

# Essentials of PCB Design

01: PCB Basics

# instructors

a24



- WPI '26 (CS + RBE minor)
- President of WPI IEEE Chapter
- Internships: Apple, MITRE
- Lots of personal projects w/ custom PCBs
- Originally took a similar class at MIT

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# instructors

a24



- WPI '27 (CS + ECE)
- IEEE Events Chair
- Internships: Finwave semi, LongWave Photonics
- Lots of personal projects w/ custom PCBs
- Designed something going to the moon!!

**hubert liu**

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# about this class

## inspiration

Course inspired by [pcb.mit.edu](http://pcb.mit.edu) (thank you Fischer and Adi)

# about this class

## background

WPI will not teach you **practical skills**, even with it's 'projects'.

Most students don't have personal projects because they **lack these skills**.

# about this class

## goals

Our goals are to

1. To augment WPI's ECE curriculum by teaching **hardware design**.
2. To instill careful, elegant, and thoughtful design methodology.
3. Give you skills and inspiration to embark on your own projects.

**We need you to be active learners!**

# about this class

## goals

This class will not teach a scientific or rigorous method for designing PCBs.

**We're teaching hands-on, design-driven methods for creating PCBs for your projects.**

# **about this class**

## **pcb design as an art**

**PCB design is an art form.**

Your skills improve with practice and experience.

Every PCB has unique constraints which require thoughtful design.

Every PCB has a unique personal touch and attention to detail.

# about this class

## schedule

### A-Term

<b>Tue, Sep. 24</b>	Basics of PCBs <b>6-7PM; SH 301</b>
<b>Thur, Sep. 26</b>	Designing your Project <b>6-7:30PM; SH 201</b>
<b>Tue, Oct. 1</b>	Layout + Routing <b>6-7:30PM; SH 201</b>
<b>Thur, Oct. 3</b>	Working with KiCad <b>6-7:30PM; SH 201</b>
<b>Mon, Oct. 7 - Fri, Oct. 11</b>	Office Hours <b>TBD; IEEE Lounge</b>

### B-Term

<b>Mon, Oct. 21 - Fri, Oct. 25</b>	Office Hours <b>TBD; IEEE Lounge</b>
<b>Fri, Oct. 25</b>	Boards Due <b>By 10PM</b>
<b>Tue, Nov. 5 (Wellness Day)</b>	Assembly <b>TBD; AK 113</b>

# about this class

## office hours

- Office hours will be in AK 106 (IEEE Lounge)
  - **Finals week** - Mon, 10/7 - Fri, 10/11; Time TBD
  - **First week of B-Term** - Mon, 10/21 - Fri, 10/25; Time TBD
- We have an amazing TA!
- Feel free to stop by with any questions or if you need help!
- Or send us an email! ([gr-pcb@wpi.edu](mailto:gr-pcb@wpi.edu))

# **about this class**

## **materials**

All class content, including:

- Lecture slides
- Lecture recordings (Echo360)
- Datasheets/Resources
- PCB files

Will be posted at [github.com/ieee-wpi/pcb](https://github.com/ieee-wpi/pcb)

**Required software:** KiCad ([kicad.org/download/](http://kicad.org/download/))

# about this class

## prerequisites

- We don't have time to teach you circuit design :(
- You should have a basic understanding of:
  - Passive components (resistors, capacitors)
  - Microcontrollers
  - Digital signals
  - Programming in C/C++

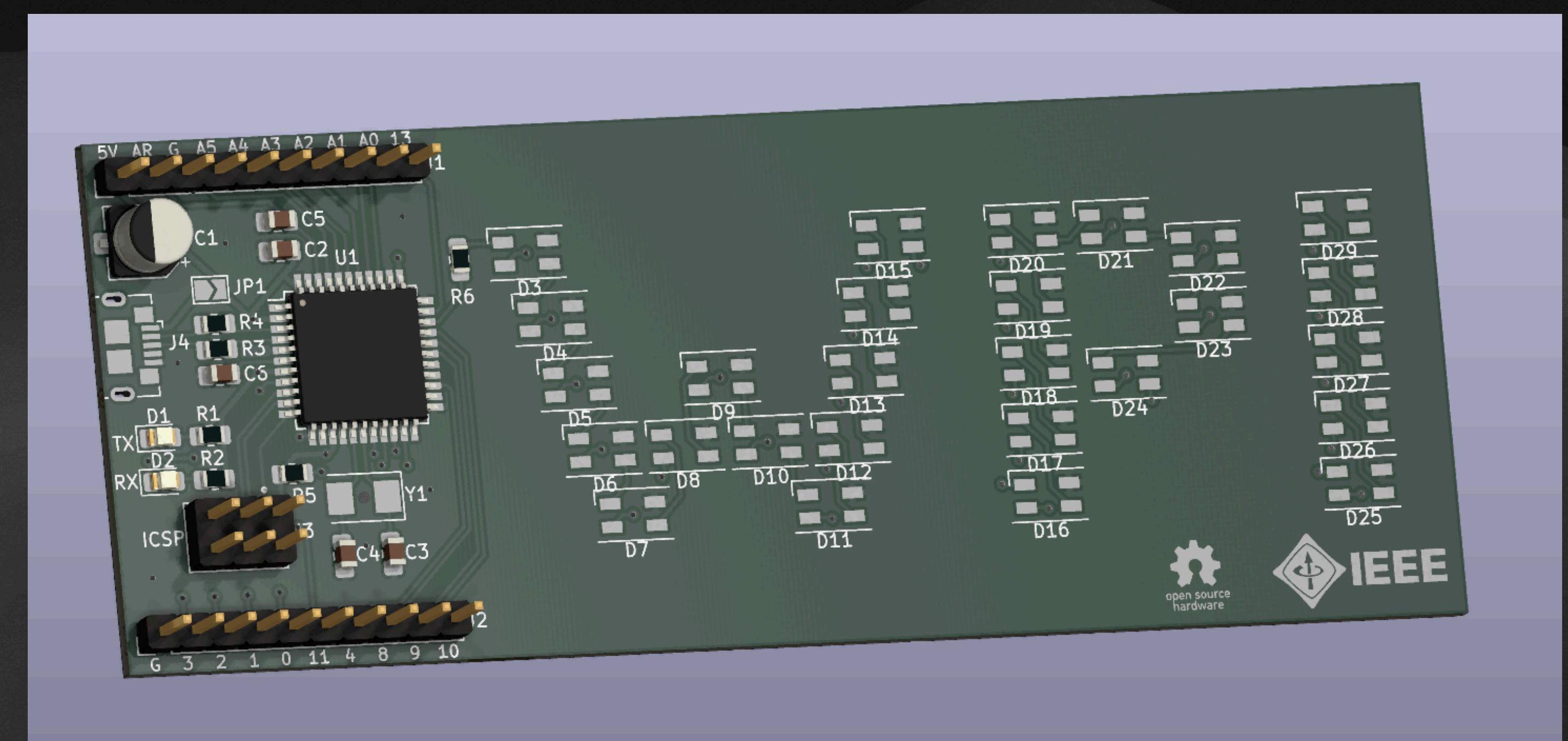
# about this class

## deliverable

You will be building a simple embedded system.

You'll layout the entire board, including a custom LED pattern, and peripherals of your choosing.

You'll program an LED pattern in C++ (we'll provide starter code).

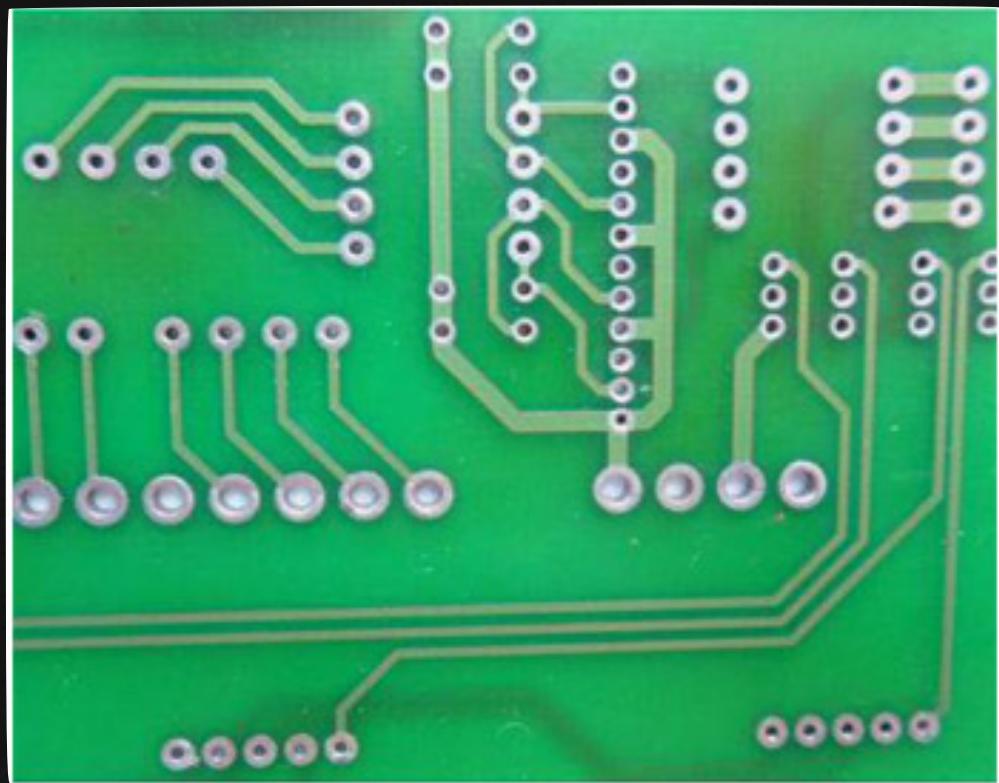


We will do our best to help you!

# what is a PCB

## the basics

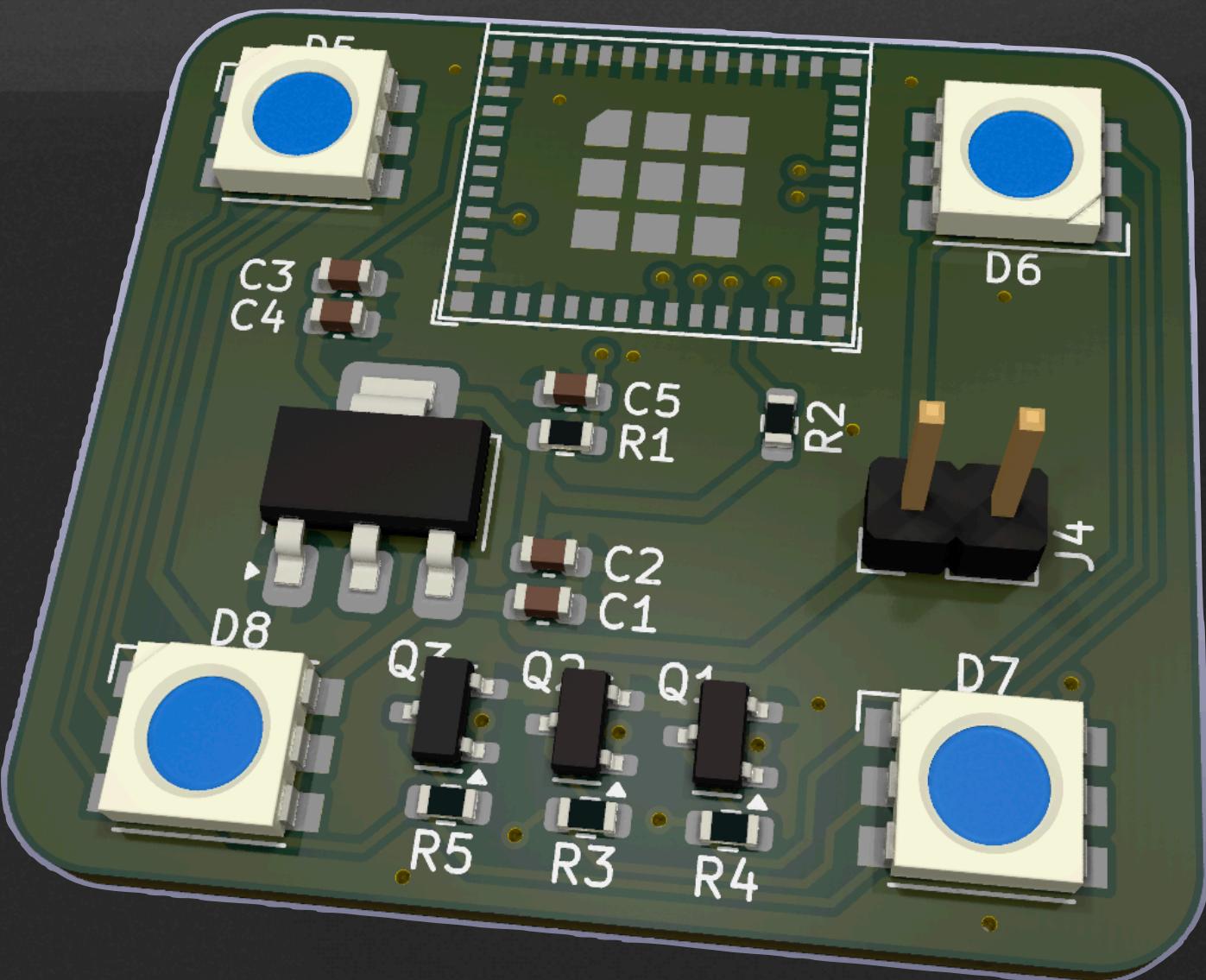
- PCB = printed circuit board
- A way to connect components!
- Functionally the same as...
  - solderless breadboards
  - solderable breadboards
  - perfboard



