

# Essentials of PCB Design

02: Project Design

# 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>

# course tracks

choose one!

## Track 1

**Recommended if you've never designed a PCB.**

Use the class LED board schematic. Lay out the PCB with your own design, and we'll help you add any extra peripherals/features.

## Track 2

**You've designed a PCB before, or have extensive knowledge of circuit design.**

Design your own schematic and board, up to 102x102mm, and we'll fund it. You'll have to fund any extra components.

# course updates

## lecture 02

- Register for the class to be added to the email alias!
- Lecture 1 feedback 
- Please stop us during lecture and ask questions!



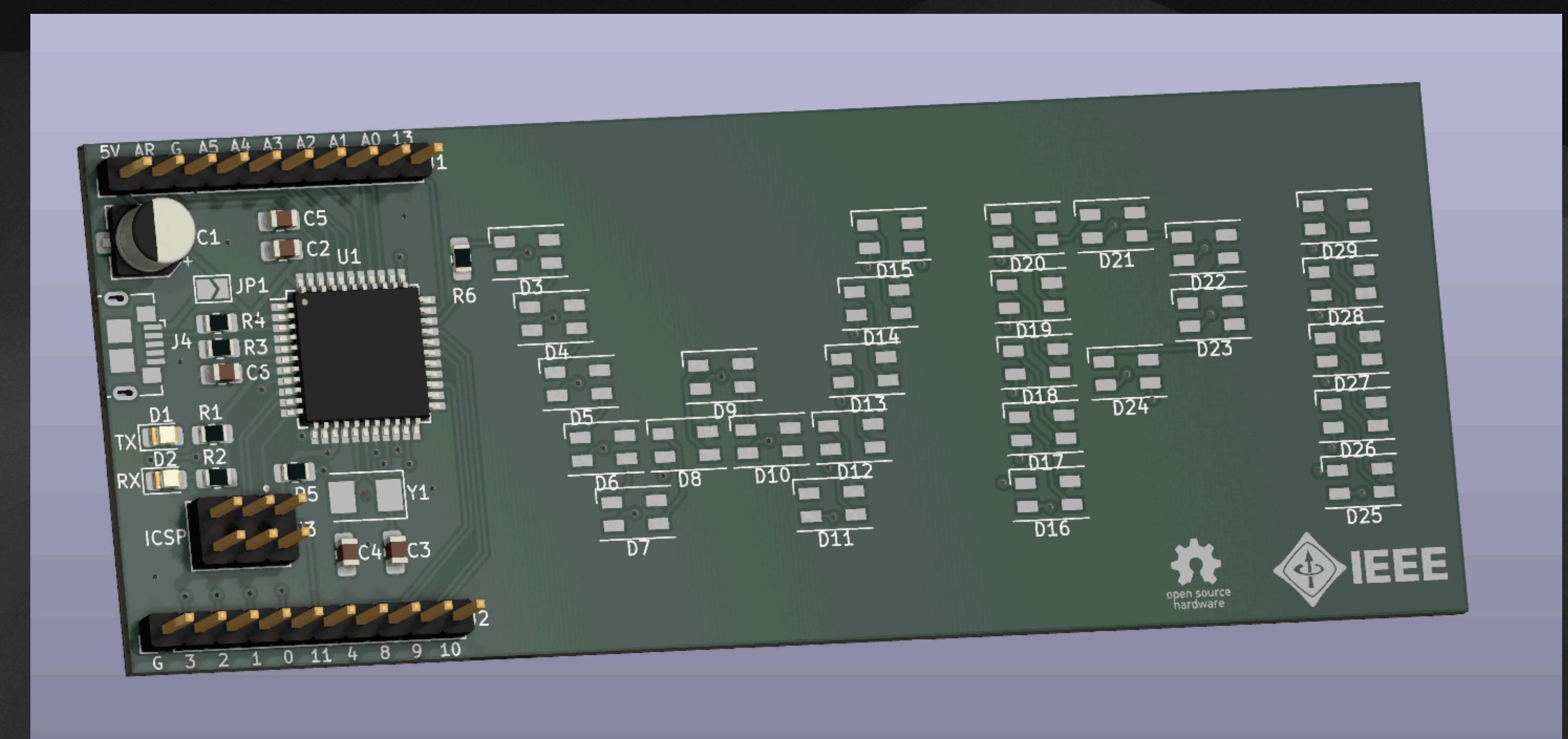
**Track Registration**

# track 1 board

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!

# lecture 1 recap

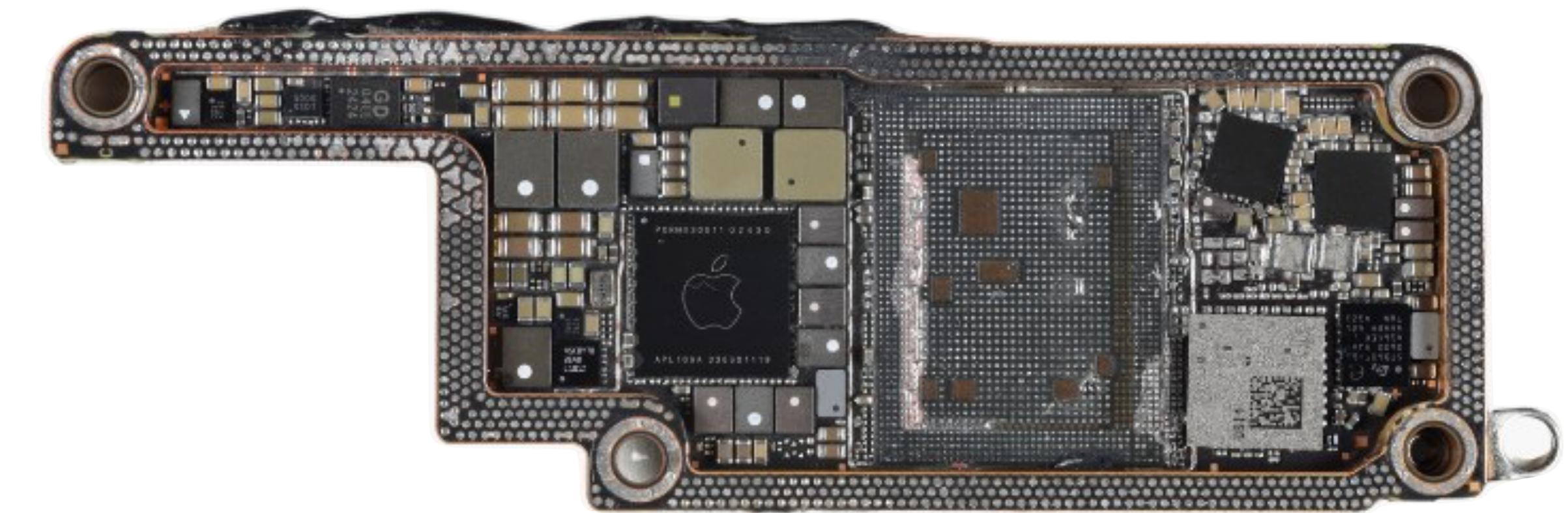
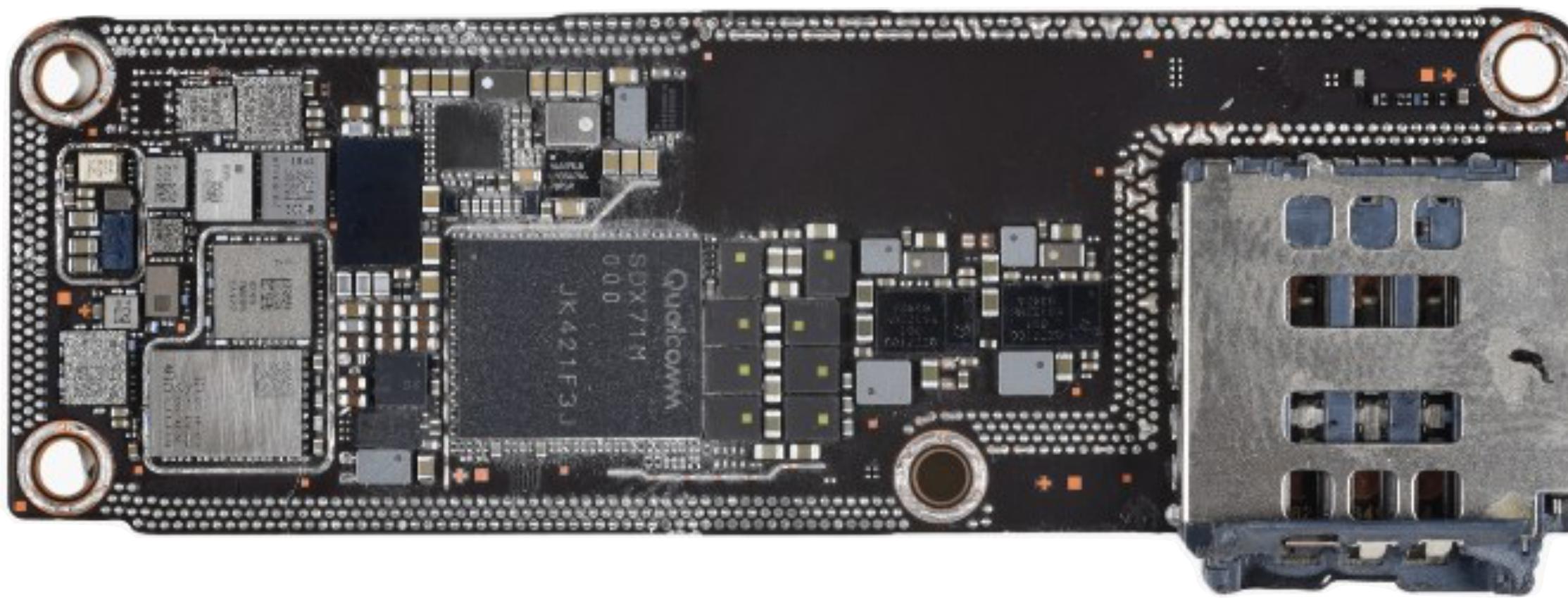
## basics of PCBs

- We covered the basics of PCB design in lecture 1
- **PCB design can be very complicated!**
  - 20+ layer boards
  - Computing hardware

