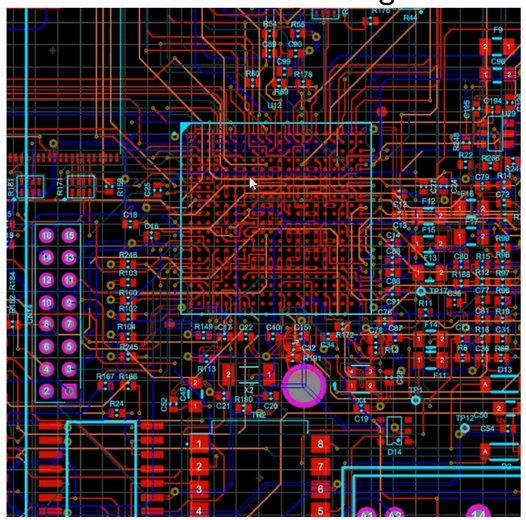
- Auto placement and routing solutions are investigated by EDA companies in decades, but it does not meet designers' expectation for general usage due to the following reasons
  - High placement and wire density
  - Custom rules
  - Intelligently use rule tolerance
  - Low return of investment

- Standardization is required

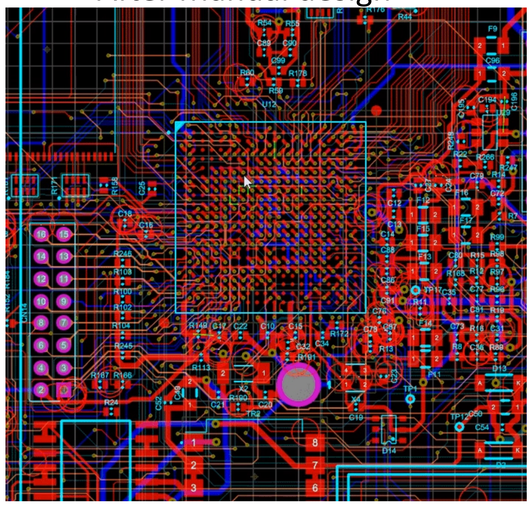
Unrouted design



Auto-routed design



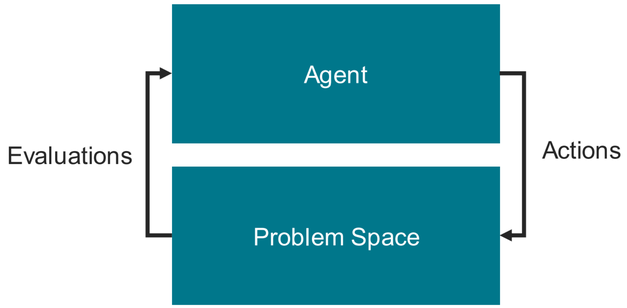
After Manual design

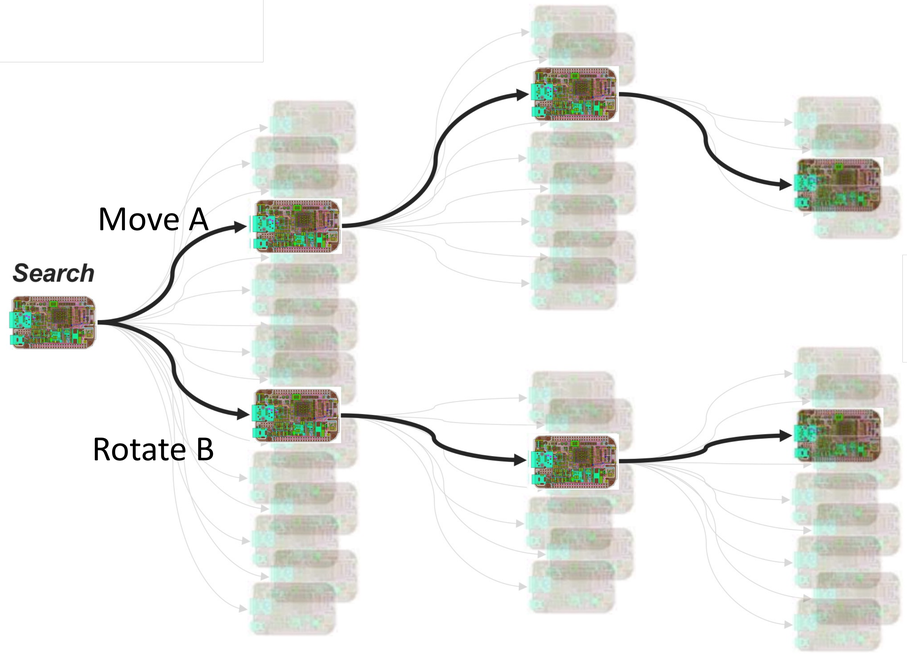


Automation Opportunity – Auto Layout

- PCB layout requires place-and-route co-design. There are several actions which are executed iteratively to approach good a solution.

- The work [6] suggested to use reinforce leaning agent to explore the best action according to the current situation.





[6] Taylor Hogan, “Goal Driven PCB Synthesis Using Machine Learning and Cloud Scale Compute,” *in Proc. of ISPD, 2023.*

Take Away

- Because the size of PCBs increases dramatically, the need of PCB automation becomes more and more critical
- Push-button solution may not be realistic at this movement, but we can consider automation engine as an assistant to help productivity
- There are several ML-based solutions which can help productivity for PCB design
- Standardization is necessary for automation