# why make a PCB?

## the basics

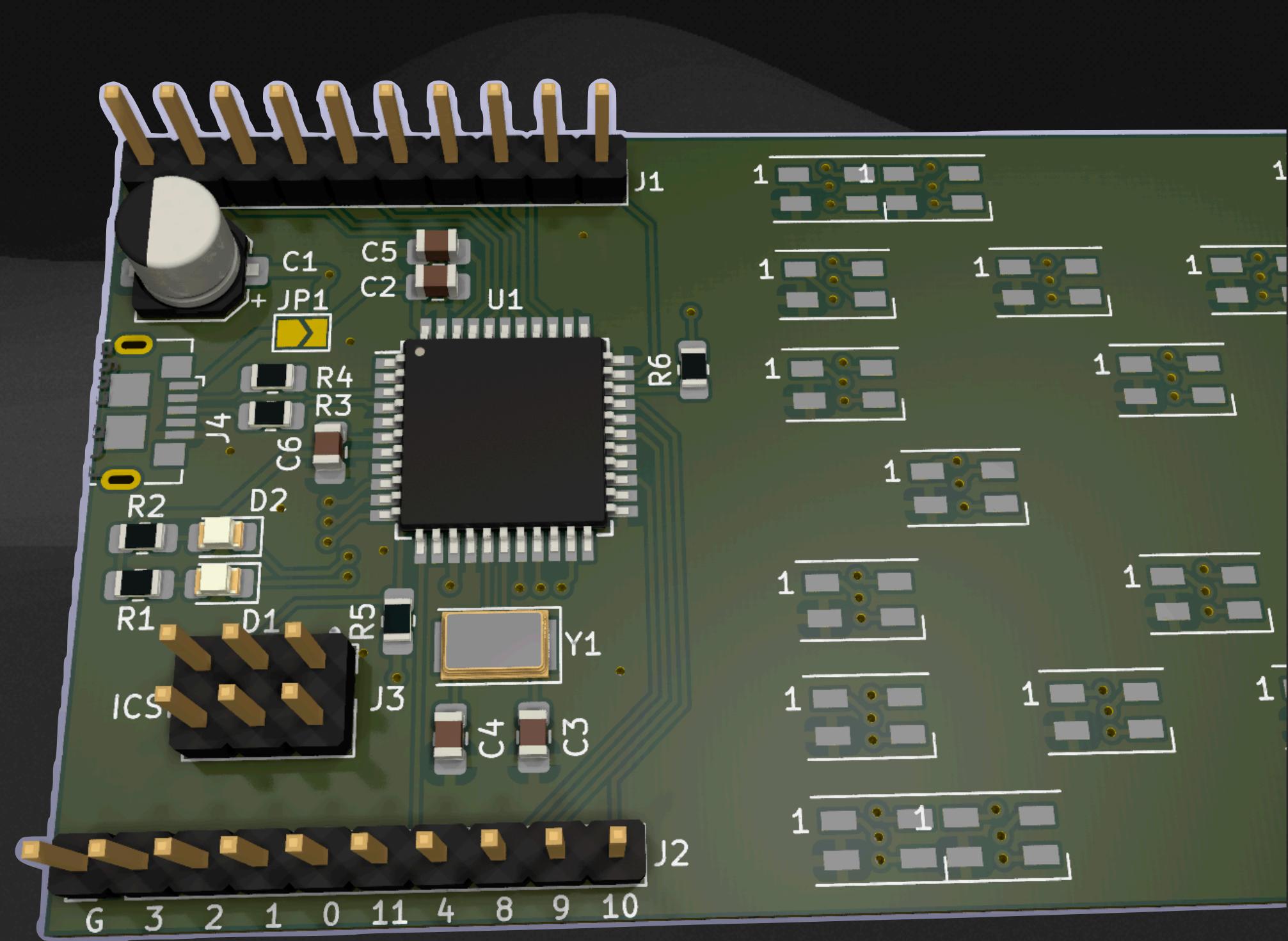
- Transform an idea from a breadboard prototype into a refined product
- Increased part availability
- Scalable for mass production
- Allows for complicated connections
- Denser than other platforms
- Entire process can be automated



# what goes on a PCB

## components

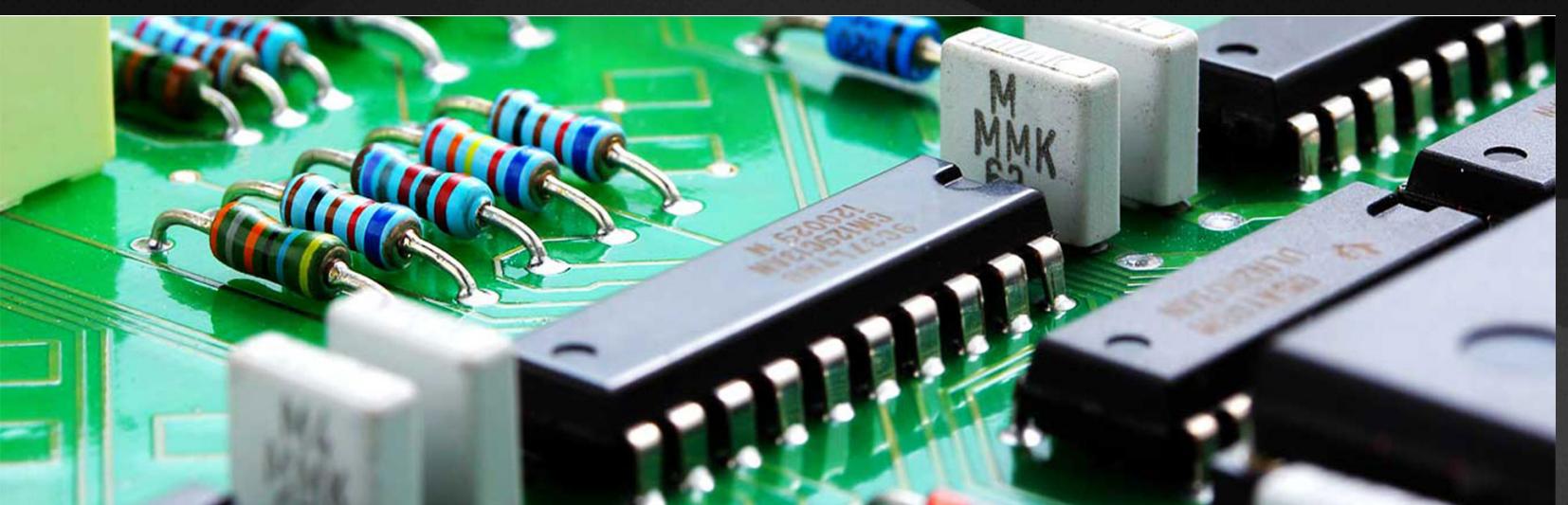
- **Passive parts**
  - Resistors, capacitors, inductors, crystals
- **Active parts** (*anything that requires power*)
  - Transistors, diodes, integrated circuits, voltage regulators
- **Mechanical parts**
  - Switches, connectors, mounting holes



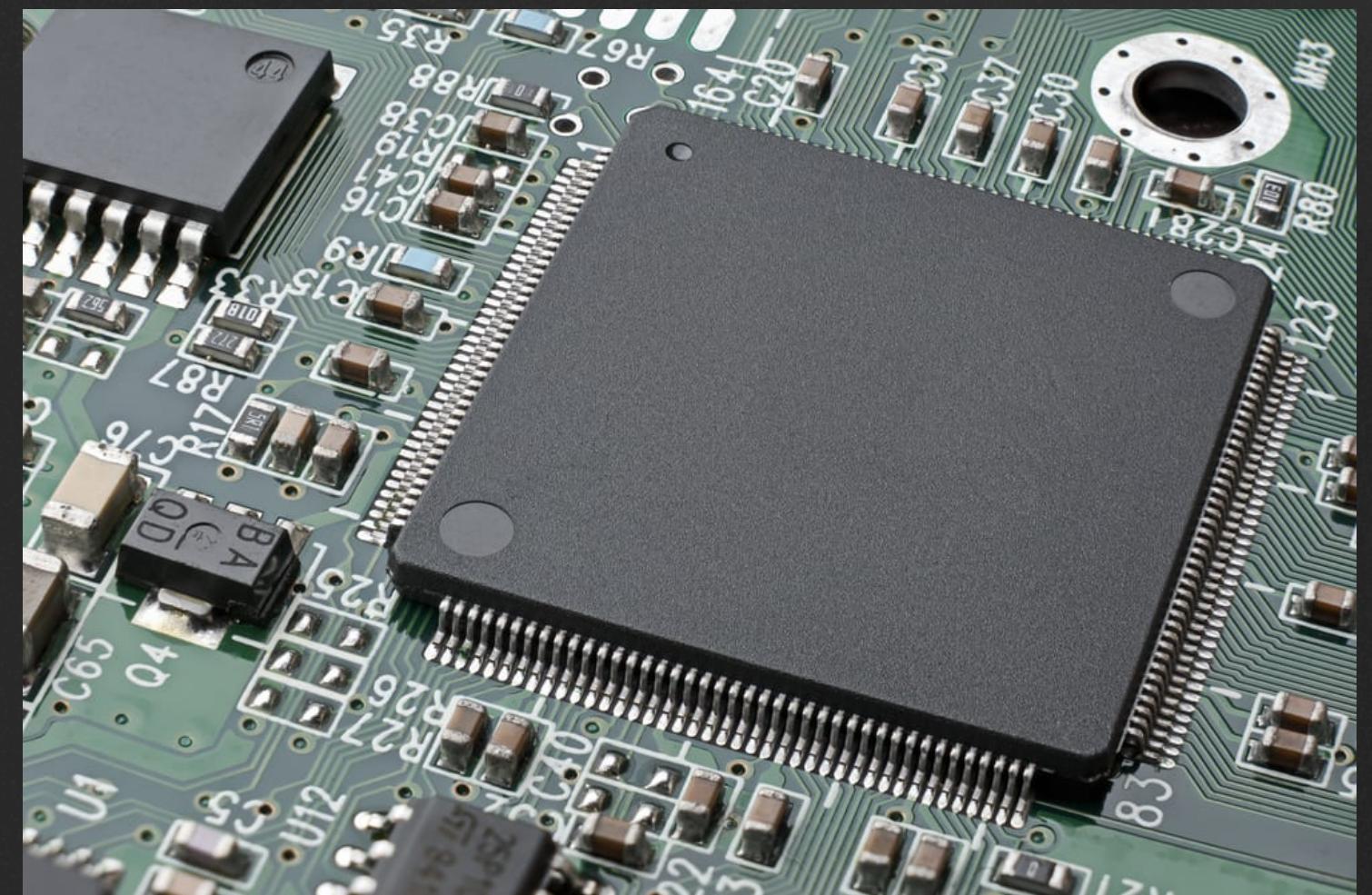
# types of components

## tht vs smt

- **THT = through hole technology**
  - Component legs put in holes drilled through PCB
  - Easy to solder by hand, larger components



- **SMT = surface mount technology**
  - Component legs solder onto pads on PCB surface
  - Easy for machines to solder, smaller components