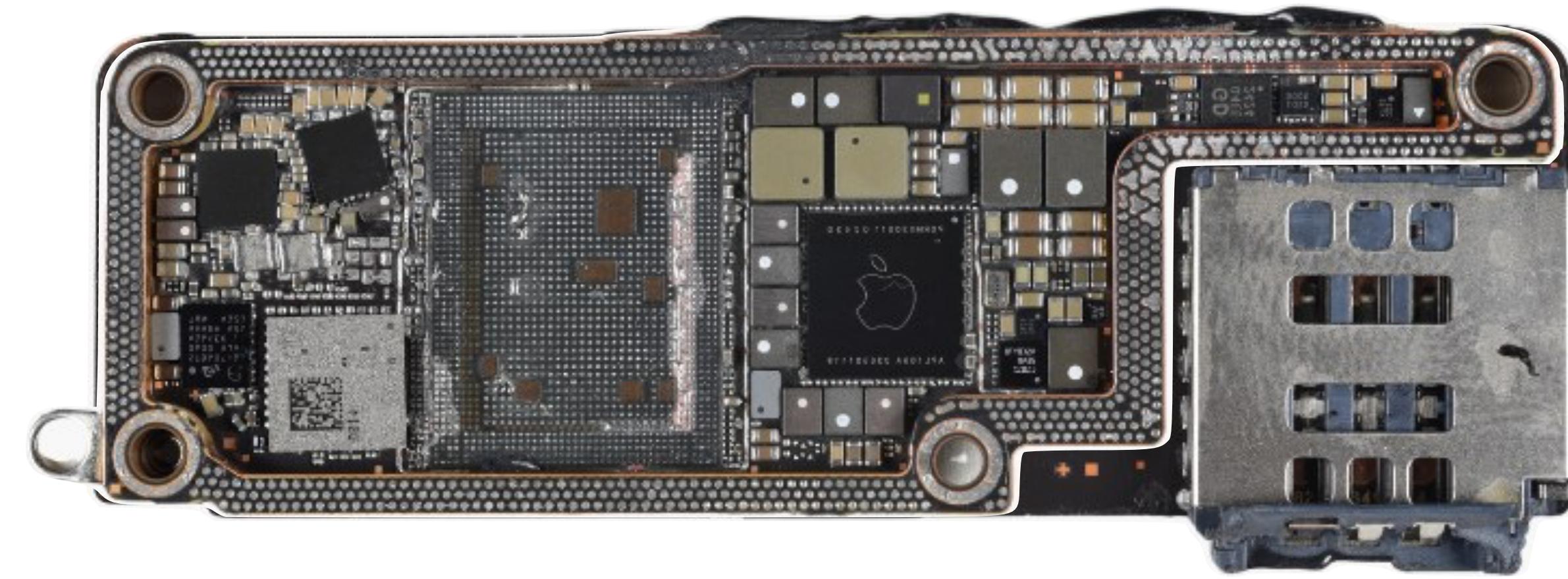
# VERY complicated PCB



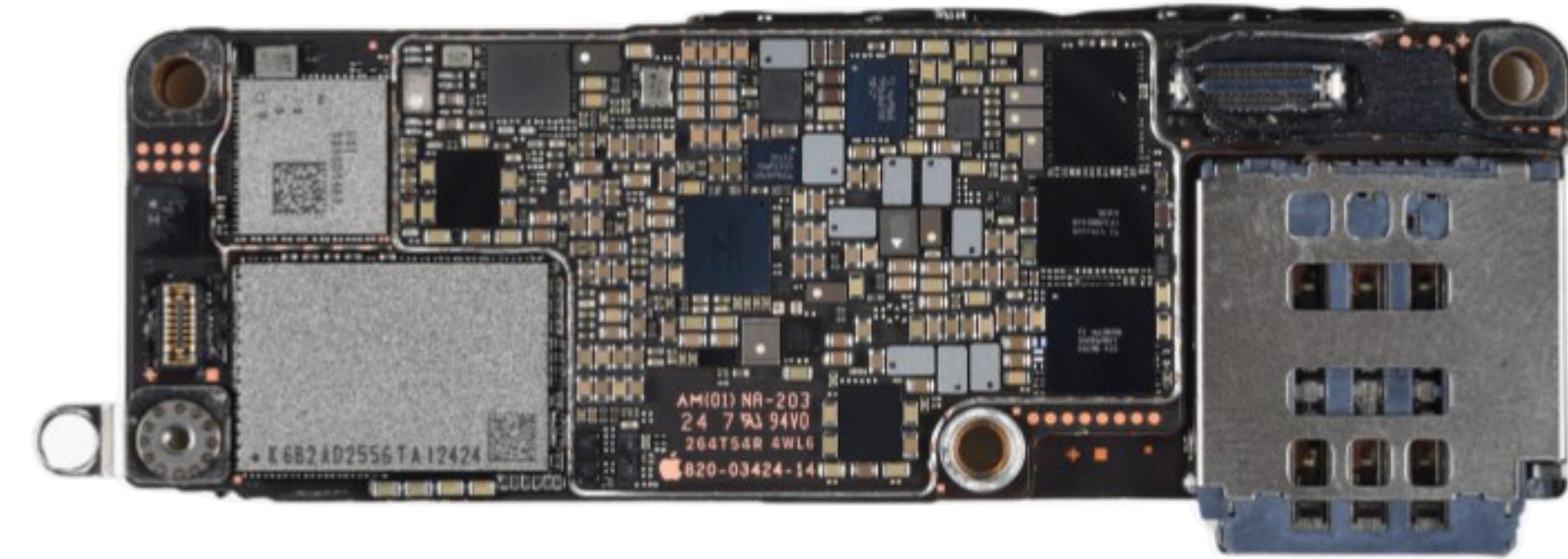
# iPhone 16 pro max motherboard



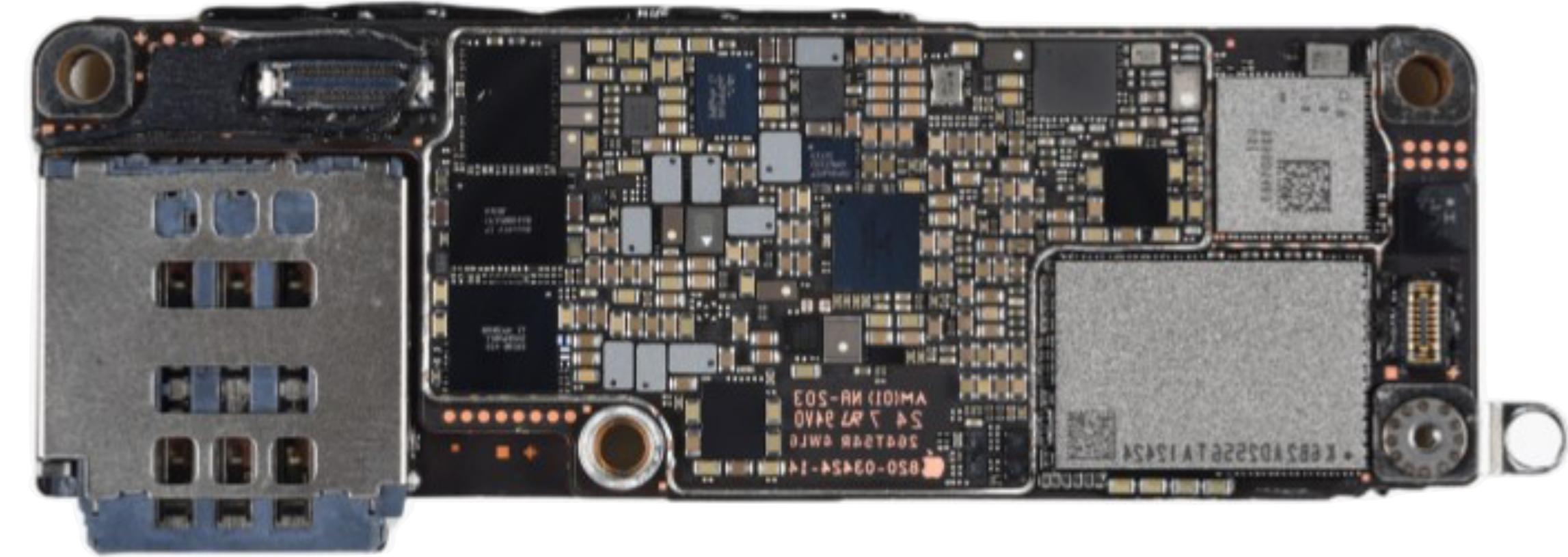
# iPhone 16 pro max motherboard



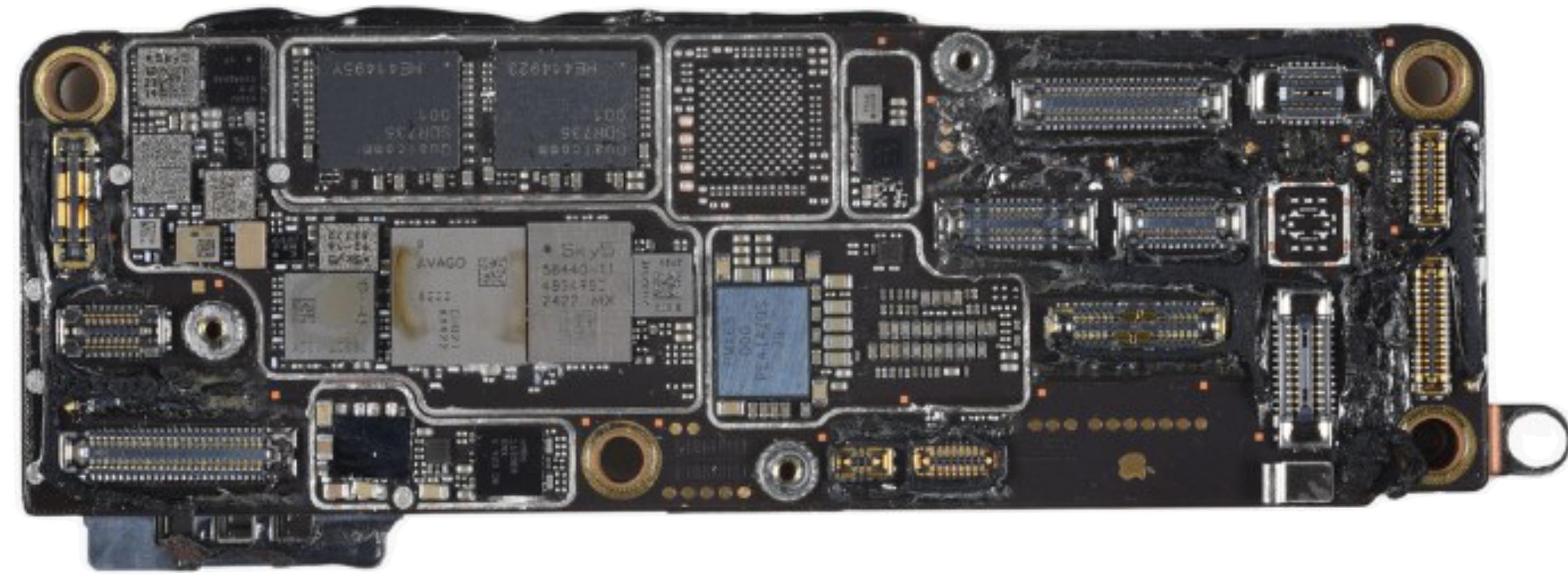
# iPhone 16 pro max motherboard



# iPhone 16 pro max motherboard



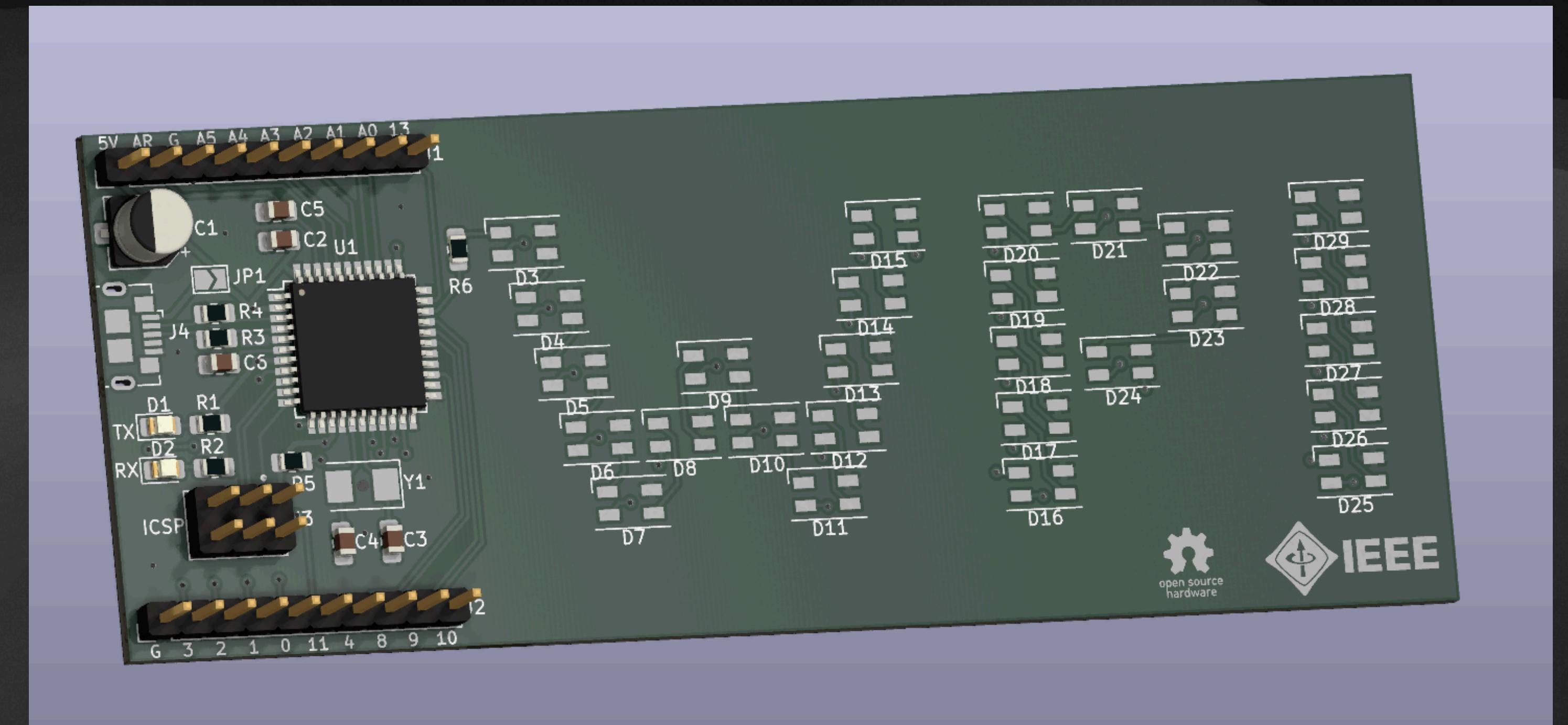
# iPhone 16 pro max motherboard



# hardware design process

## walkthrough

1. Research and Design
2. Schematic Capture
3. Layout
4. Routing
5. Order
6. Assembly



# project ideation

i want to make something epic

- Start with the basics (ex: track 1 board!)
- Any project idea is a good one if you can:
  1. Come up with an interesting concept.
  2. Identify key components needed to build it.
- **This class is focused on a top down design-driven methodology.**
- **Turning ideas => schematics => final products (PCBs!)**

# project examples to get you excited!

- LED music visualizer
- Reactive LED Art
- Wireless haptic feedback system

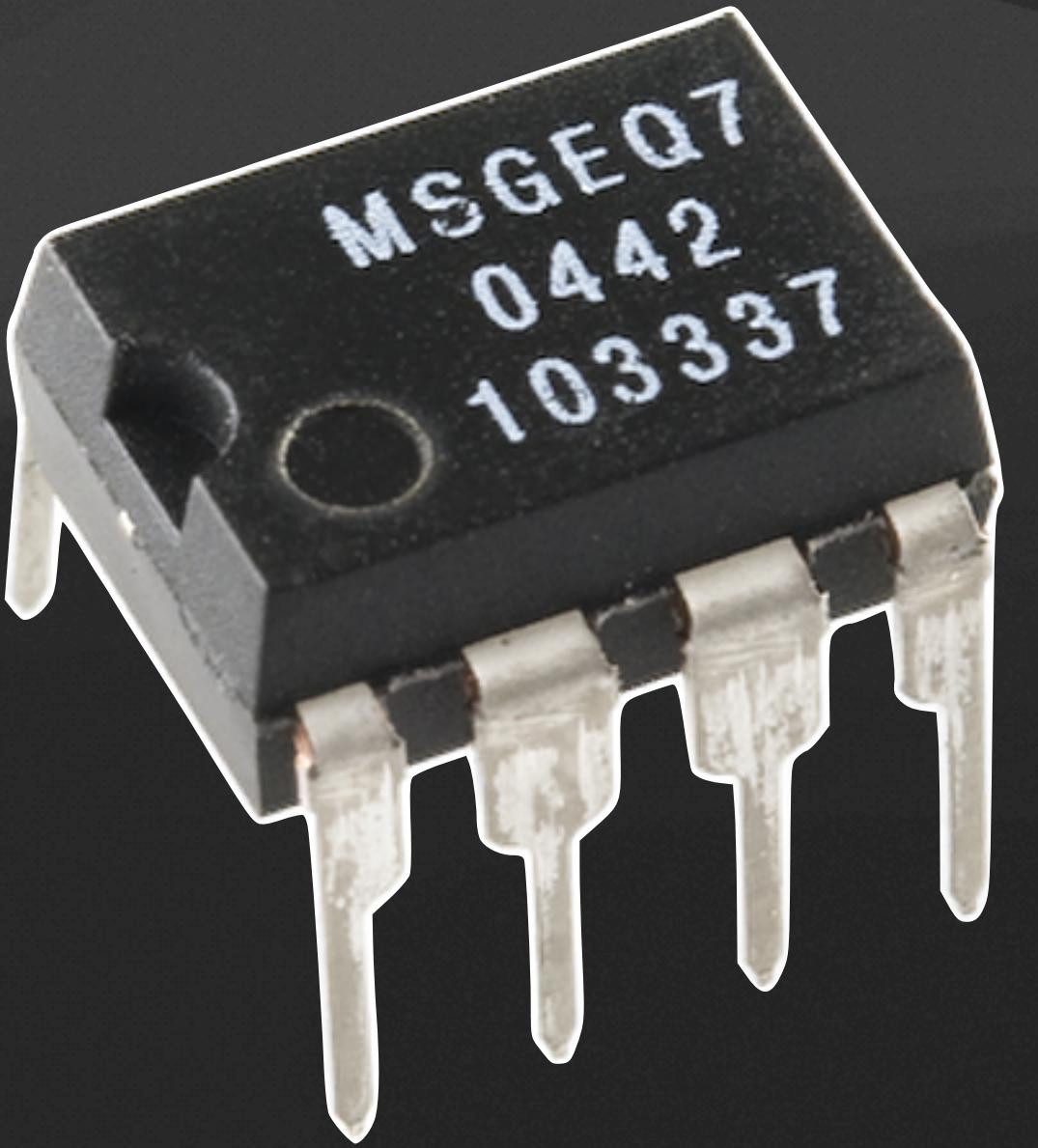
# teensy visualizer

## inspiration

- A good way to visualize music
- Use LED matrices for something
- A device I can keep on my desk
- Microphone/line-in modes

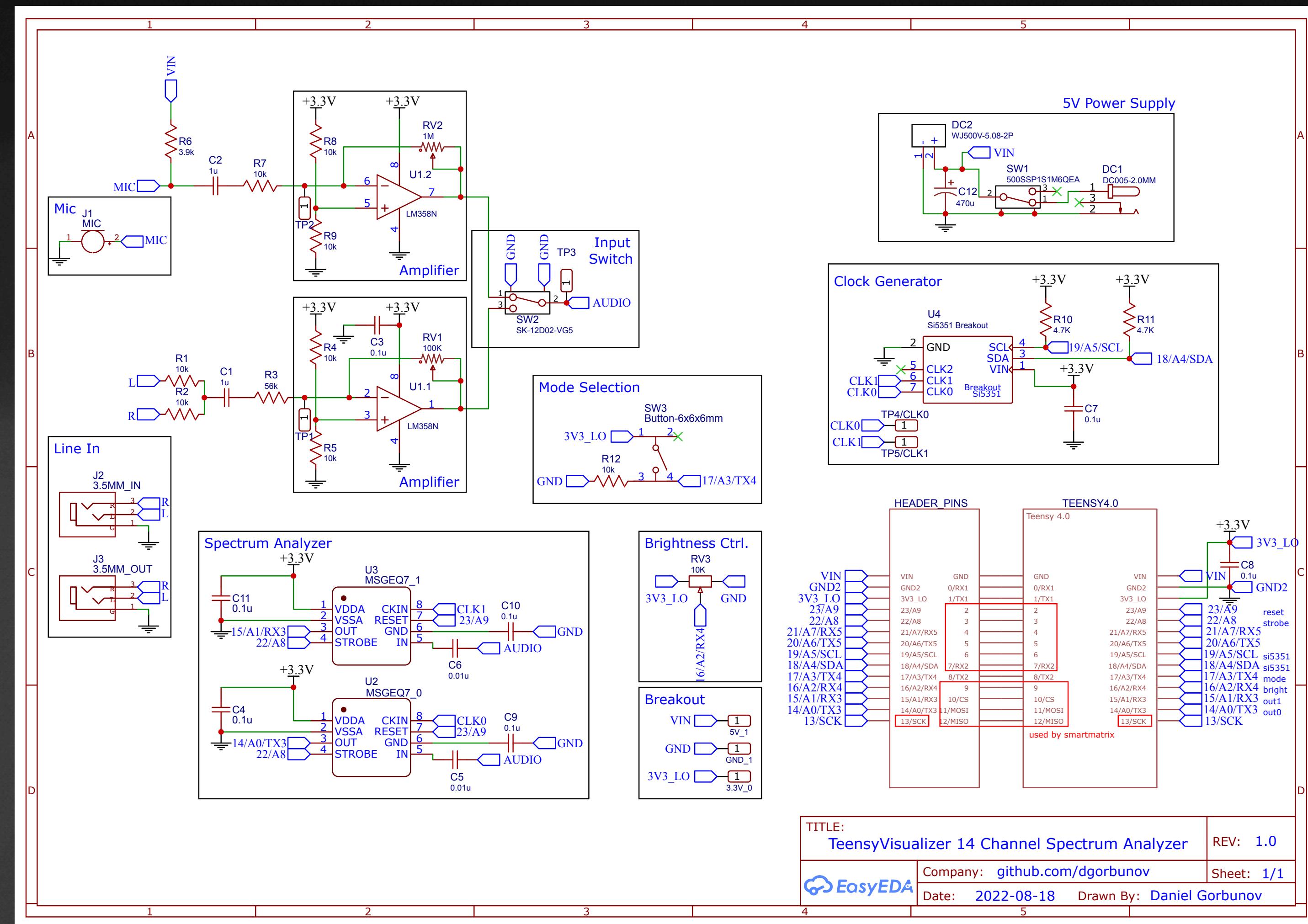
# teensy visualizer components?

- Microcontroller (Teensy 4.0)
- LED Matrix
- Line-in jack
- Microphone
- Amplifier (LM358)
- Graphic EQ chip (MSGEQ7)

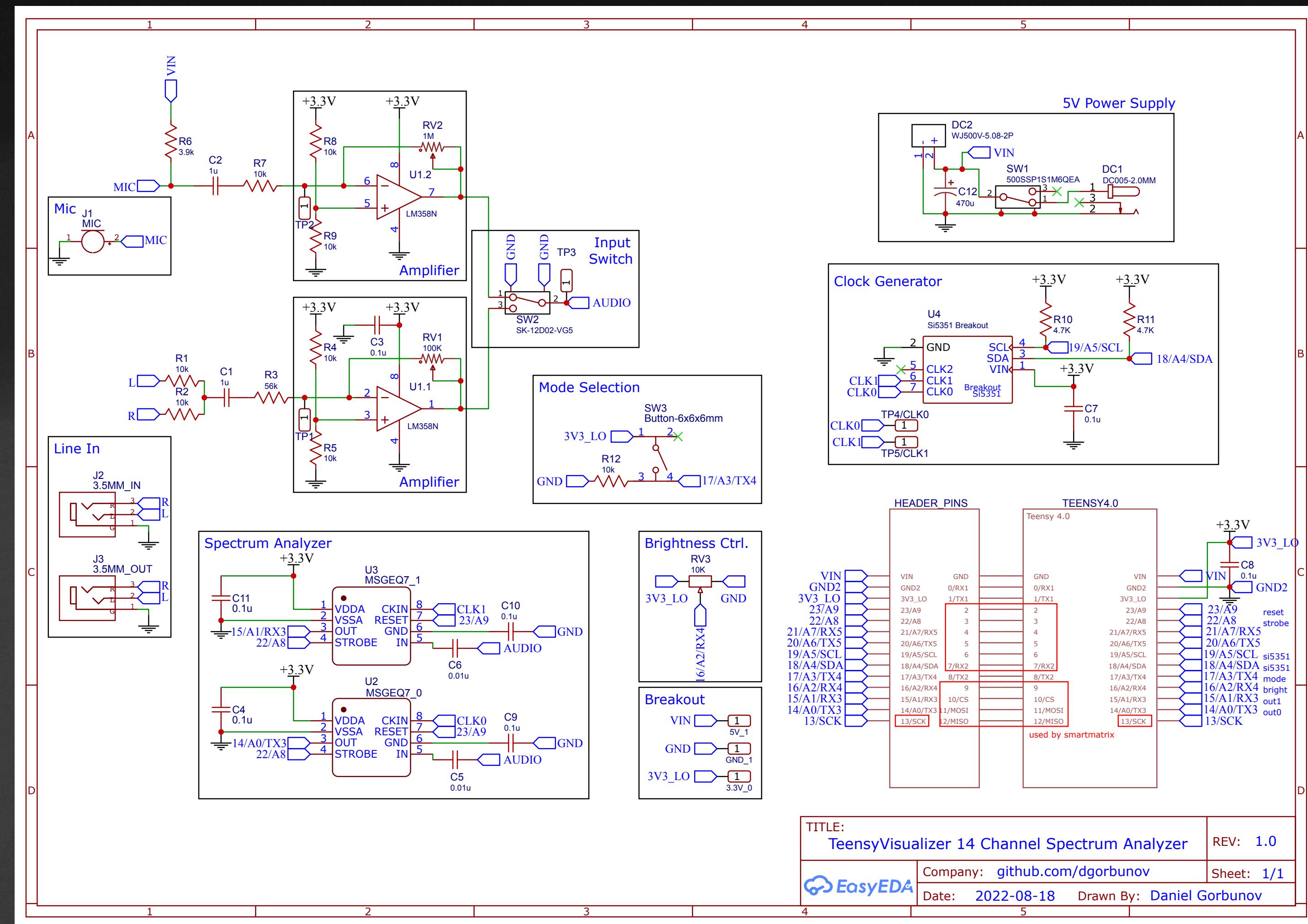


# teensy visualizer

## schematic

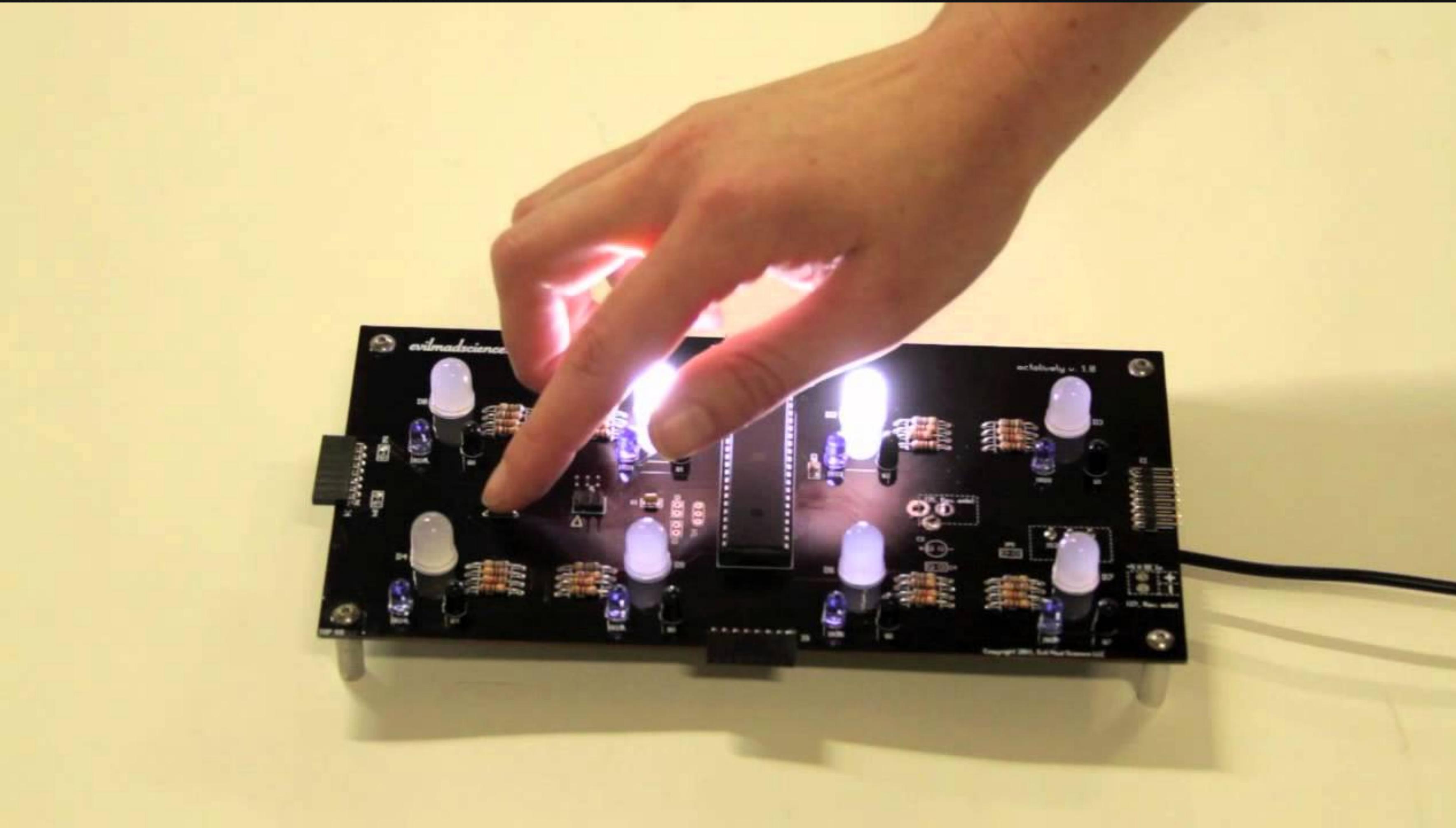


# teensy visualizer board



# reactive LEDs

## inspiration



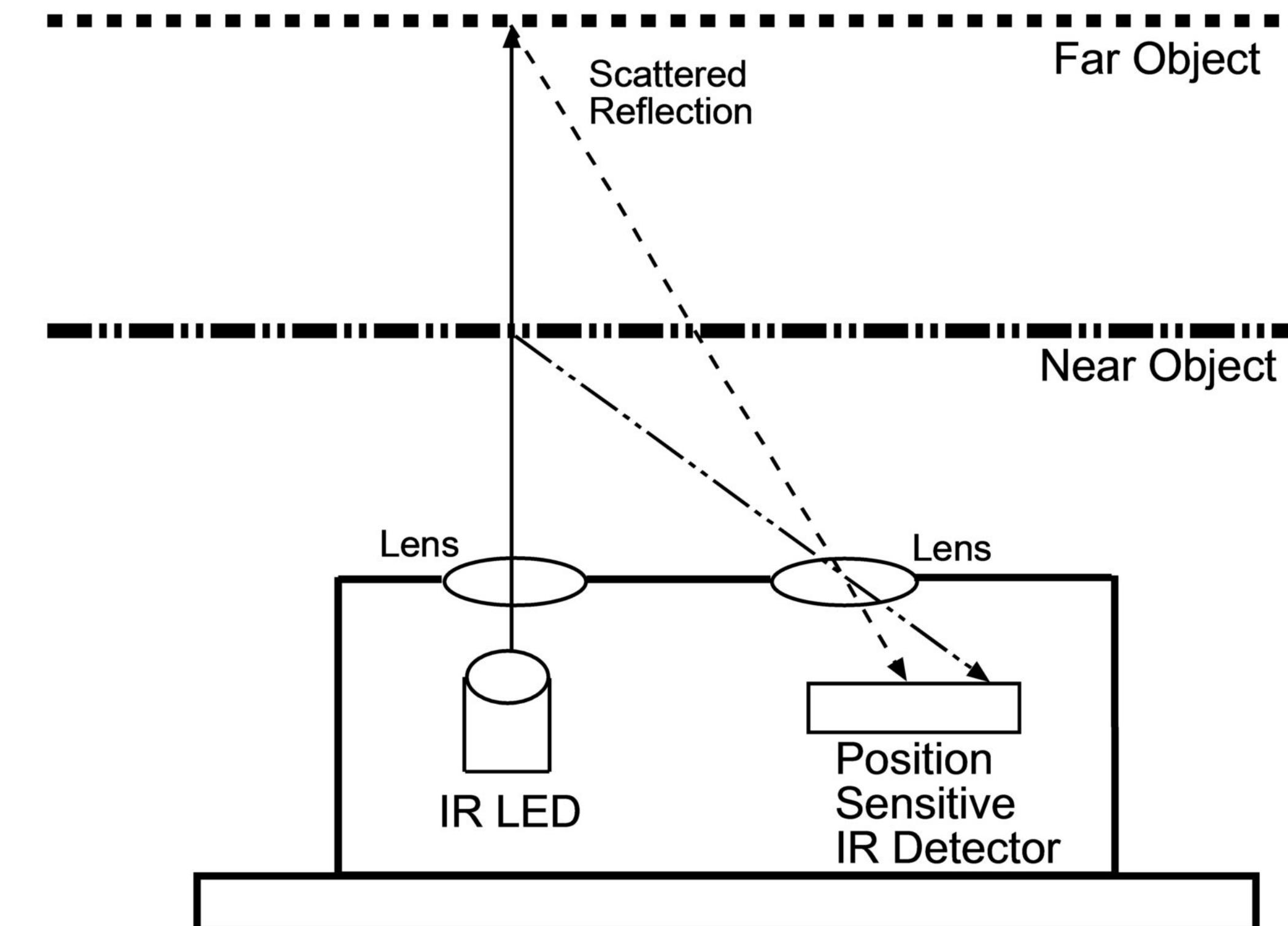
# reactive LEDs

## components?

- Microcontroller
- LEDs
- Distance sensors?
  - Ultrasonic
  - ToF (time-of-flight)
  - LiDAR
  - Infrared