**LAYERS    THICKNESS****2 LAYER RIGID PCB STACK-UP****LAYER DEFINITION**

0.80

Solder Mask

Mask

L1 2.00

Copper

Layer 1

59.00

FR4 / Dielectric

L2 2.00

Copper

Layer 2

0.80

Solder Mask

Mask

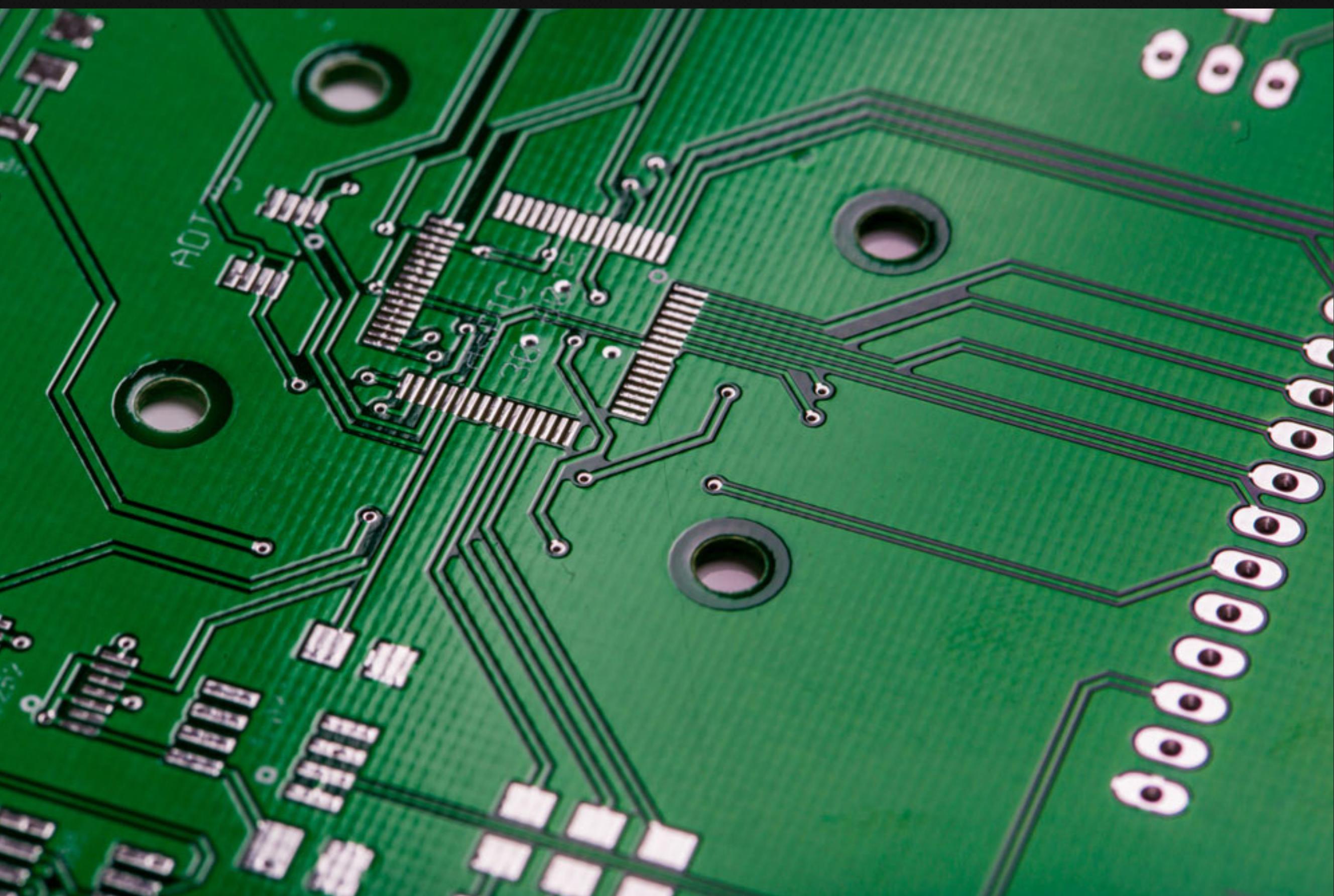
**TOTAL THICKNESS WITH MASK: 63.800 mils**

**Notes:** Outer layer copper thickness is 1/2 oz before plating. Finished outer layer CU thickness is approximately 1.4 to 2.2 mils after plating.

# pads

the things that components go on

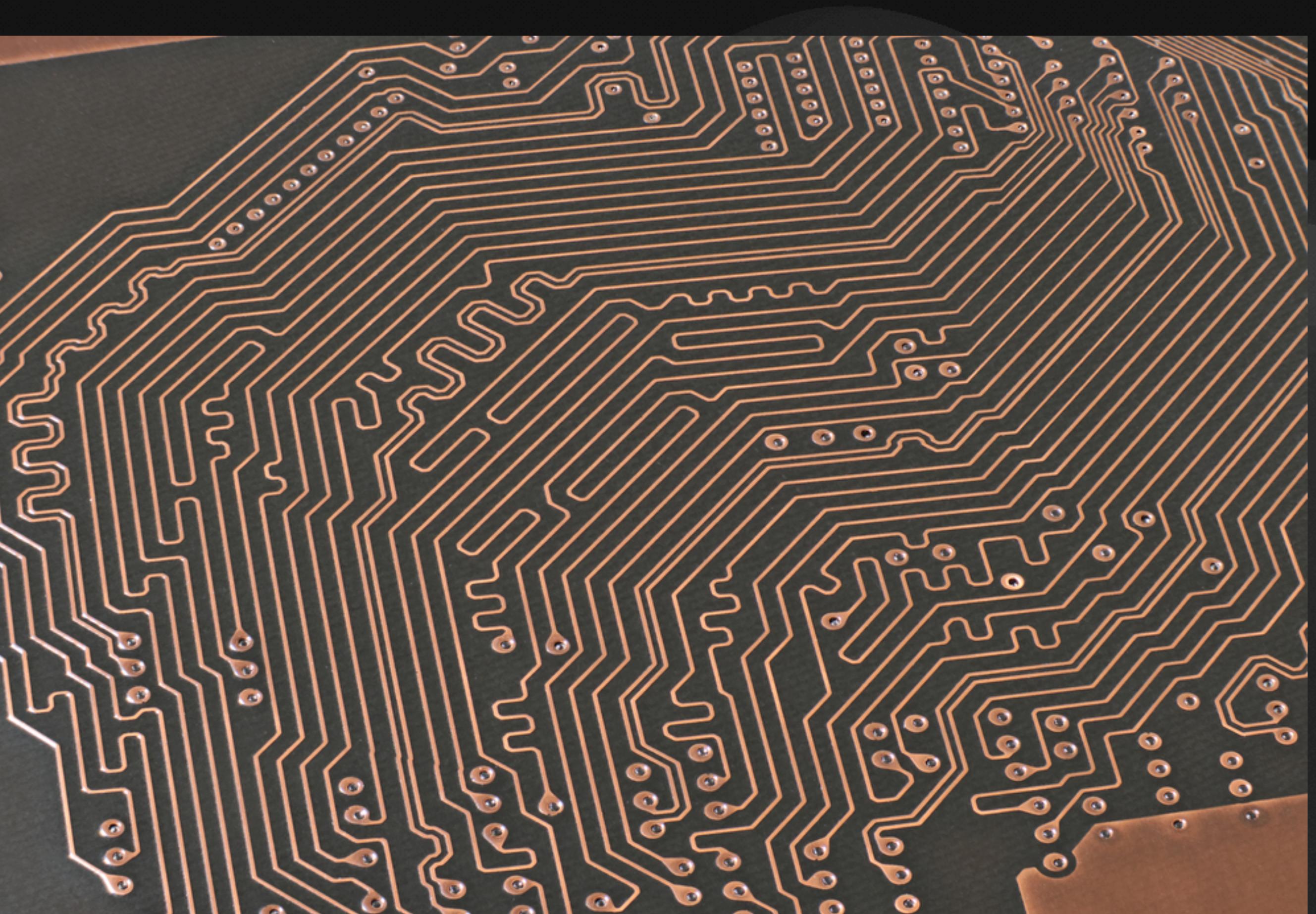
- The thing the component connects to
- The goal of a PCB is to connect traces to each other as defined by the schematic
- Come in all shapes and sizes depending on component



# traces

they connect pads

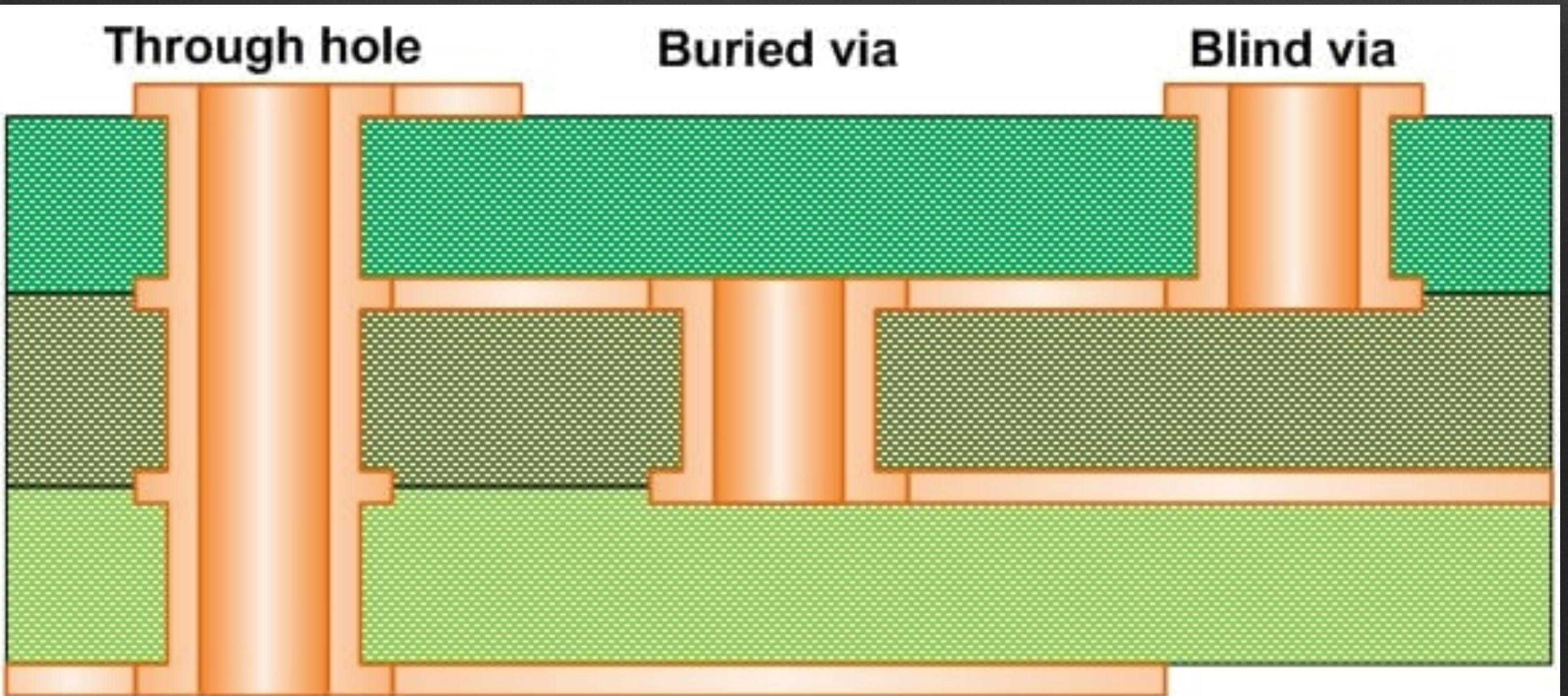
- This is what makes PCBs so useful!
- Usually straight lines with 45 or 135 degree bends
  - Why not 90 degrees?
- Wider trace width = **less** resistance
- Lower trace length = **less** resistance