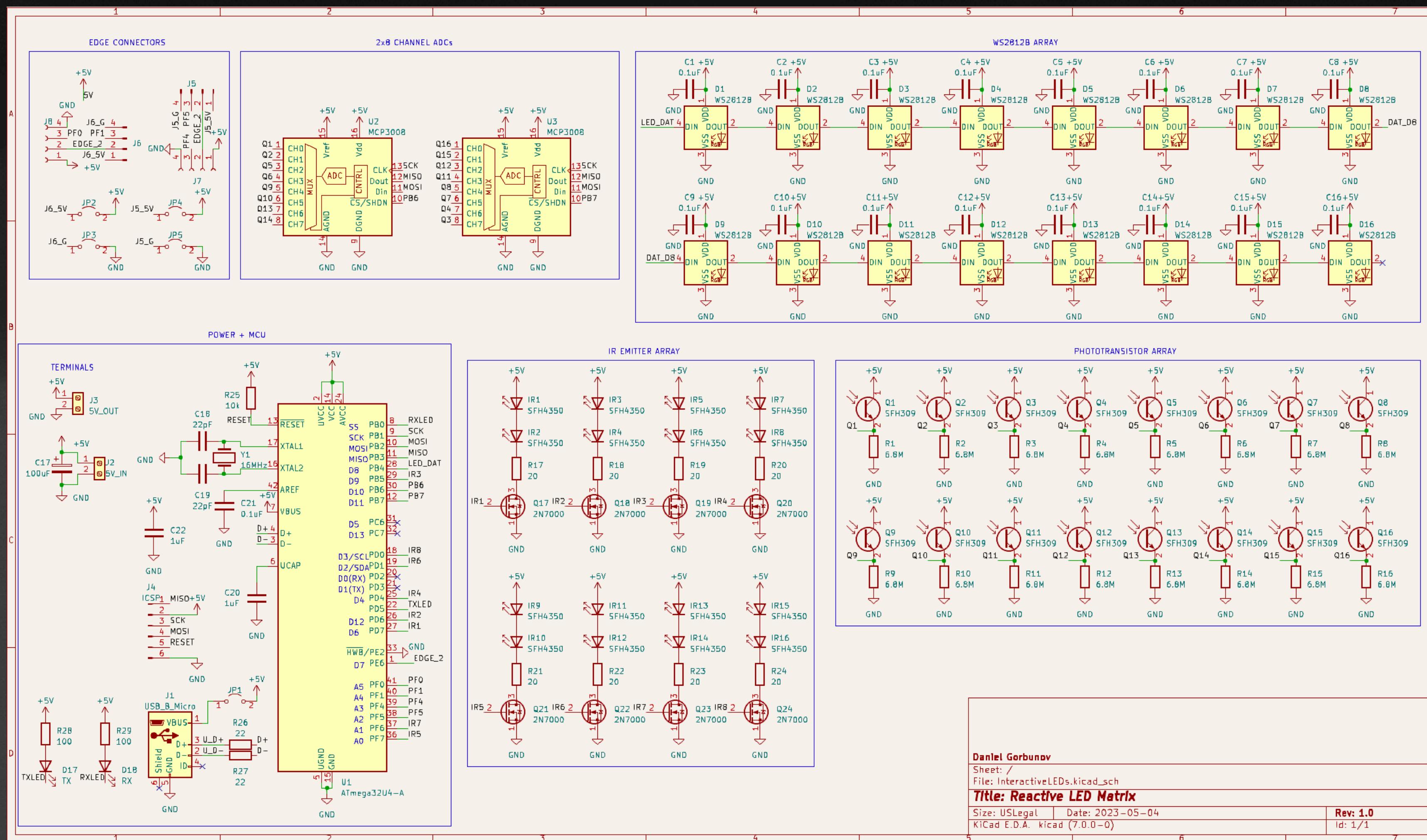
# reactive LEDs

## infrared sensing

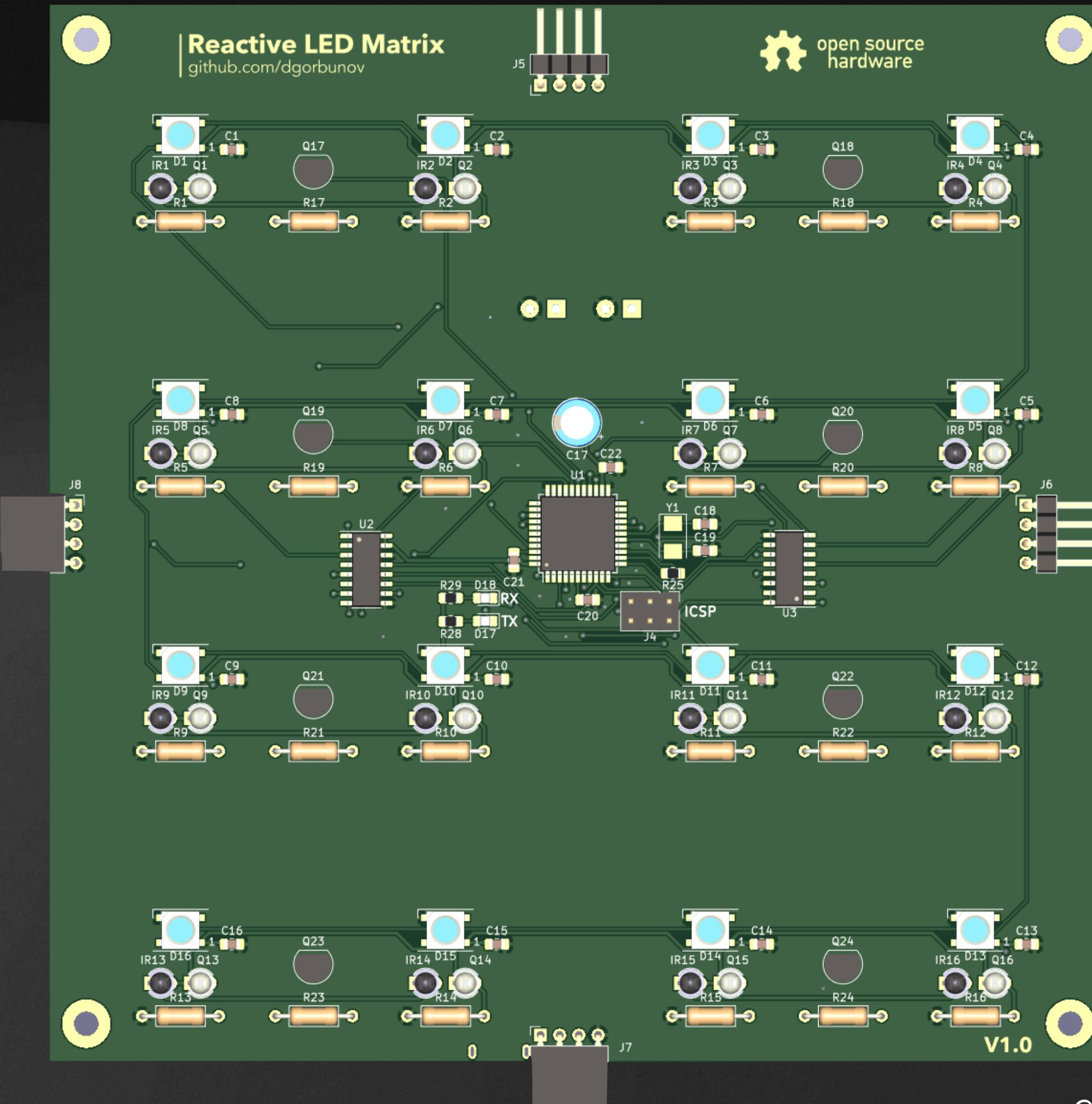


# reactive LEDs

## schematic



# reactive LEDs board



[github.com/dgorbunov/ReactiveLEDMatrix](https://github.com/dgorbunov/ReactiveLEDMatrix)

# SpatialSense

## introduction

- Wireless haptic feedback system for visually impaired people
- Visually impaired user must balance a tray while walking
- Multiple units that attach to someone's body and vibrate patterns based off which direction the tray needs to be rotated

# SpatialSense

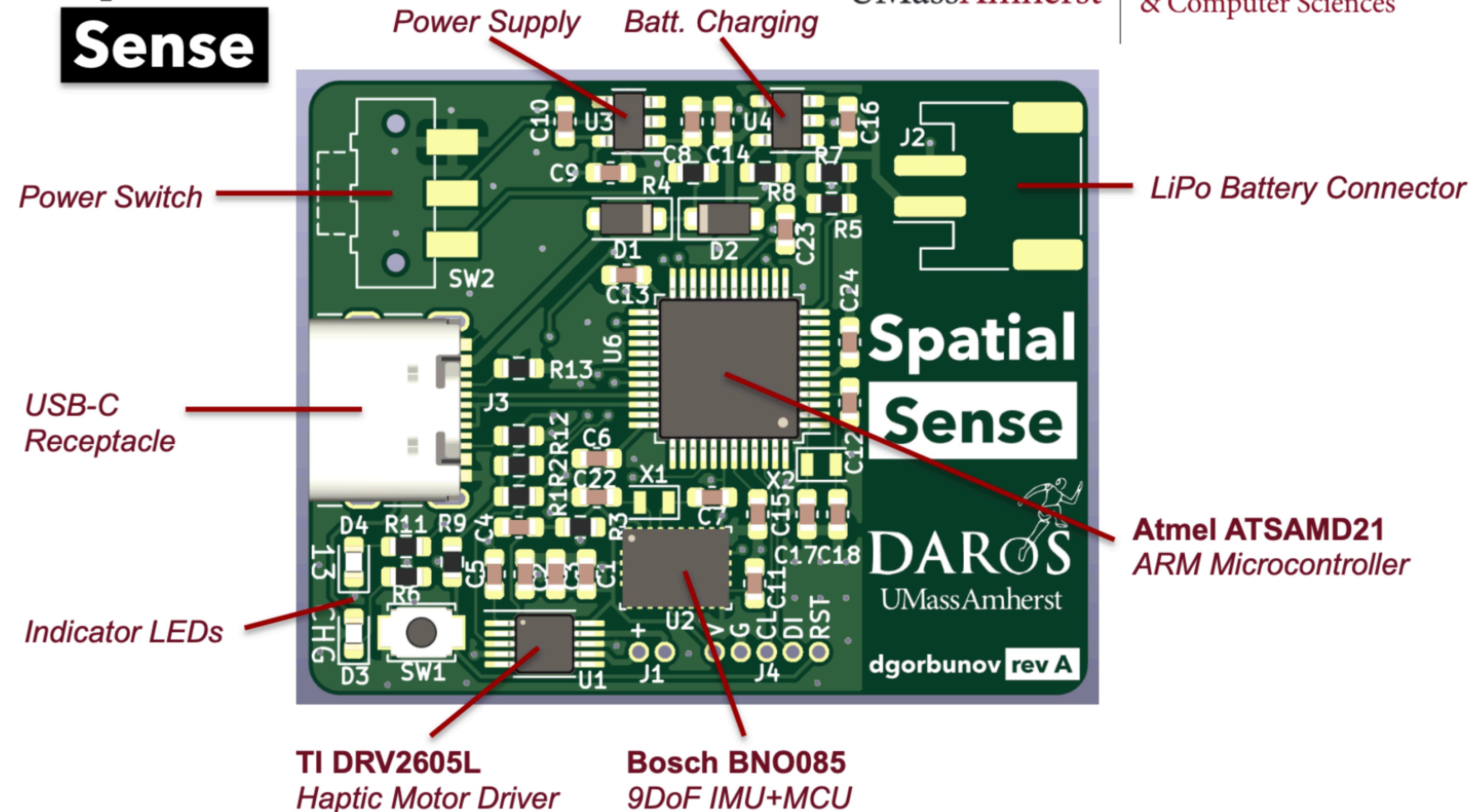
## components?

- ARM Microcontroller (Atmel)
- Vibration motor (Vybrronics)
- Haptic Motor Driver (Texas Instruments)
- 6 axis IMU (Bosch)
- LiPo battery charging IC
- Voltage regulator
- Packet radio (915MHz)

# Spatial Sense

UMassAmherst

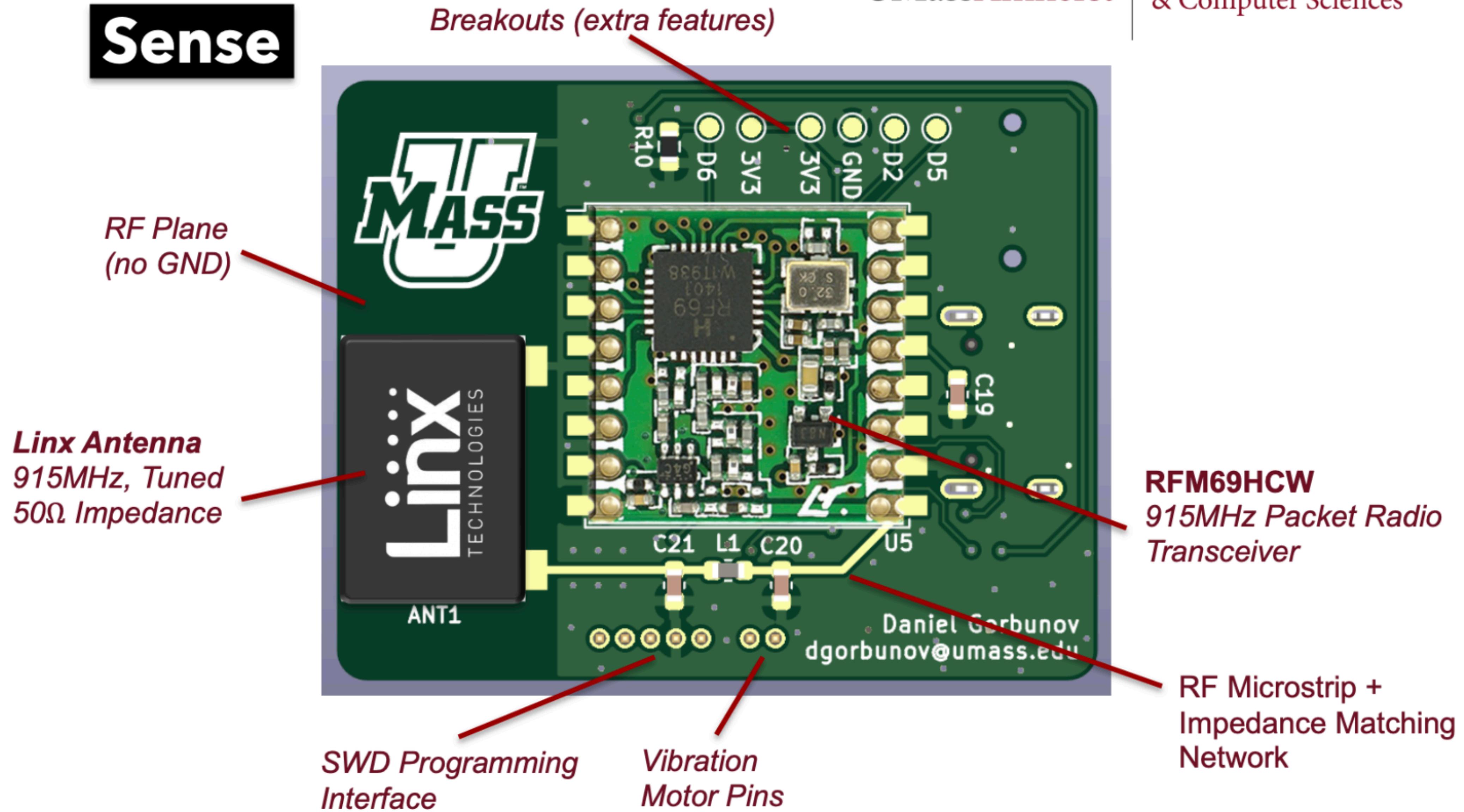
Manning College of Information  
& Computer Sciences



# Spatial Sense

UMassAmherst

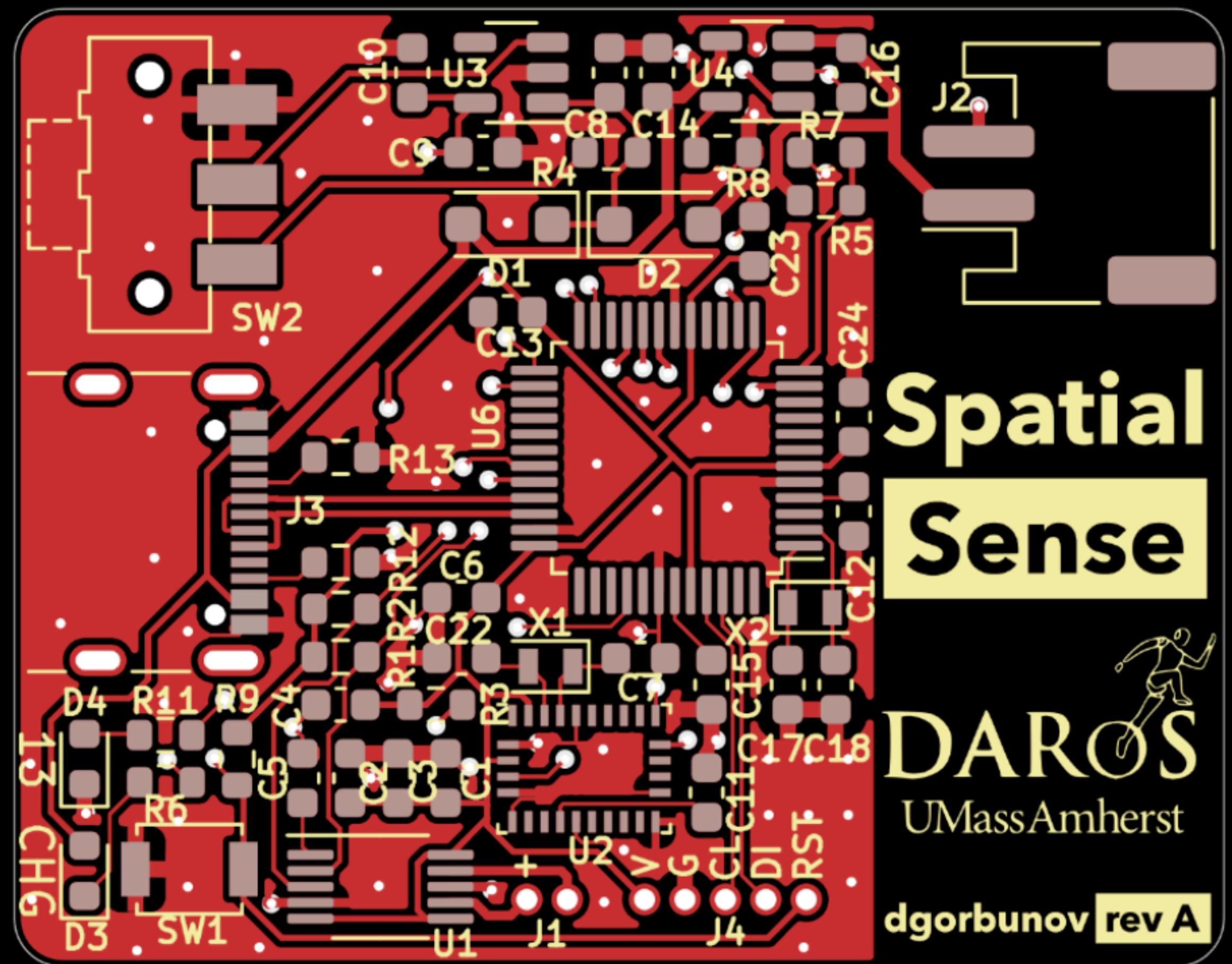
Manning College of Information  
& Computer Sciences