# vias

they connect layers

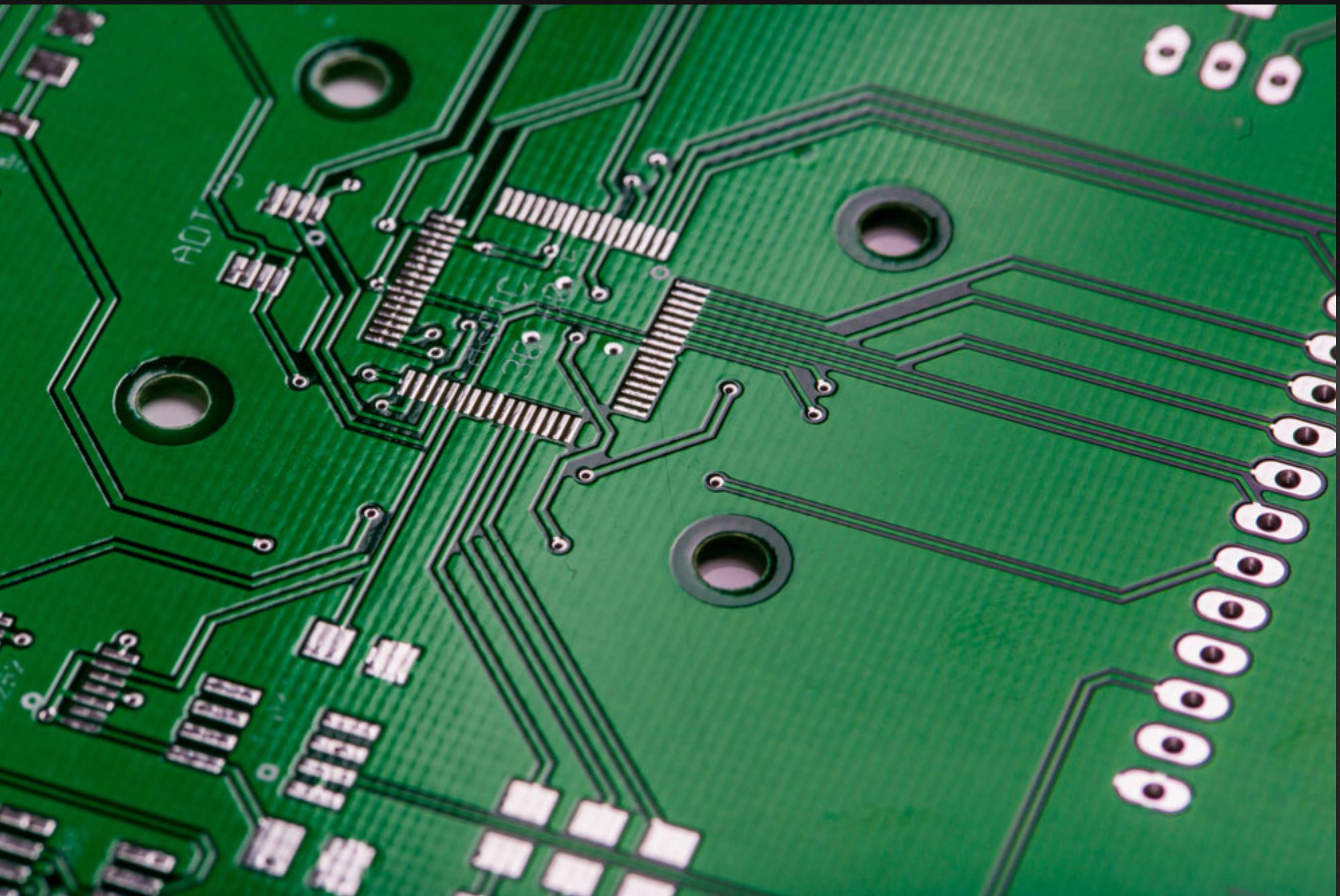
- Connect traces on different layers
- Through holes (normal) vias
- Blind vias (\$)
- Buried vias (\$\$\$)



# planes

big areas of copper

- Good practice to have a ground plane to reduce noise
- Nice to have a power plane
- Signal planes are nice to have!  
Usually not used in 2-layer pcbs
- Planes make routing much easier!



# solder mask

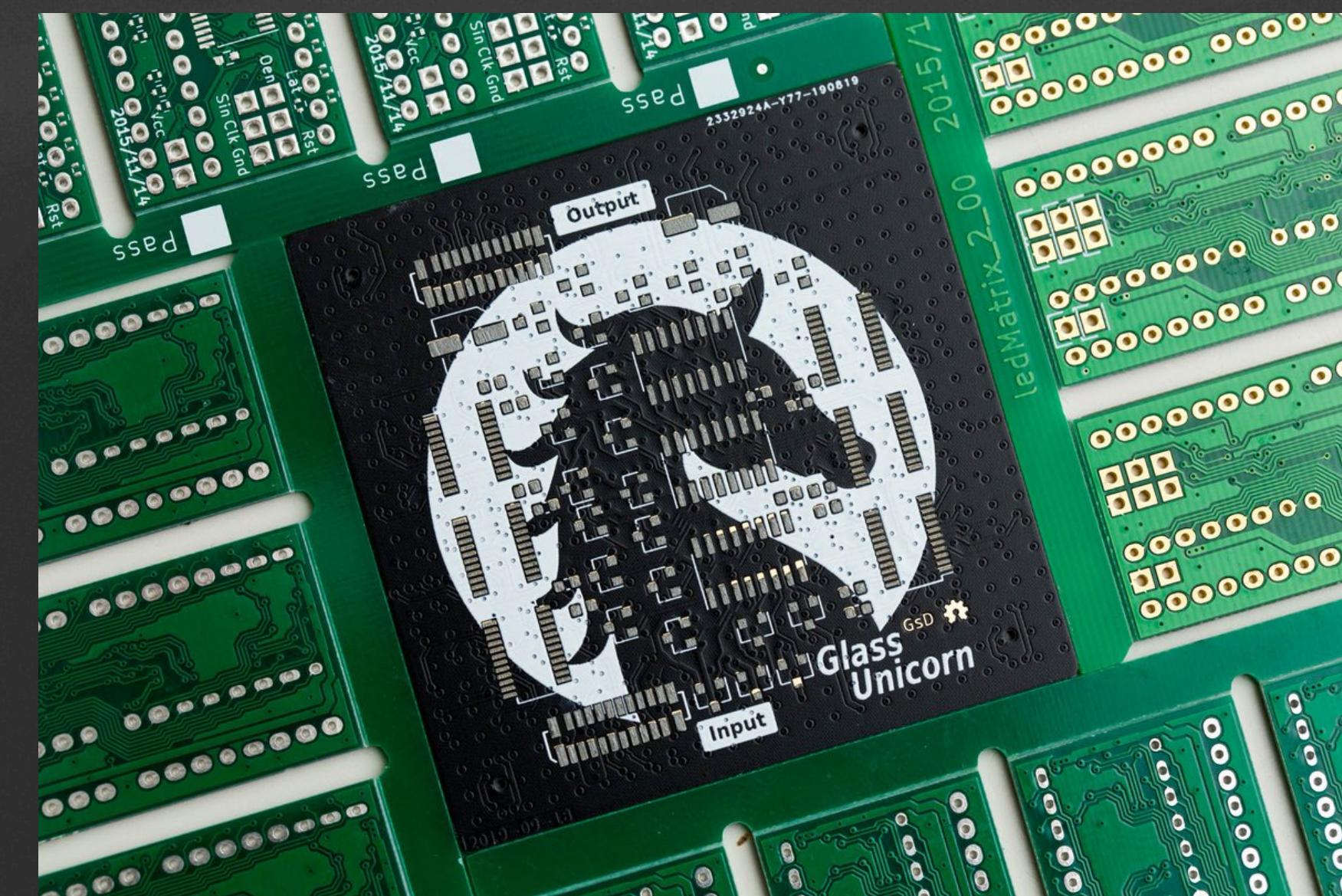
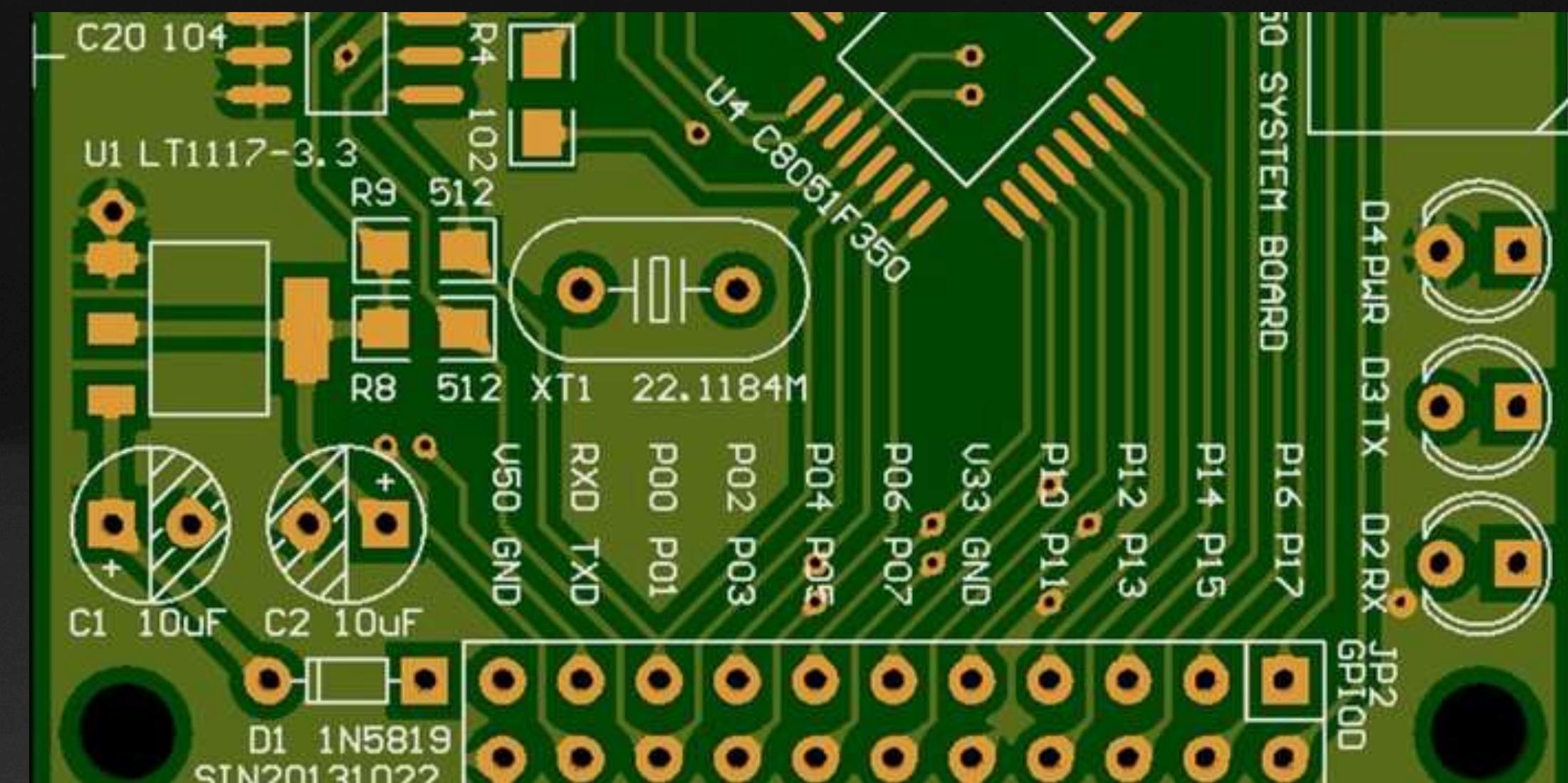
the thing that keeps solder from going everywhere

- Protects your board
- Prevents trace oxidation
- Prevents solder riding
- ‘Painted’ on
- COLORS



# silkscreen labels and art!

- Typically printed on with inkjet style printed
- You can do cool art!

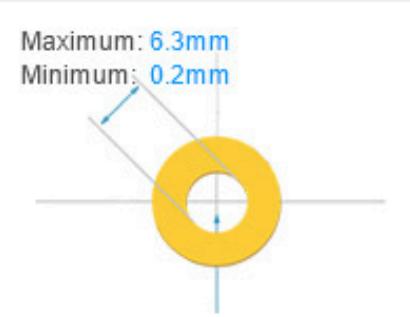
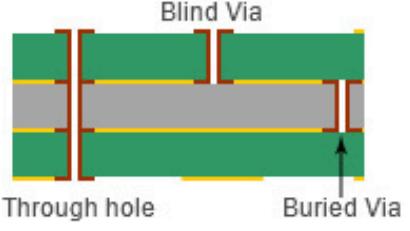
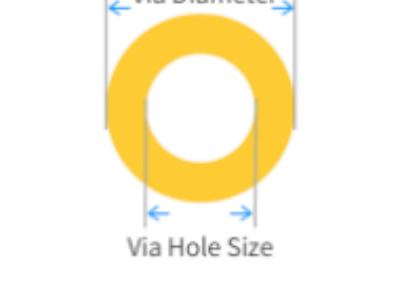
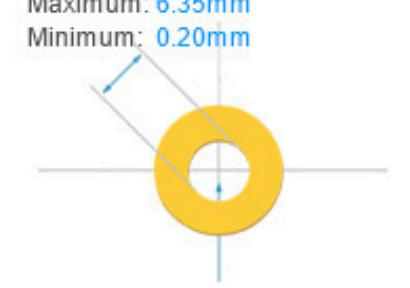
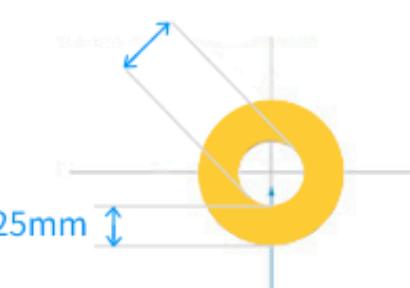


# tolerances

## the stuff the manufacturer cares about

- The boring stuff: layer count, max dimensions
- Via diameters
- Clearances
- Trace width and spacings
- Solder mask
- Silkscreen

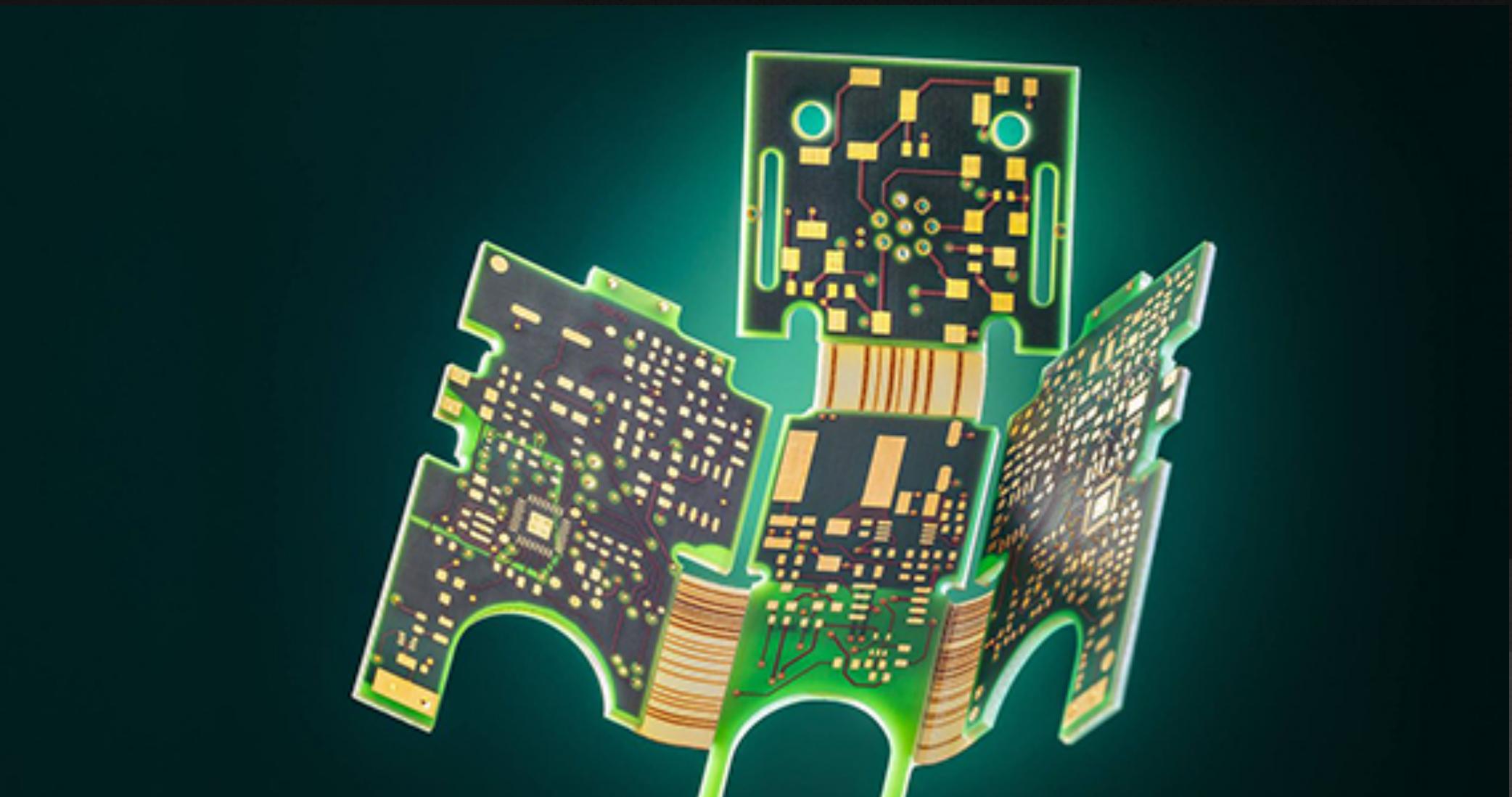
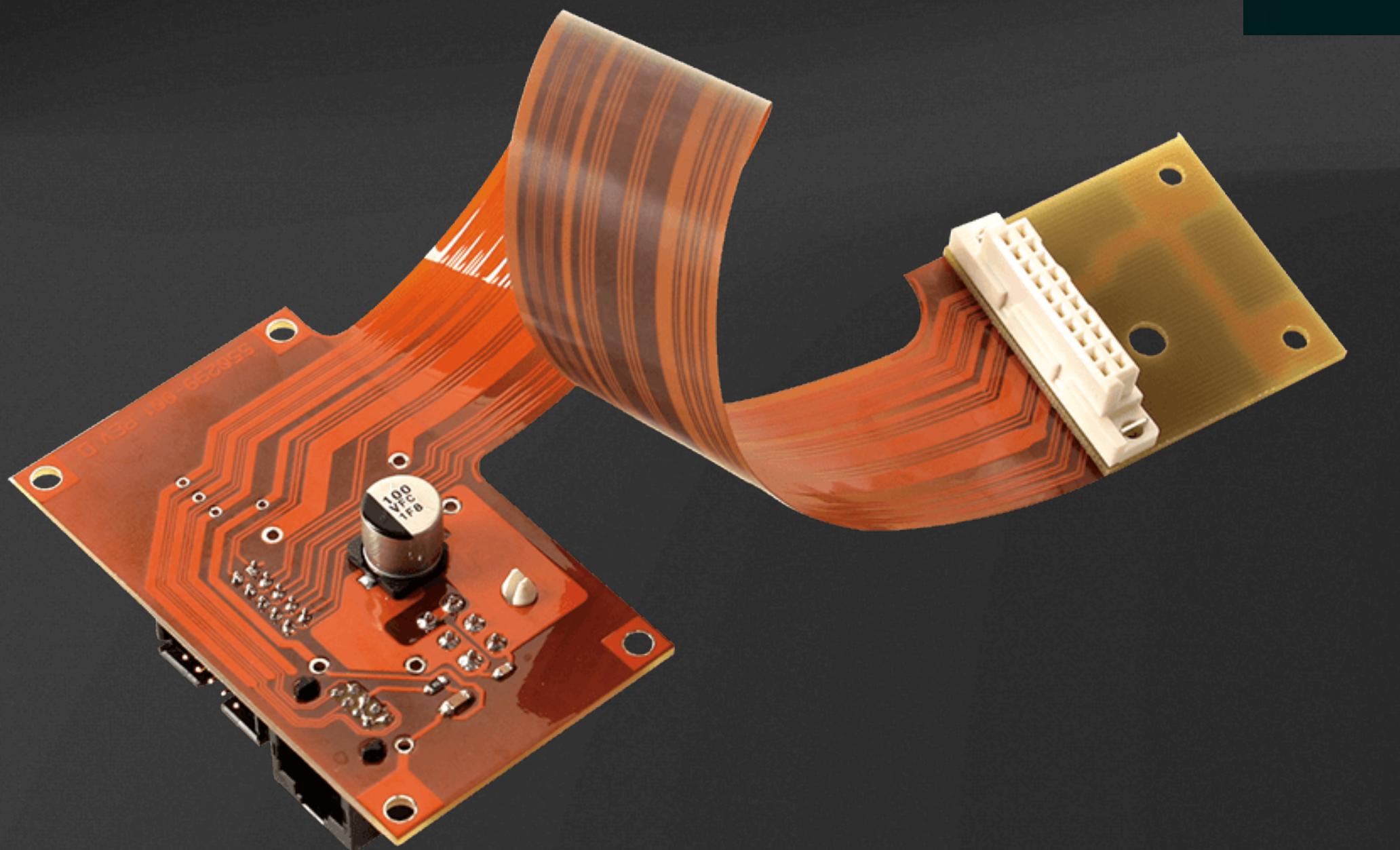
# tolerances from jlpcb

Features	Capability	Notes	Patterns
Drill Hole Size	0.15mm - 6.30mm	1 & 2 Layer PCB: 0.3 - 6.3mm Multi-Layer PCB: 0.15 - 6.3mm (0.15mm more costly)	
Drill Hole Size Tolerance	+0.13/-0.08mm	e.g. for the 0.6mm hole size, the finished hole size between 0.52mm to 0.73mm is acceptable.	
Blind/Buried Vias	Don't support	Currently we don't support Blind/Buried Vias, only make through holes.	
Min. Via hole size/diameter	0.15mm / 0.25mm	- 1 & 2 Layer PCB: 0.3mm(hole size) / 0.5mm(diameter)  - Multi-Layer PCB: 0.15mm(Via hole size) / 0.25mm(Via diameter) ① Via diameter should be 0.1mm(0.15mm preferred) larger than Via hole size ② Preferred Min. Via hole size: 0.2mm	
PTH hole Size	0.20mm - 6.35mm	The annular ring size will be enlarged to 0.15mm in production.	
Pad Size	Minimum 1.0mm	The pad size will be enlarged by 0.5mm than the hole size. The minimum size of annular ring around plated through hole pads is 0.25mm. If the recommended sizes are not respected then the pad will not be produced properly.	

# base materials

the stuff that everything is built on

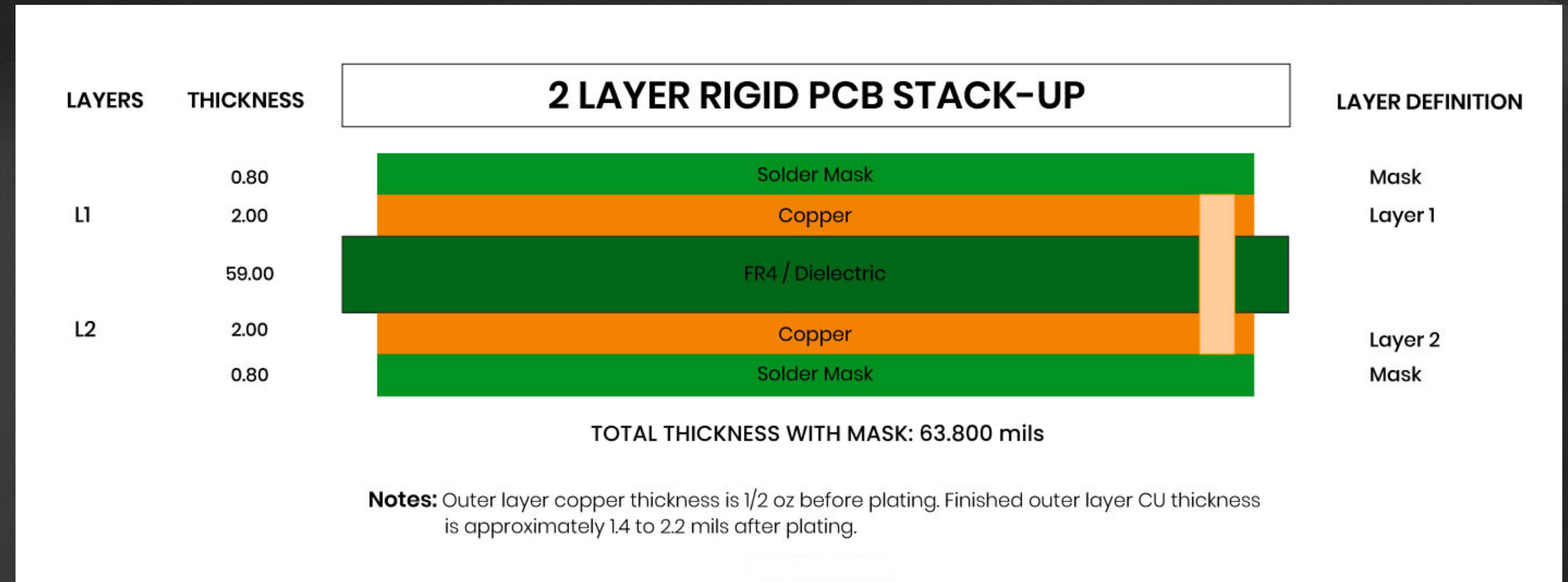
- FR-4 (we will be using this)
- Flex
- Rigid flex
- Others