# PCB Layout

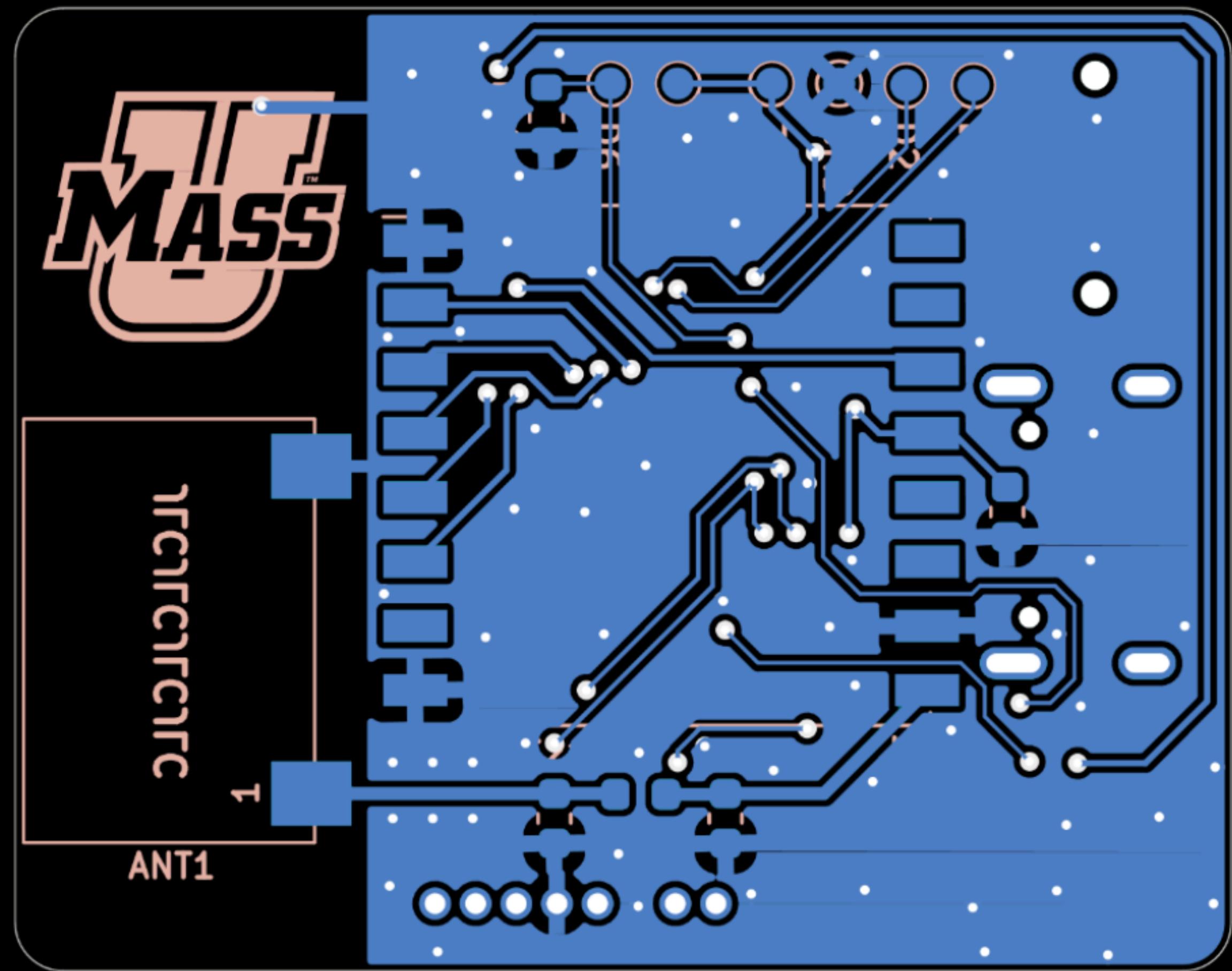
30mm

Front



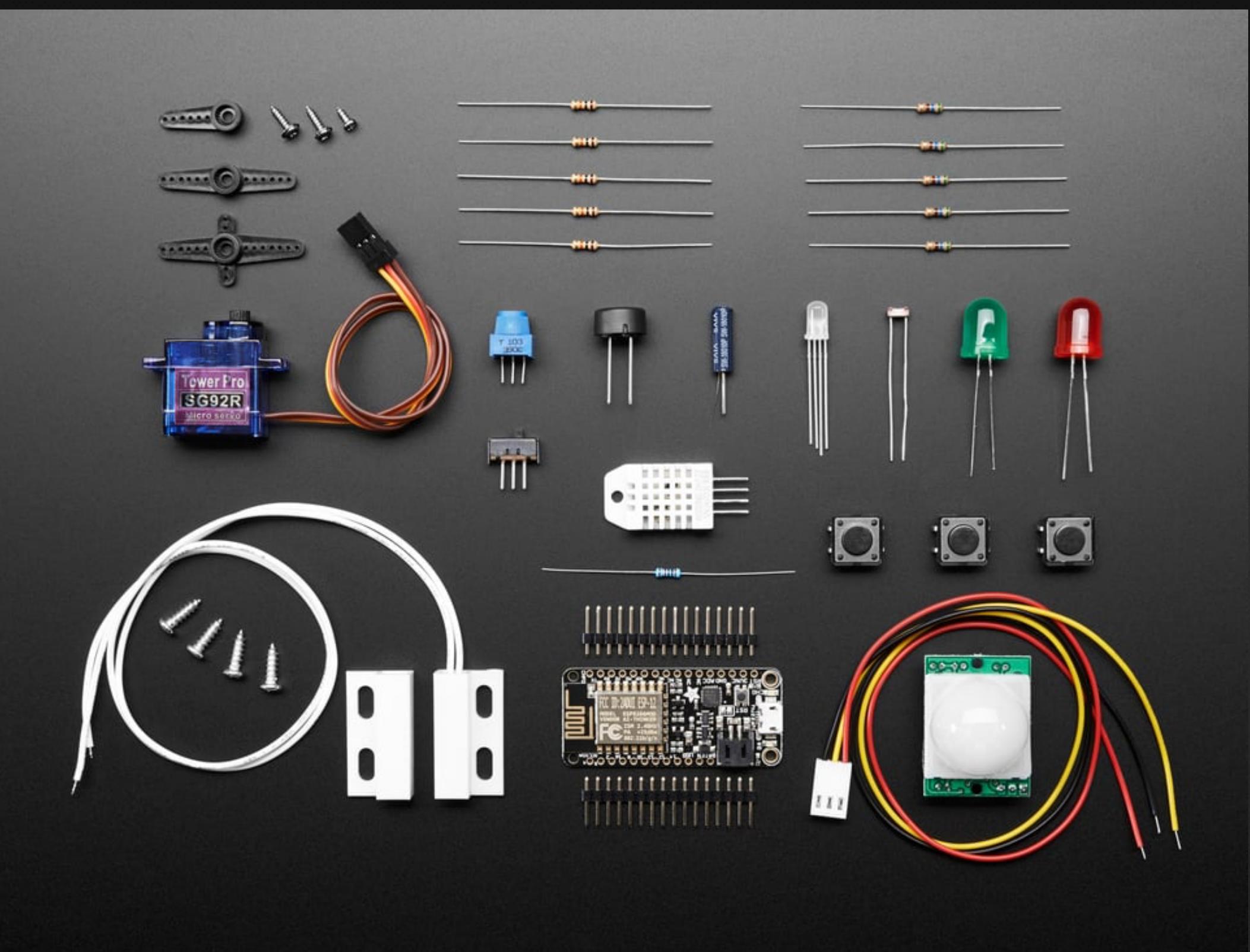
38mm

Back



# research and design process

- Start with a project idea
    - Often fun to start with **peripherals** and what you want them to do
  - Break down design into **major components**
  - Research possible components and how to connect them to your peripherals
  - Worry about details (passives) later



# research and design

## research

- “Amazon” for Makers:

- Adafruit

- SparkFun

- Parts Distributors:

- DigiKey

- Mouser

- LCSC (China)

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# research and design

## open source

- **Research, research, research!**
- You will learn a lot from looking at existing **open source designs** of similar projects
- Websites like Adafruit and SparkFun usually open source all of their schematics
- This is a great starting point for you to build off!
- When you're done, **open-source your project** to inspire others and showcase your technical skills

The screenshot shows a GitHub repository page for 'IEEE-WPI / pcb'. The repository is public and was created by @dgorbunov. It has an MIT license, 4 stars, 1 fork, and 0 branches. The activity section shows the following commits:

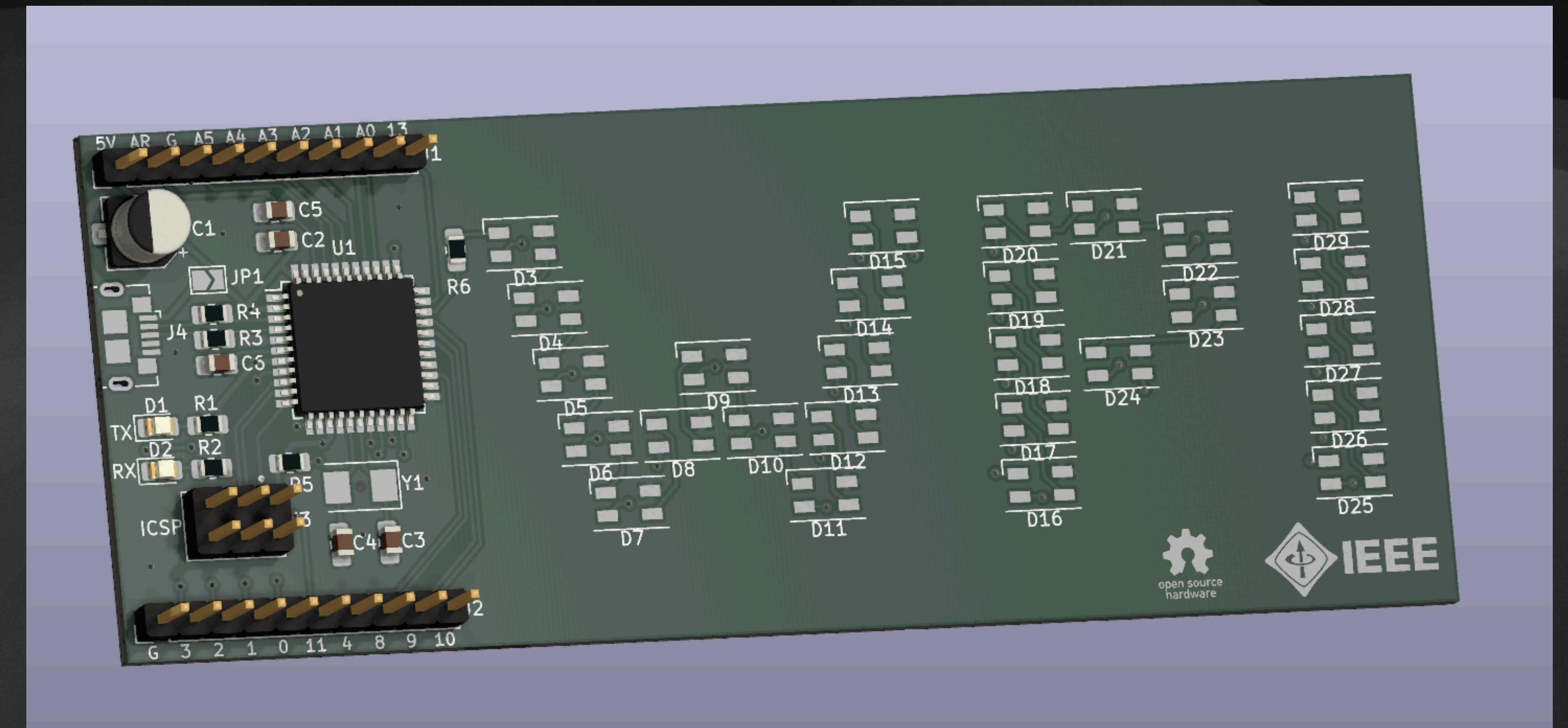
File / Commit Message	Time Ago
dgorbunov add d24 gerbers and update readme	a986431 · 4 hours ago
datasheets add datasheets and new sample board ...	4 hours ago
sample_board add d24 gerbers and update readme	4 hours ago
slides cleanup	2 days ago
starter_board update board files for A24	4 hours ago
starter_code remove cached starter board files	4 hours ago
.gitignore untrack kicad cache files	4 hours ago
LICENSE Initial commit	5 days ago
README.md add d24 gerbers and update readme	4 hours ago

This class itself is open-source!