# types of PCBs

there are many

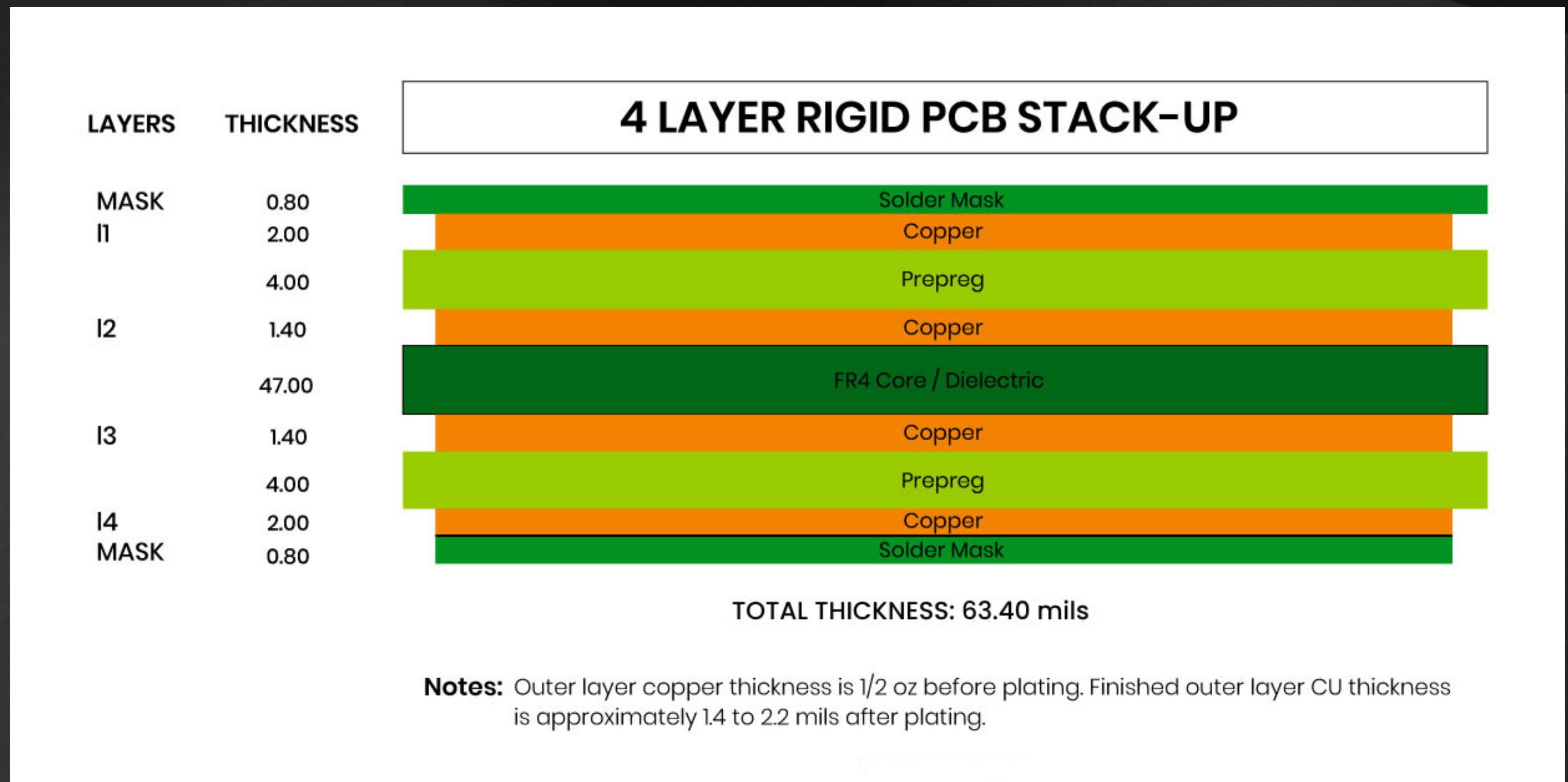
- 2 layer PCB



# types of PCBs

there are many

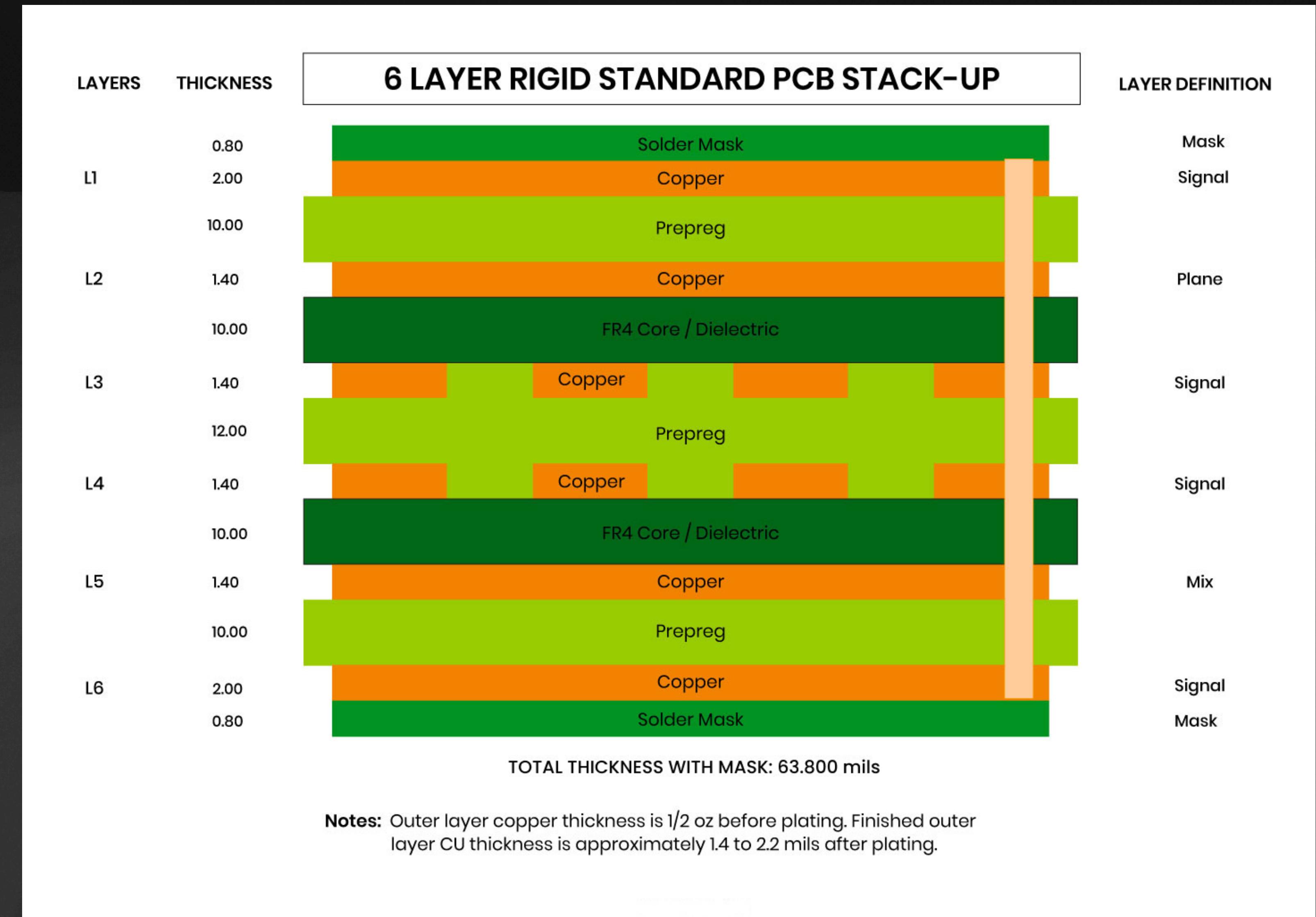
- 4 layer PCB



# types of PCBs

## there are many

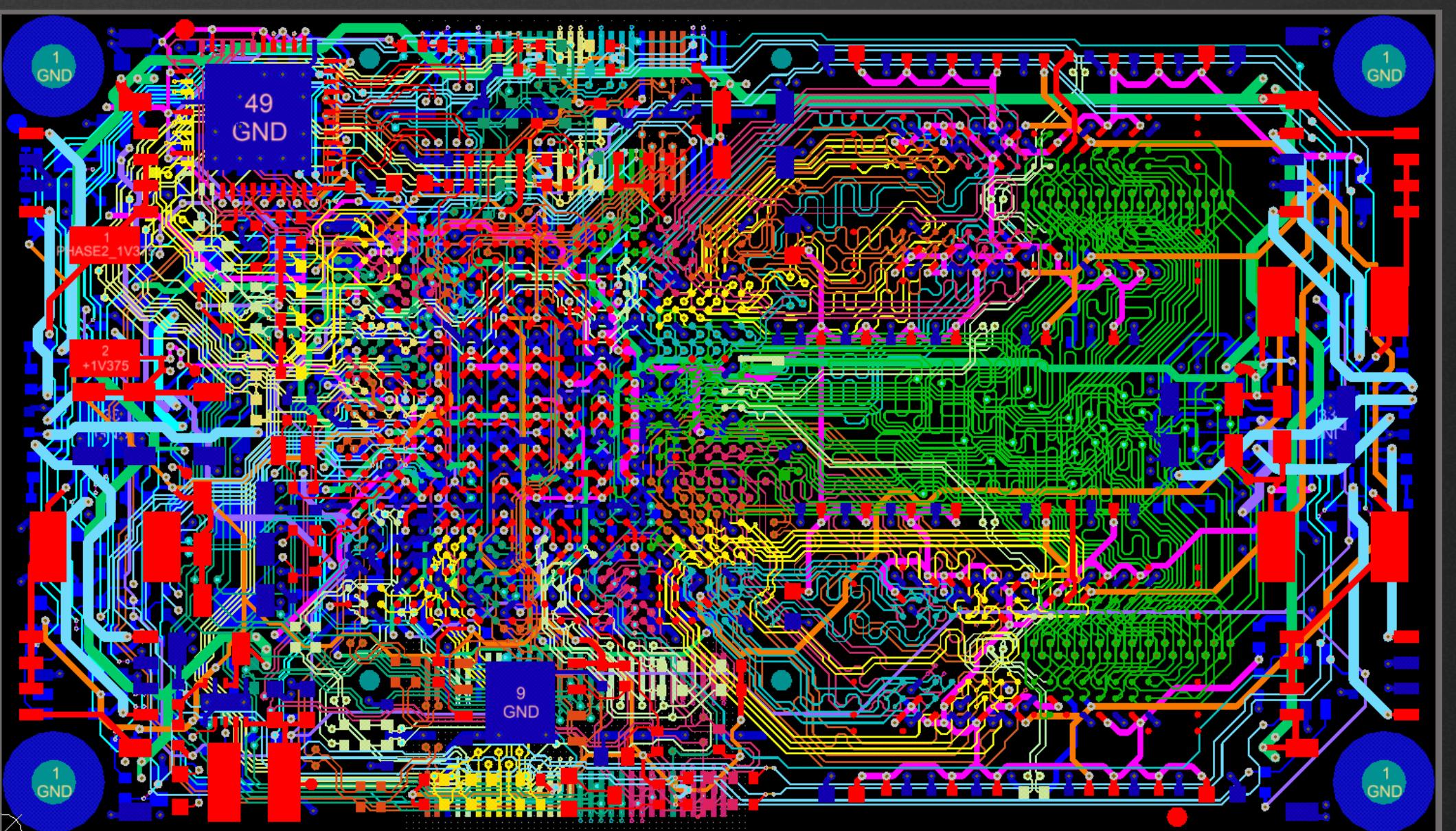
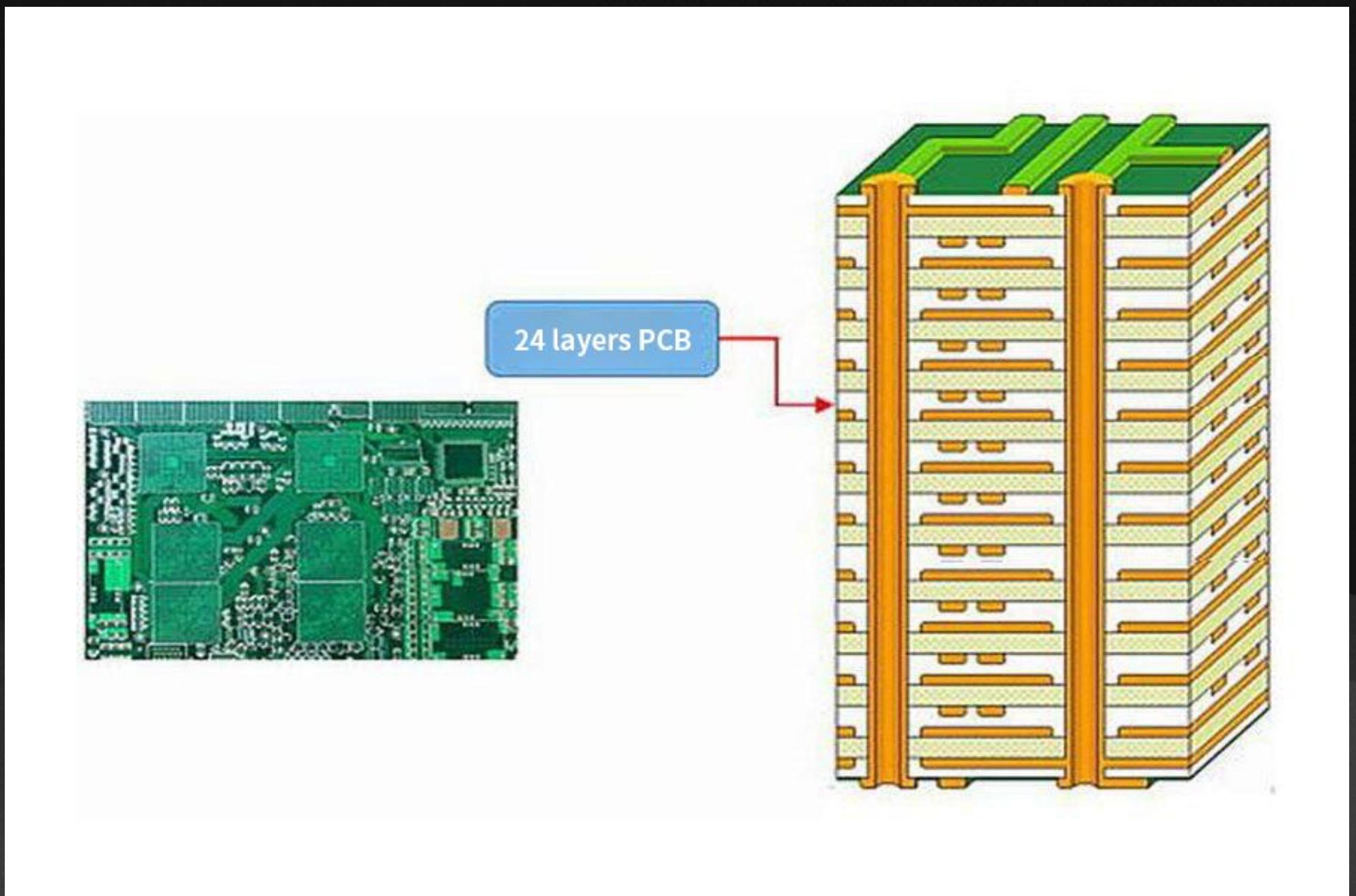
- 6 layer PCB



# types of PCBs

there are many

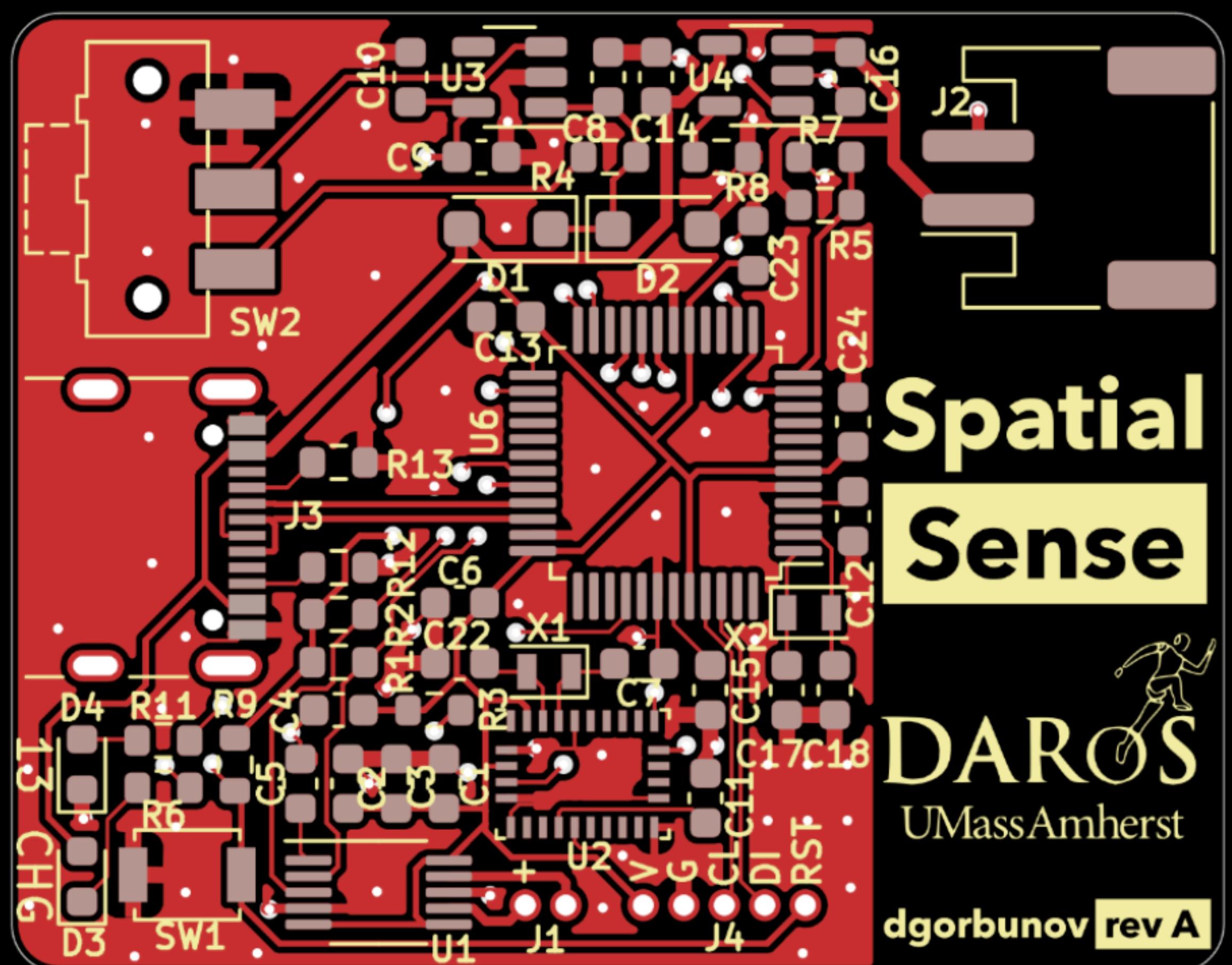
- 20+ layer PCBs
- Computing hardware



# example board

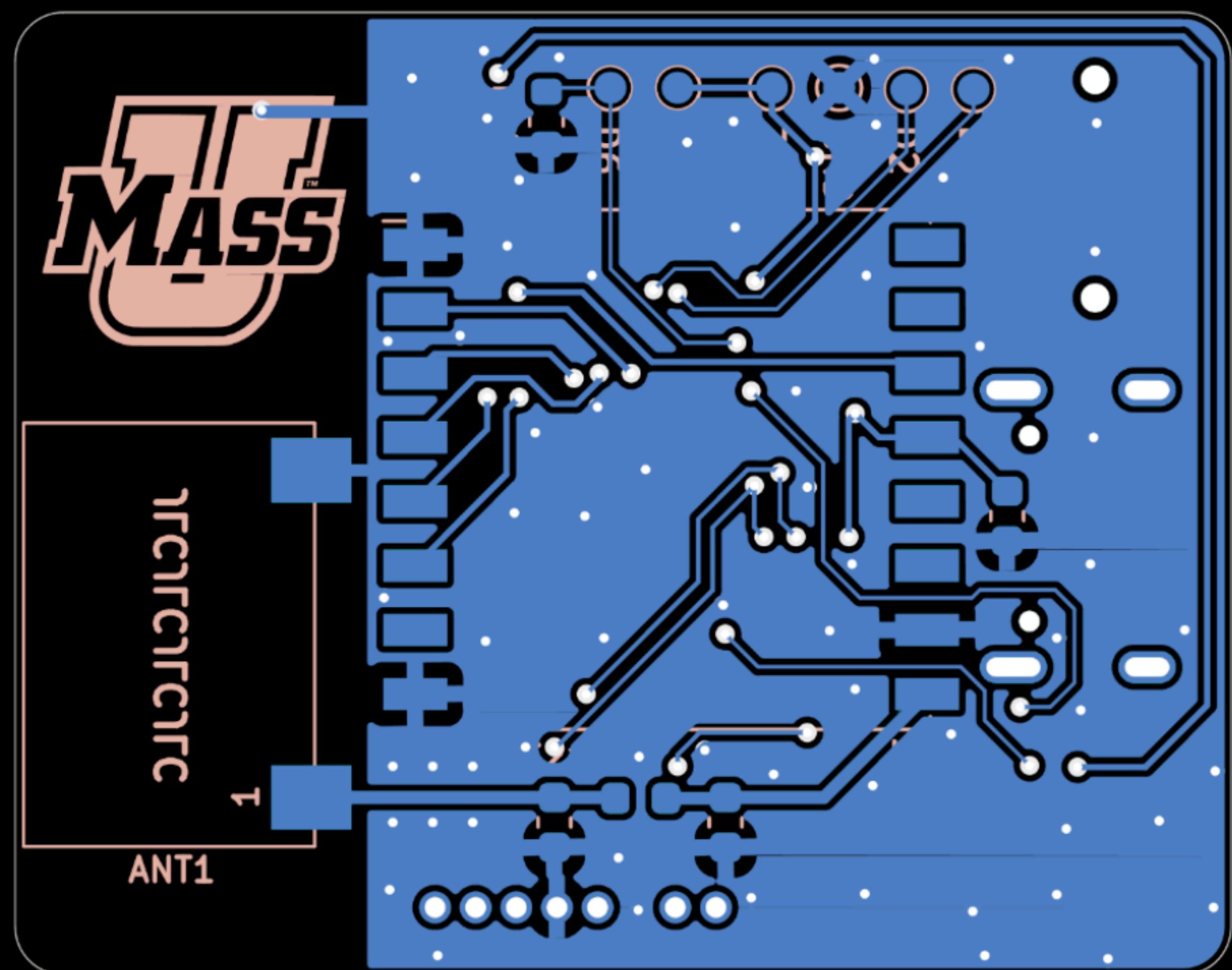
Front

30mm



38mm

Back



# who needs layers?

## the problem of intersections

- THT wastes valuable space by drilling through all layers
- SMT components allow traces to be routed on reverse side
- Traces cannot intersect! More layers gives us more options.
- Higher **board complexity = More layers**