# hardware design process

## walkthrough

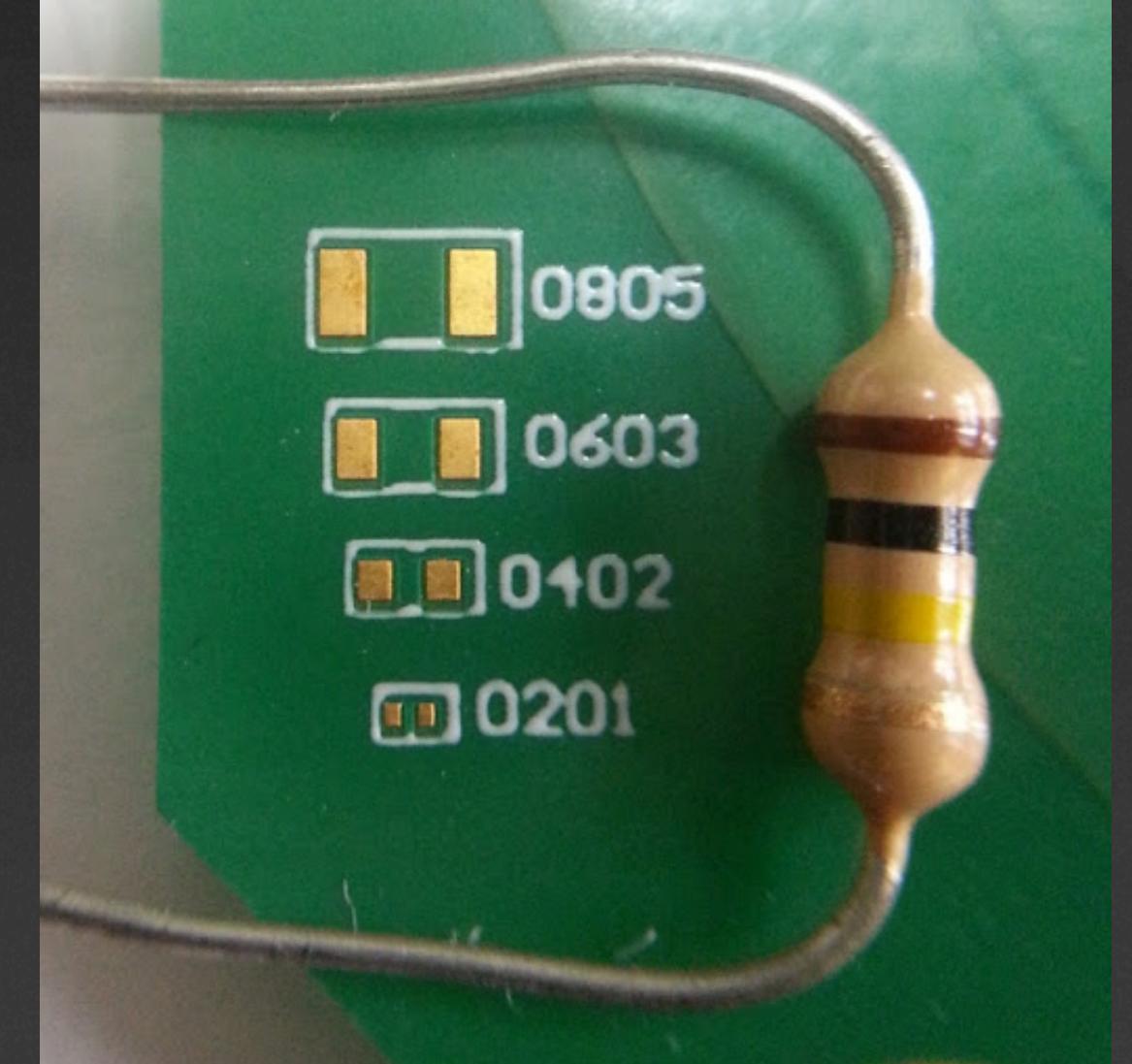
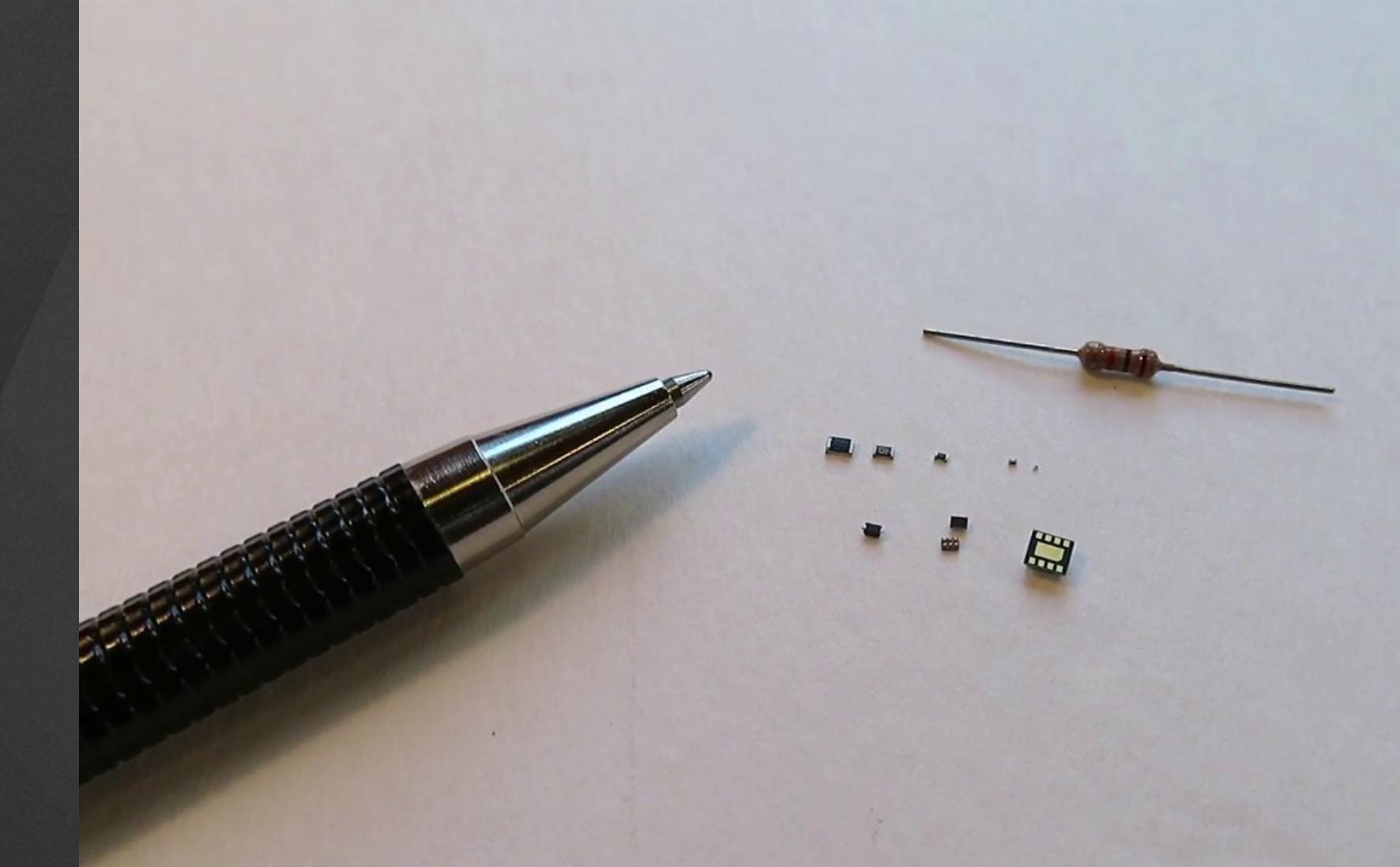
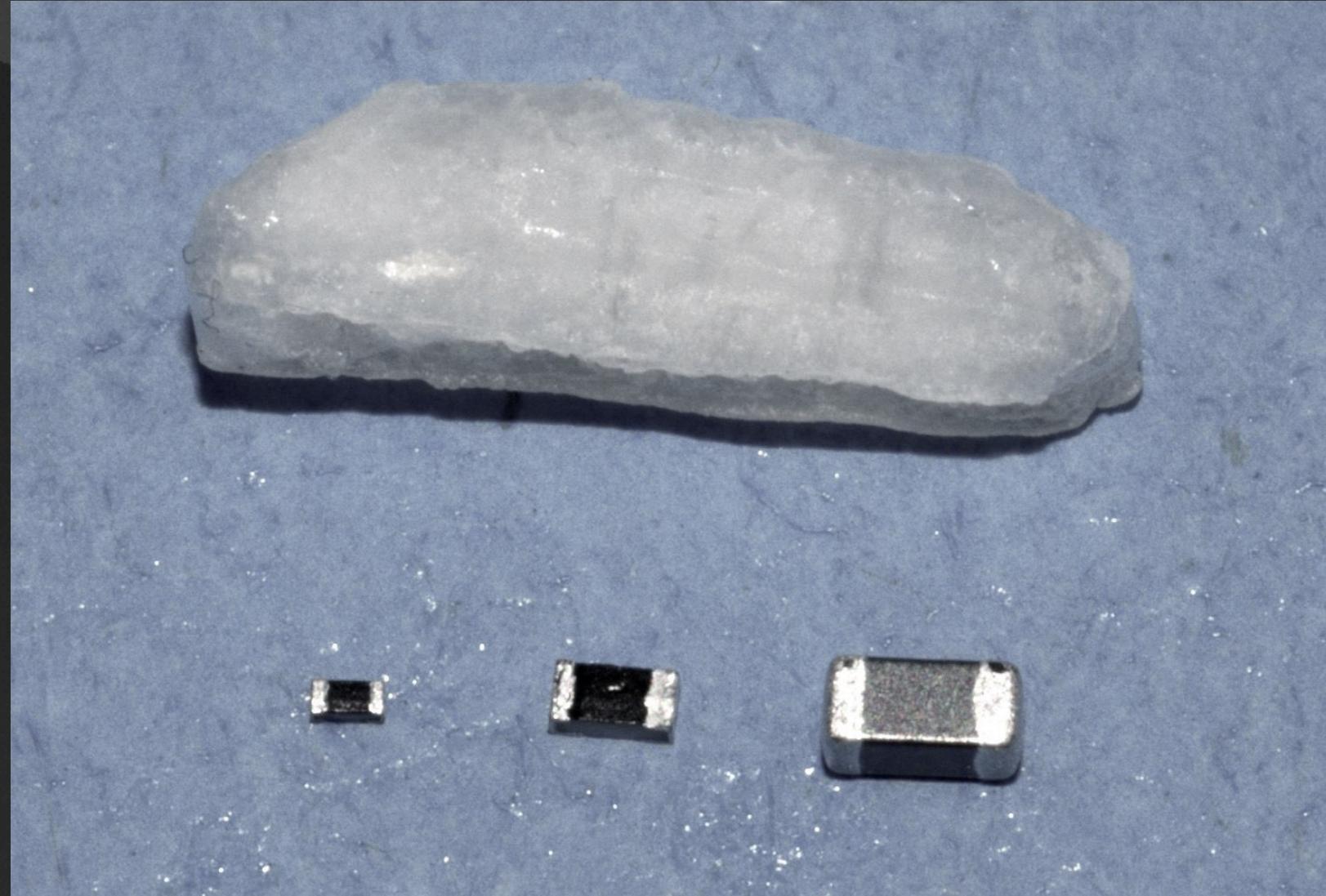
1. Research and Design
2. Schematic Capture (?)
3. Layout
4. Routing
5. Order
6. Assembly



# Packages

An aside

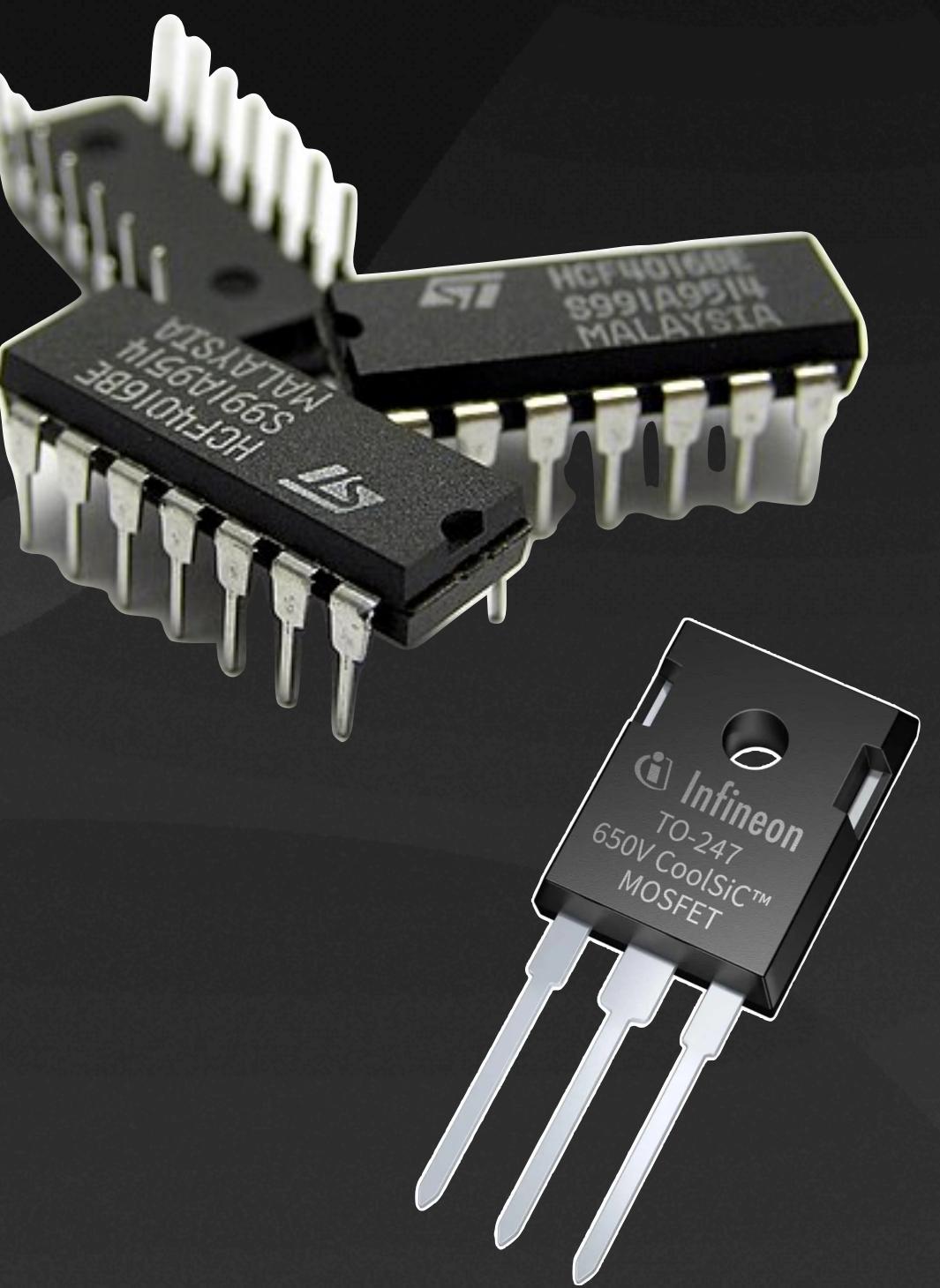
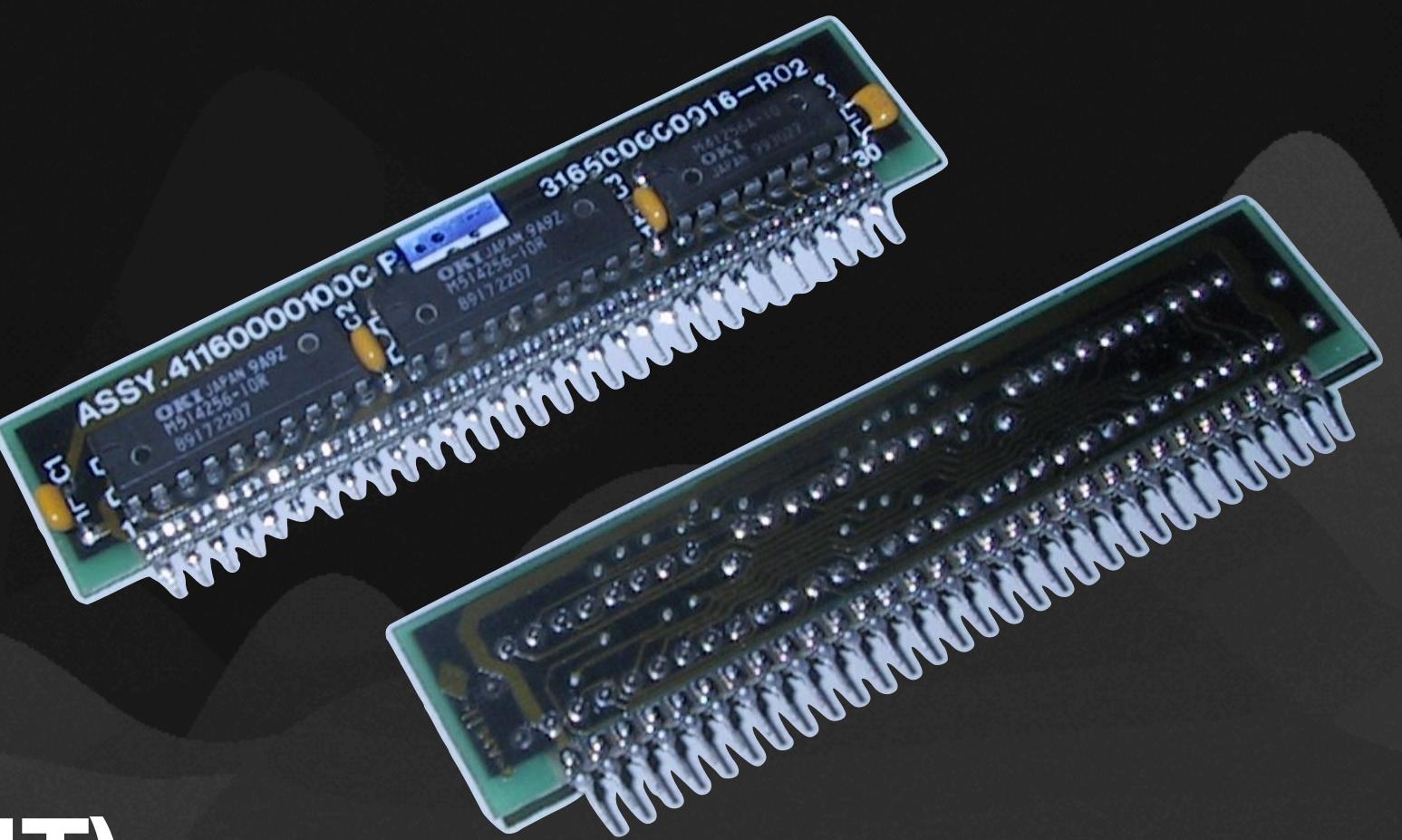
- Size matters -- don't make your life miserable



# Packages

## Simple Components

- Shape matters too!
- Though Hole Technology (THT)
  - Single in-line package (SIP)
  - Dual in-line package (DIP)
- Surface Mount Technology (SMT)
  - Small outline package (SOP)
  - Small outline transistor (SOT)