# manufacturing

## how the board is made

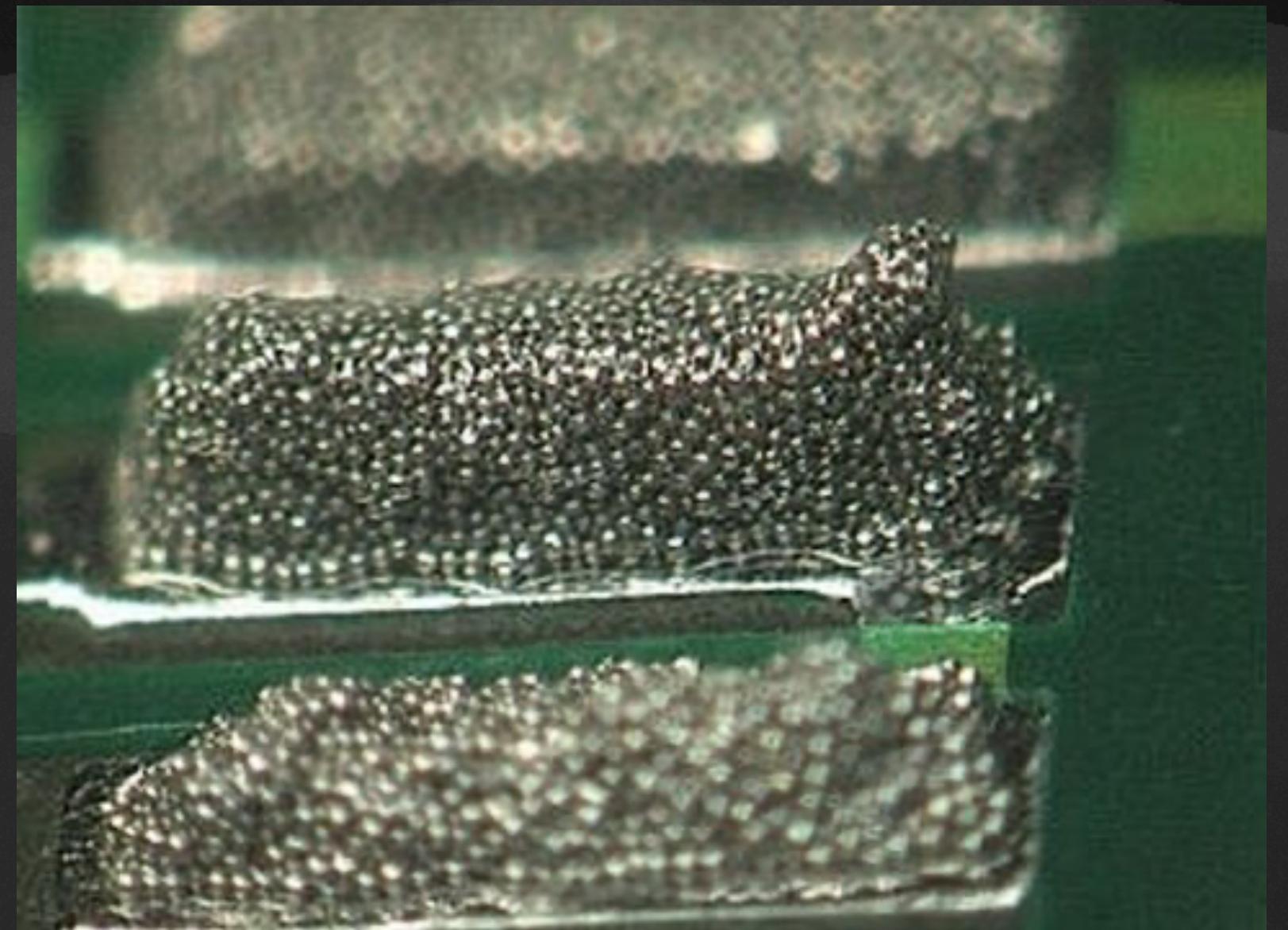
- China has brought consumer PCBs down to \$2/5 boards



# assembly

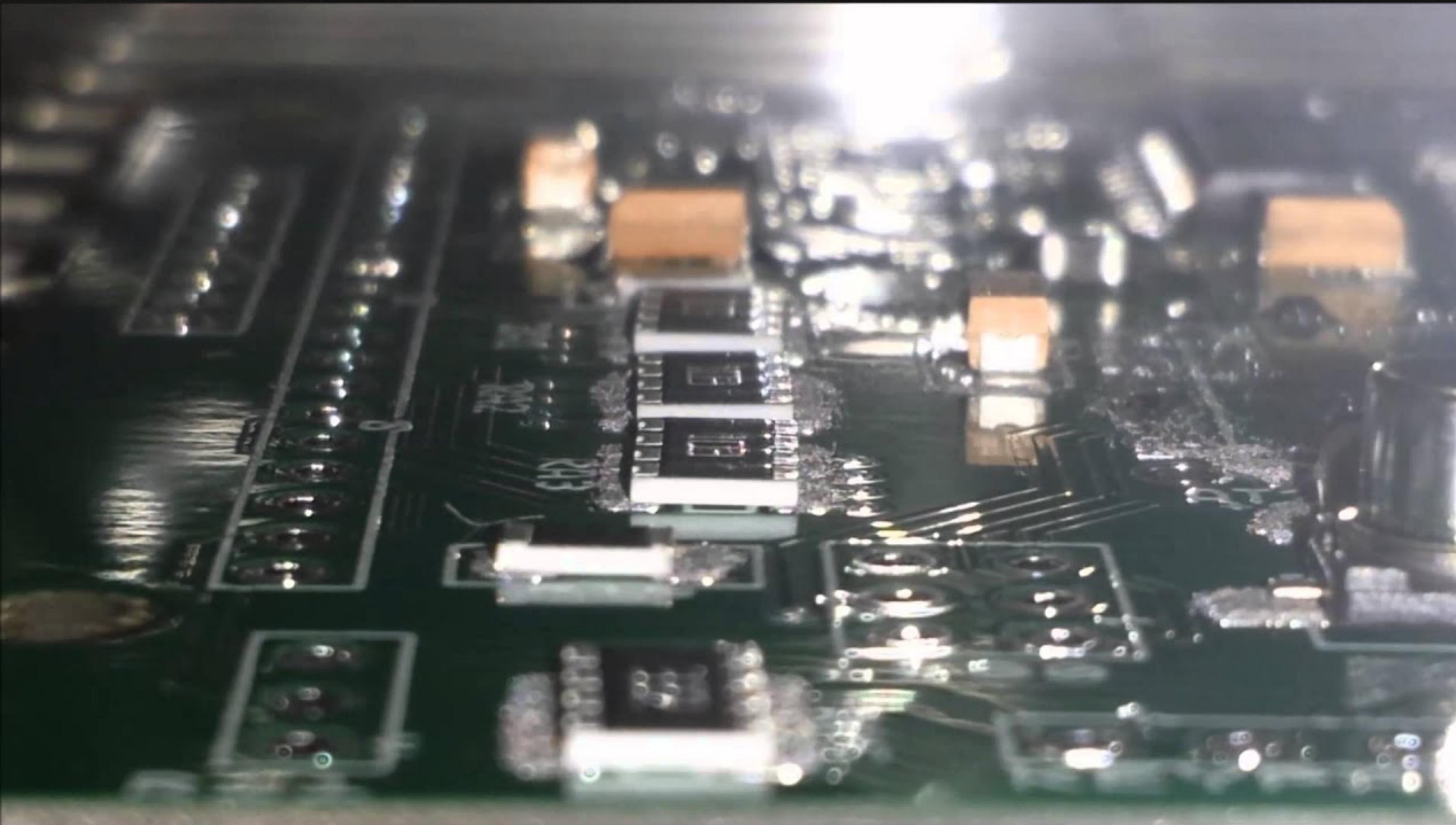
## how to put components on

- **THT** components usually soldered **by hand** (even in factories!)
  - Good, old fashioned soldering iron
- To place **SMT** components, we use **solder paste**
  - Balls of solder powder and flux
  - Flux allows solder to flow onto pads
  - Components placed on solder paste
  - High temp. → solder flows between pads and comp. legs



# reflow soldering

you will be doing this!



# automated assembly

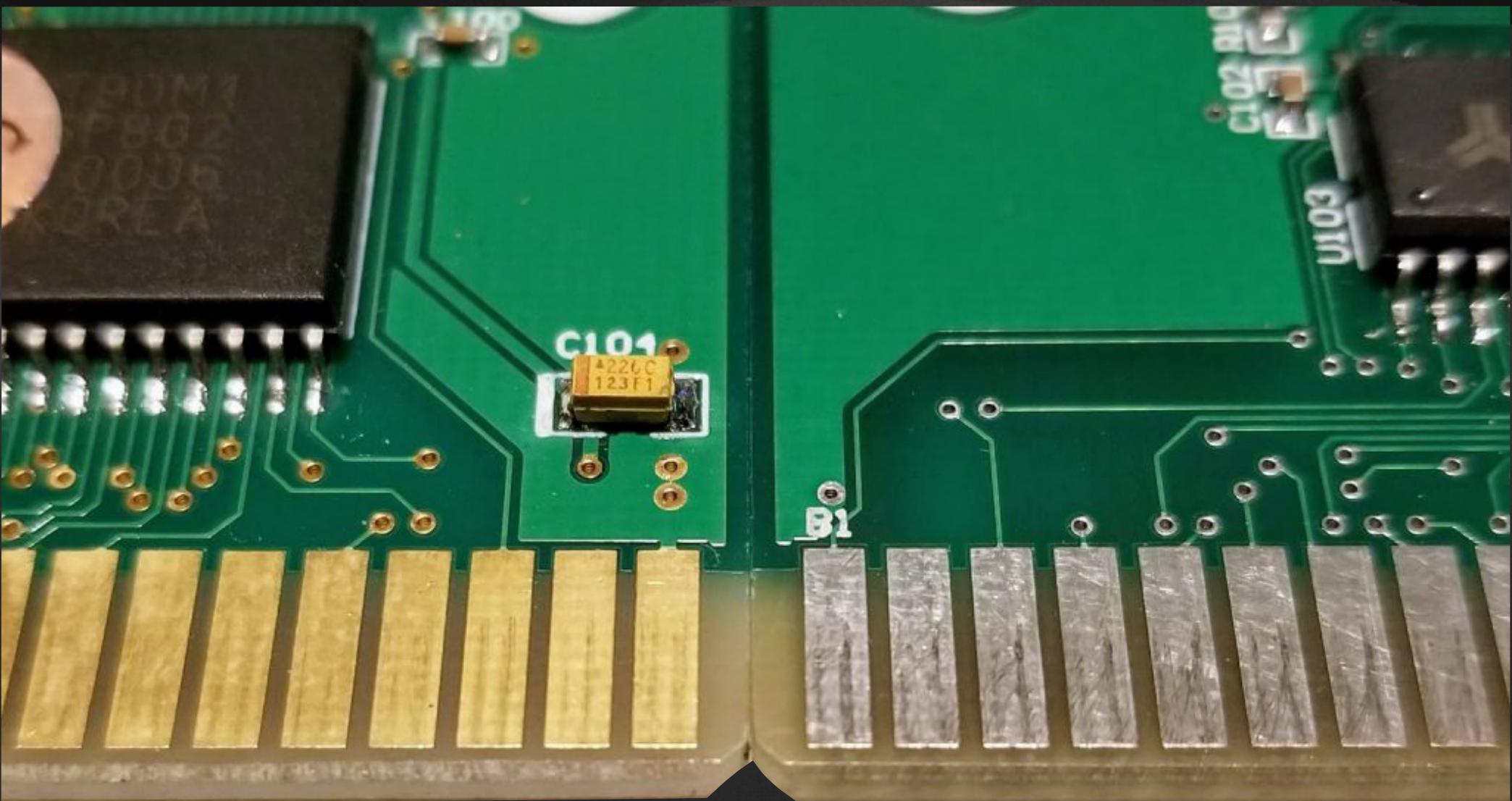
## pick and place, reflow oven



# finishes

## the stuff that makes soldering easier

- **HASL** = hot air surface leveling
  - dip board in molten solder, level pads with hot air
  - pads can have uneven surfaces
- **ENIG** = electroless nickel with immersion gold (\$)
  - apply thin layer of electroless nickel, then immerse board in gold solution
  - pads don't have a thickness to them



# class PCB

what you will be making

- Steps of PCB Design:

- Circuit Design
- Schematic Capture
- Layout
- Routing
- Order
- Assembly