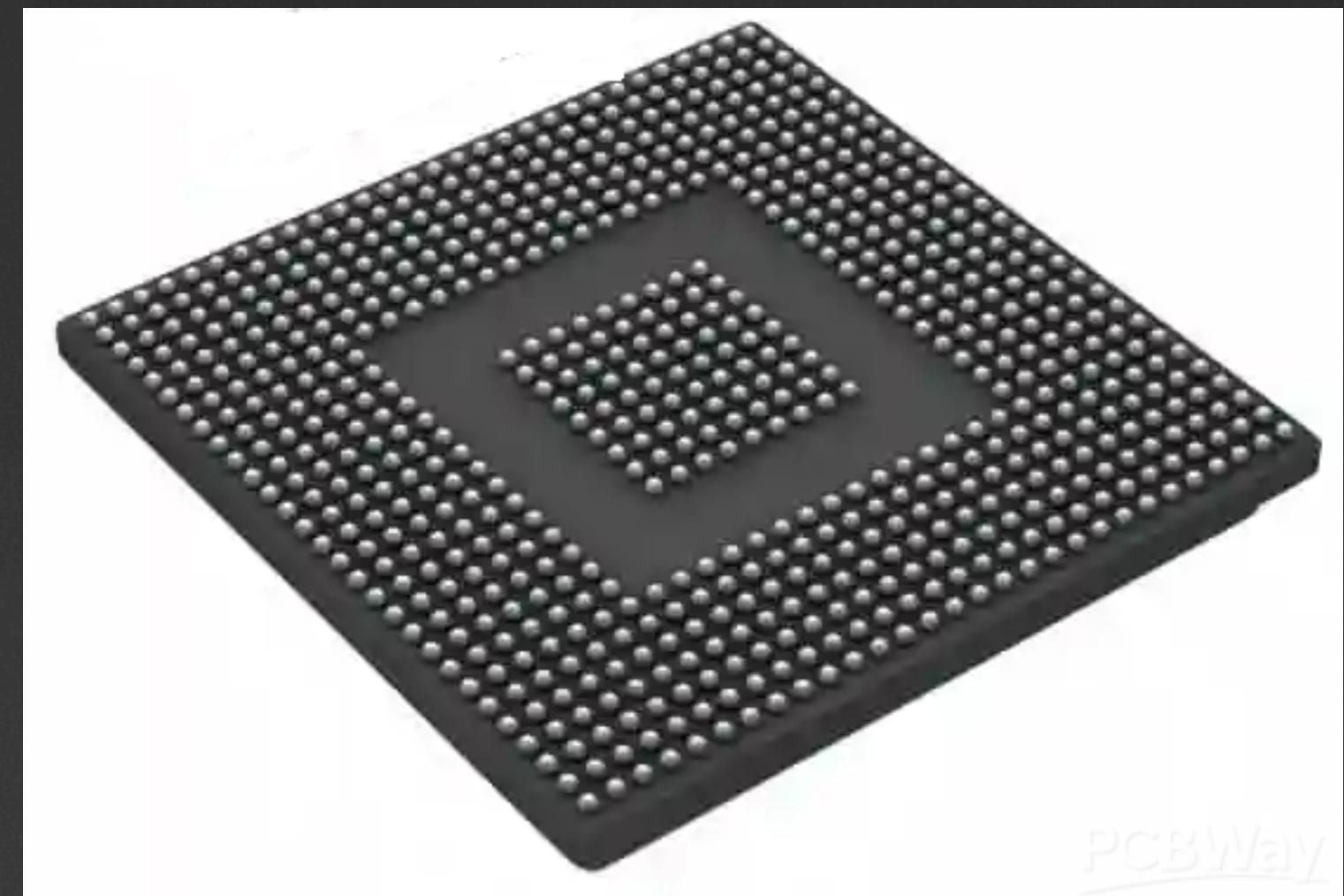
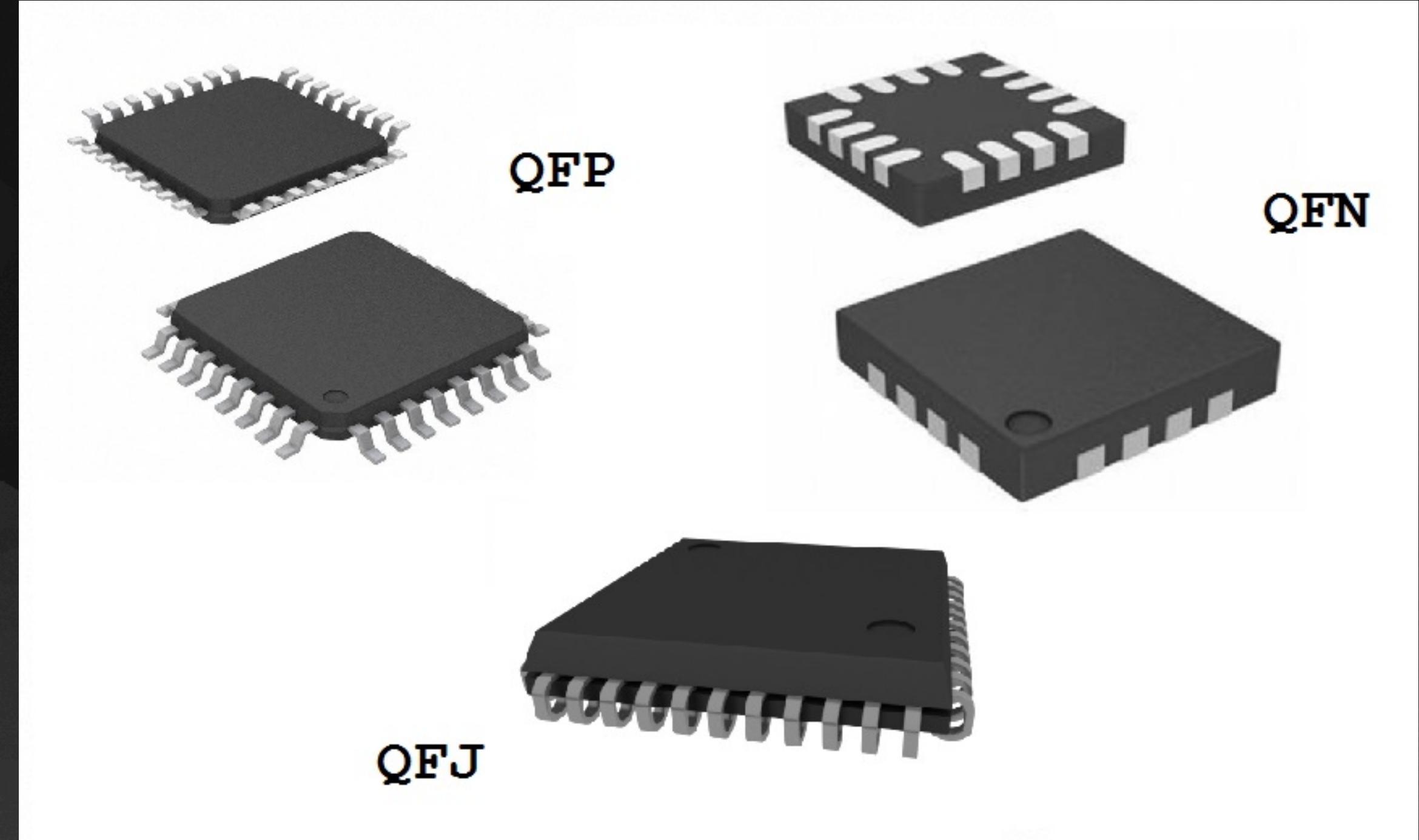


# Packages

## Complicated Components

- IC Packages

- Quad flat pack (QFP, TQFP)
- Quad flat J (QFJ)
- Quad flat pack no-lead (QFN, TQFN)
- Ball Grid Array (BGA, FBGA)



# Packages

## An aside

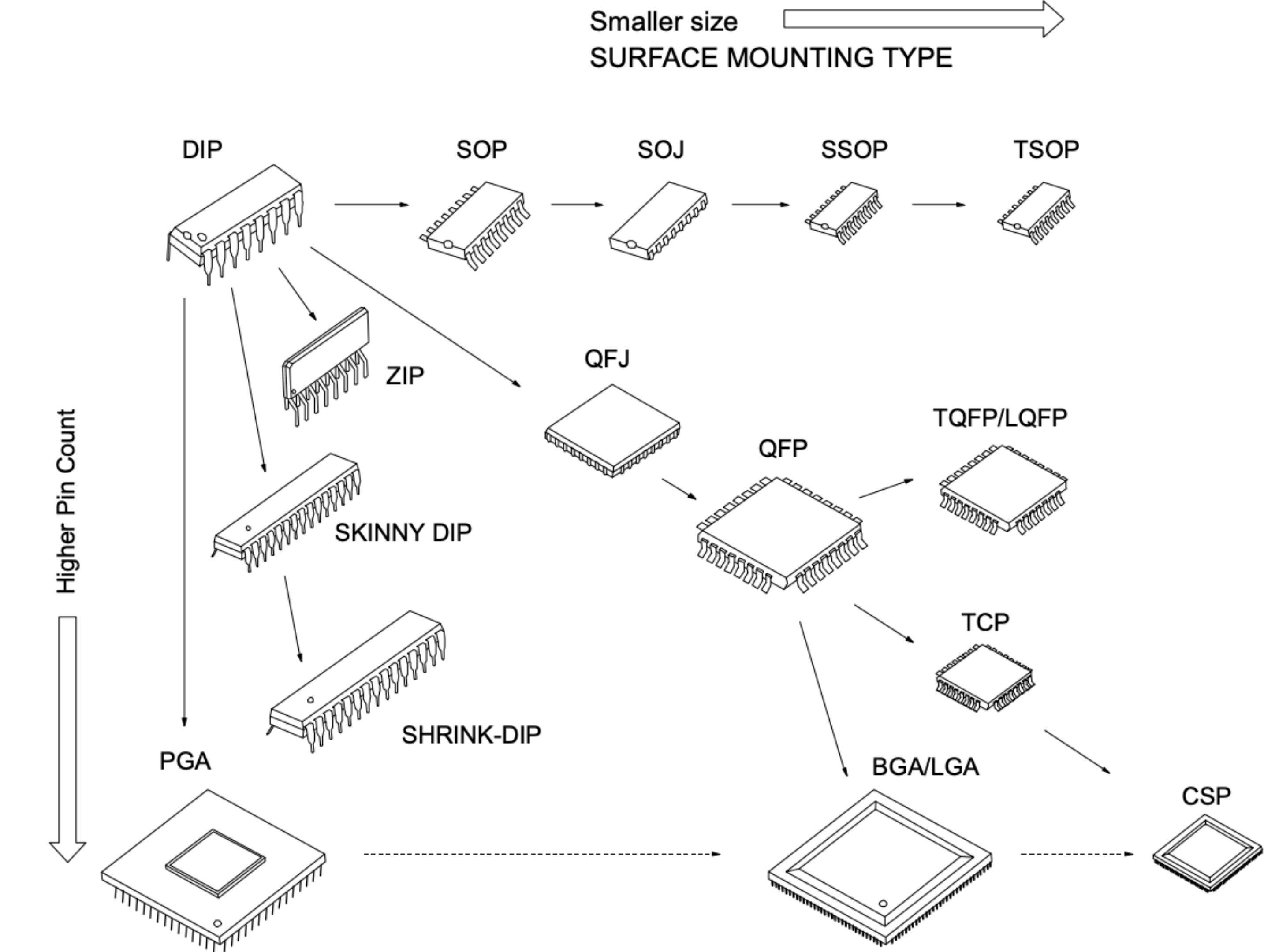
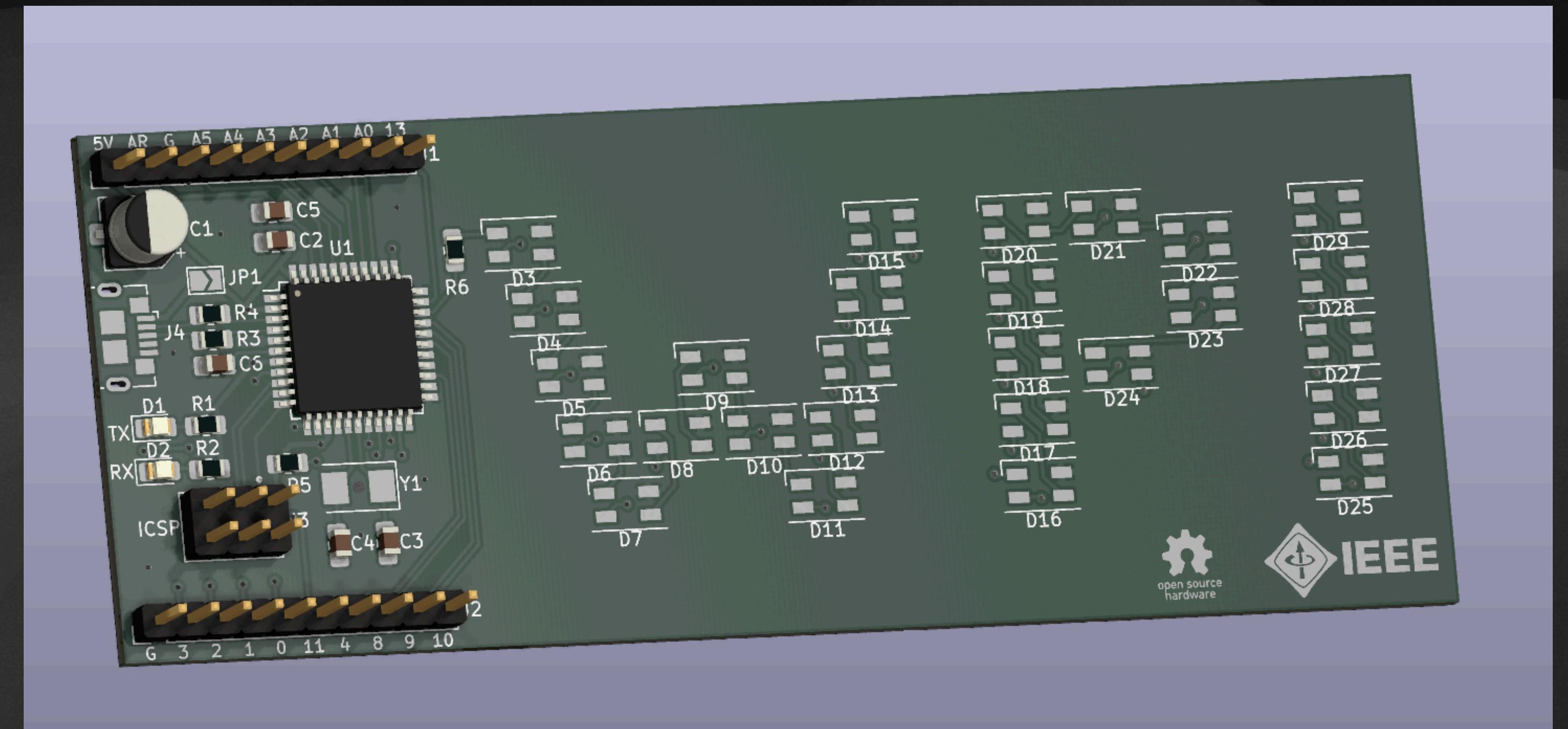


Figure 1.1.1 Packaging Trend

# hardware design process

## walkthrough

1. Research and Design
2. **Schematic Capture**
3. Layout
4. Routing
5. Order
6. Assembly



# schematic capture process

- Use parts distributors (DigiKey, Mouser) to find specific components
- Read datasheets to find what the exact product number you need
- Footprints matter here!
  - Consider board size, and desired manufacturing + assembly process!
  - Start with key components first!

Mfr Part #	Quantity Available ⓘ	Price	Series	Package	Product Status
	^	^	^	^	^
  <b>ATMEGA32U4-MU</b> IC MCU 8BIT 32KB FLASH 44VQFN <i>Microchip Technology</i>	14,742 In Stock	1 : \$5.26000 Tray	AVR® ATmega	Tray ⓘ	Active
  <b>ATMEGA32U4RC-MU</b> IC MCU 8BIT 32KB FLASH 44VQFN <i>Microchip Technology</i>	10,393 In Stock	1 : \$5.26000 Tray	AVR® ATmega	Tray ⓘ	Active
  <b>ATMEGA32U4-AU</b> IC MCU 8BIT 32KB FLASH 44TQFP <i>Microchip Technology</i>	17,825 In Stock	1 : \$5.29000 Tray	AVR® ATmega	Tray ⓘ	Active
  <b>ATMEGA32U4-AUR</b> IC MCU 8BIT 32KB FLASH 44TQFP <i>Microchip Technology</i>	43,172 In Stock	1 : \$5.39000 Cut Tape (CT)  1,500 : \$4.48003 Tape & Reel (TR)	AVR® ATmega	Tape & Reel (TR) ⓘ Cut Tape (CT) ⓘ Digi-Reel® ⓘ	Active
  <b>ATMEGA32U4-MUR</b> IC MCU 8BIT 32KB FLASH 44VQFN <i>Microchip Technology</i>	23,528 In Stock	1 : \$5.40000 Cut Tape (CT)  4,000 : \$4.49000 Tape & Reel (TR)	AVR® ATmega	Tape & Reel (TR) ⓘ Cut Tape (CT) ⓘ Digi-Reel® ⓘ	Active
  <b>ATMEGA32U4RC-AU</b> IC MCU 8BIT 32KB FLASH 44TQFP <i>Microchip Technology</i>	3,336 In Stock	1 : \$5.26000 Tray	AVR® ATmega	Tray ⓘ	Active
  <b>ATMEGA32U4RC-MUR</b> IC MCU 8BIT 32KB FLASH 44VQFN <i>Microchip Technology</i>	77,872 In Stock	1 : \$5.40000 Cut Tape (CT)  4,000 : \$4.49000 Tape & Reel (TR)	AVR® ATmega	Tape & Reel (TR) ⓘ Cut Tape (CT) ⓘ Digi-Reel® ⓘ	Active

# schematic capture

## finding parts

The  
microcontroller  
we will be using

Mfr Part #	Quantity Available	Price	Series	Package	Product Status
^	^	^	^	^	^
 <b>ATMEGA32U4-MU</b> IC MCU 8BIT 32KB FLASH 44VQFN <i>Microchip Technology</i>	14,742 In Stock	1 : \$5.26000 Tray	AVR® ATmega	Tray	Active
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Arduino IDE comes pre-installed with a compiler for this microcontroller, as they use it on some of their boards. Convenient for us!

# schematic capture

## finding parts

External crystal,  
larger package

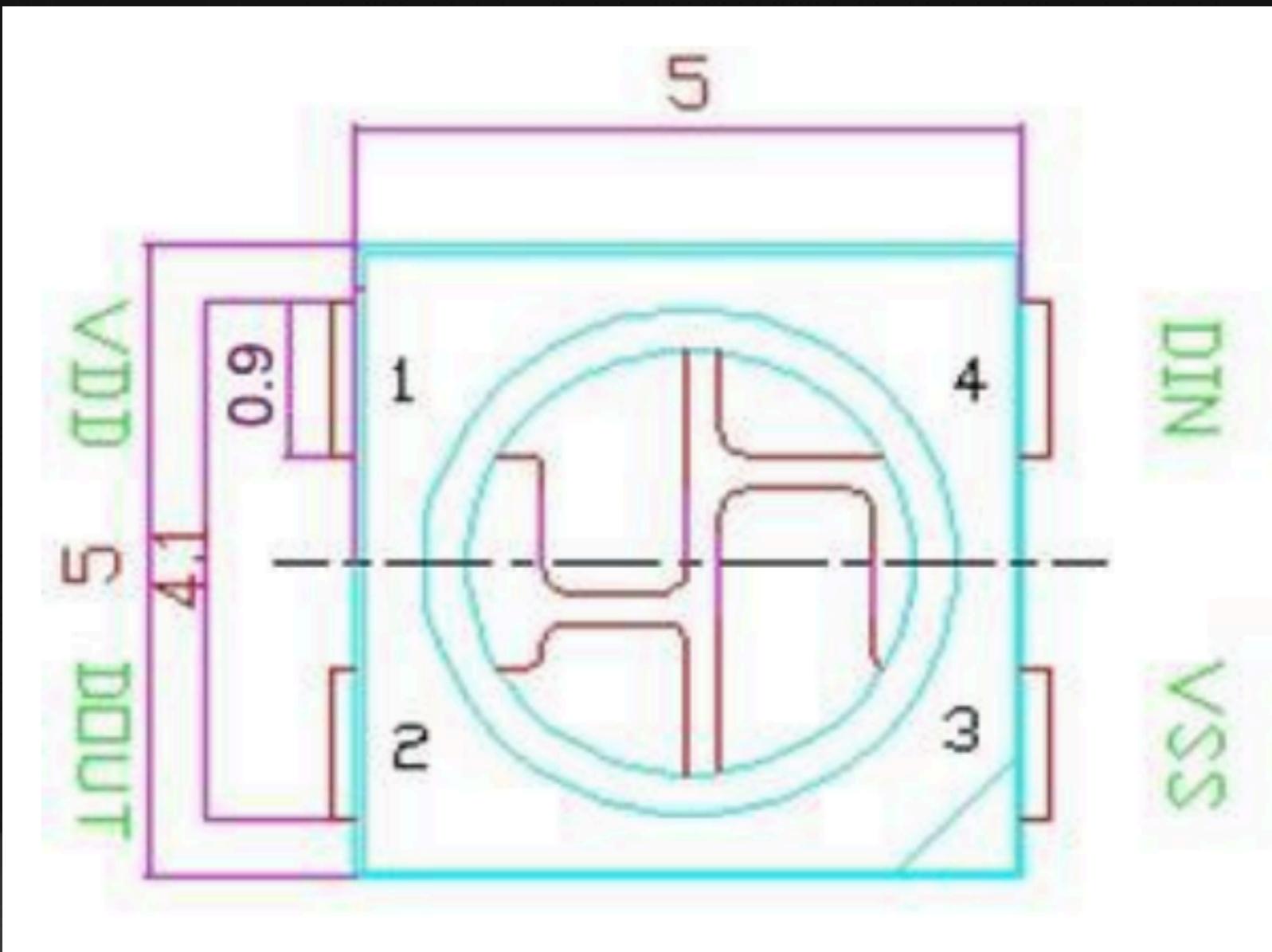
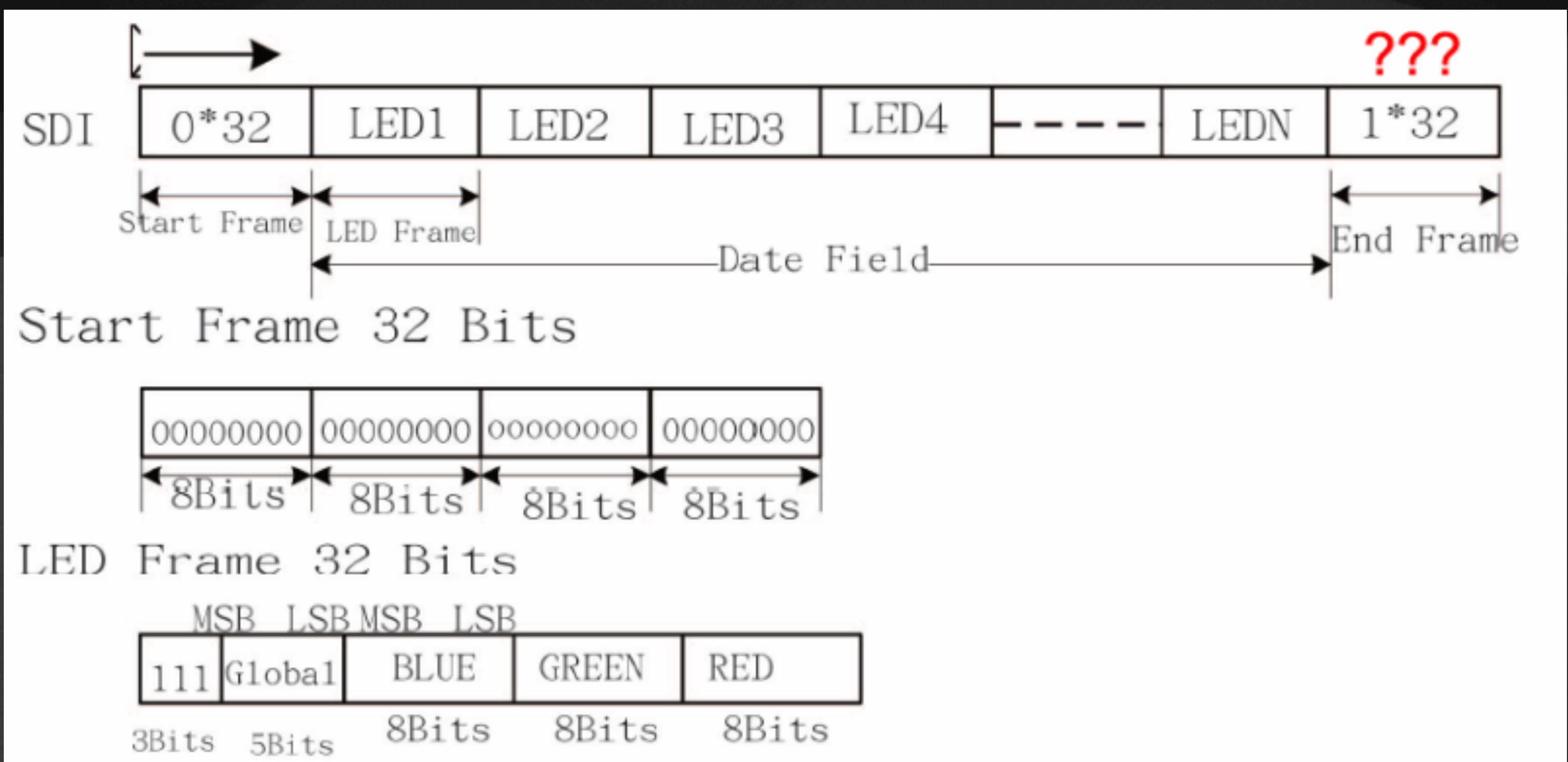
### 6.2 ATmega32U4

Speed [MHz]	Power Supply	Ordering Code	Default Oscillator	Package	Operation Range	
16	2.7 - 5.5V	ATmega32U4-AU	External XTAL	44ML	Industrial (-40° to +85°C)	
		ATmega32U4RC-AU	Internal Calib. RC			
		ATmega32U4-MU <sup>(1)(2)(3)</sup>	External XTAL	44PW		
		ATmega32U4RC-MU <sup>(1)(2)(3)</sup>	Internal Calib. RC			

- Notes:
1. For more information on running the USB from internal RC oscillator consult application note AVR291: 8MHz Internal Oscillator Calibration for USB Low Speed on Atmel ATmega32U4RC.
  2. USB operation from internal RC oscillator is only guaranteed for 0°C to 40°C.
  3. These parts are shipped with no USB bootloader pre-programmed.

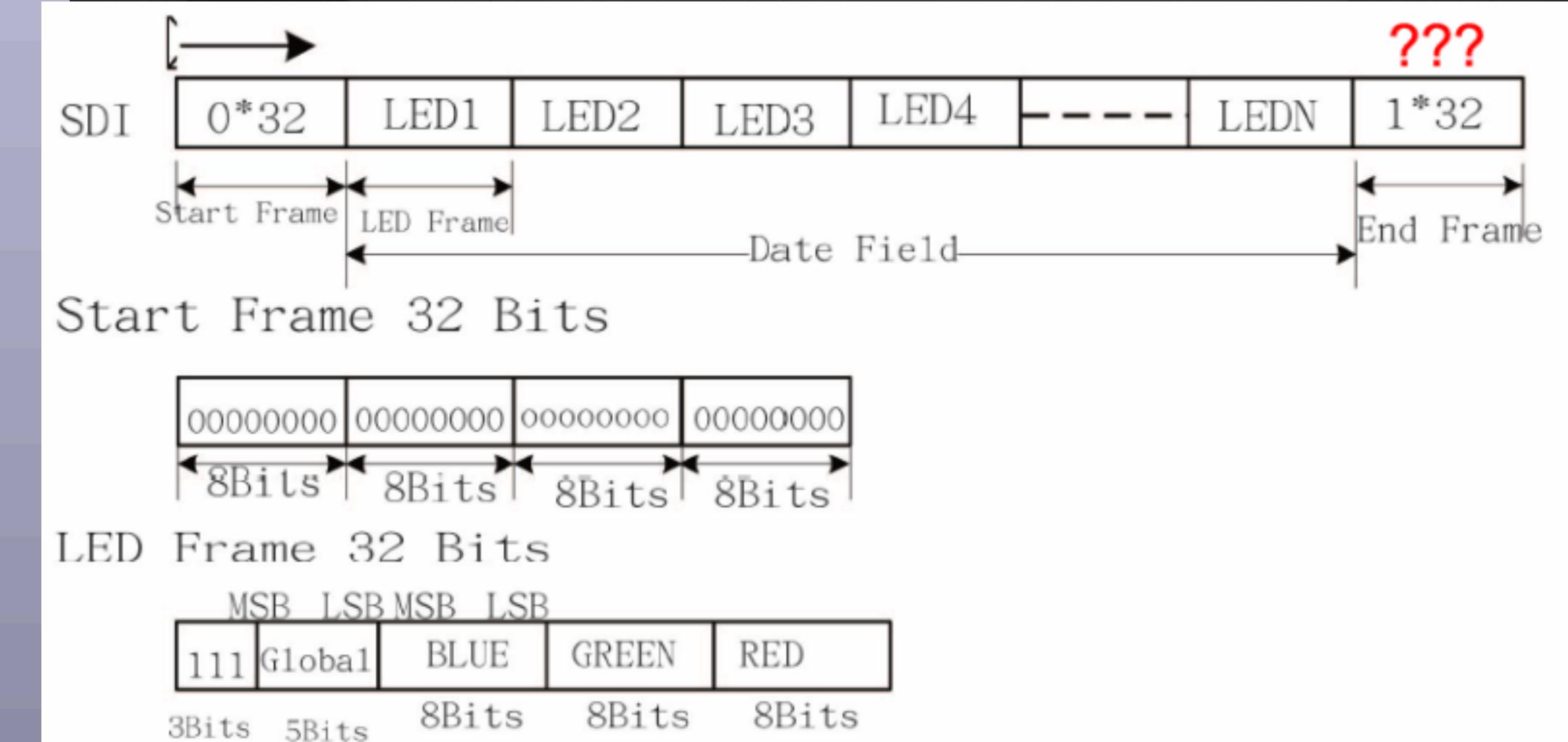
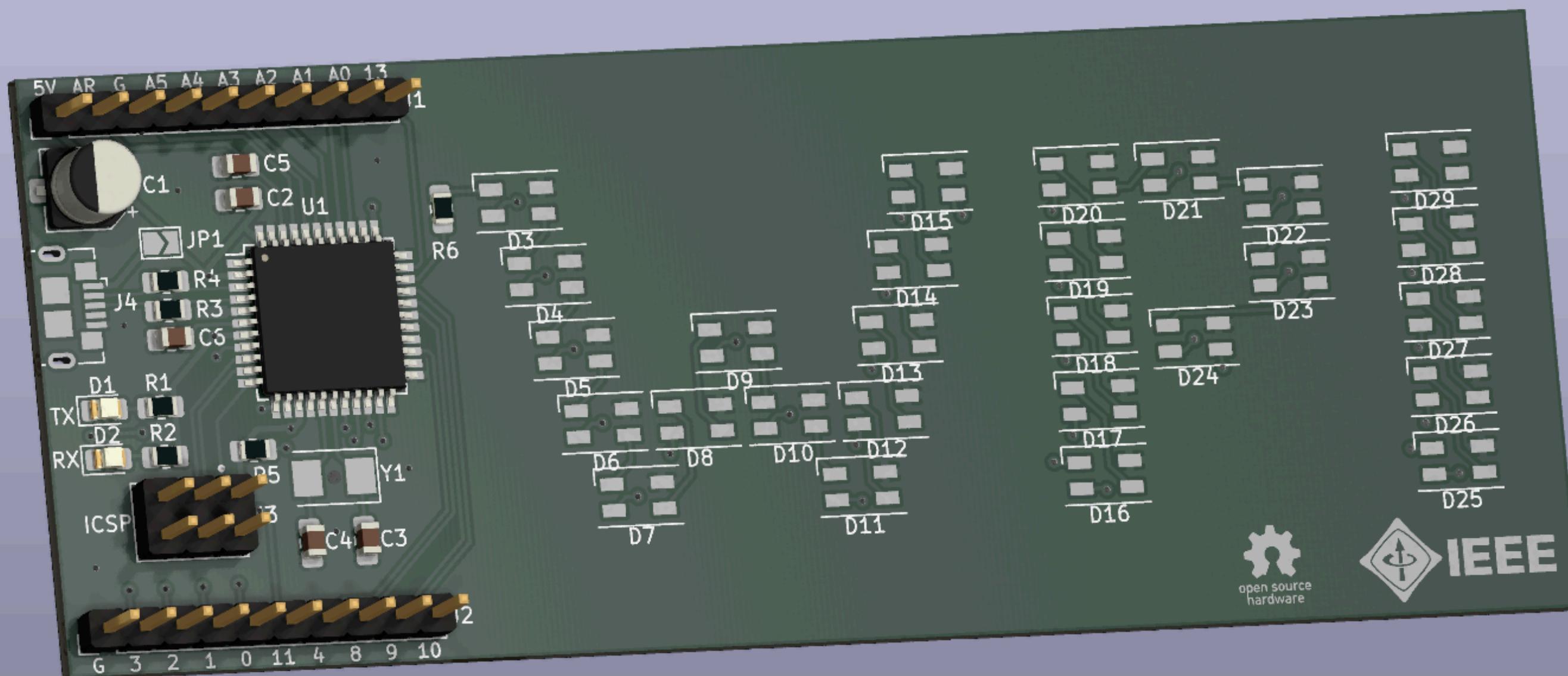
# schematic capture

## finding parts



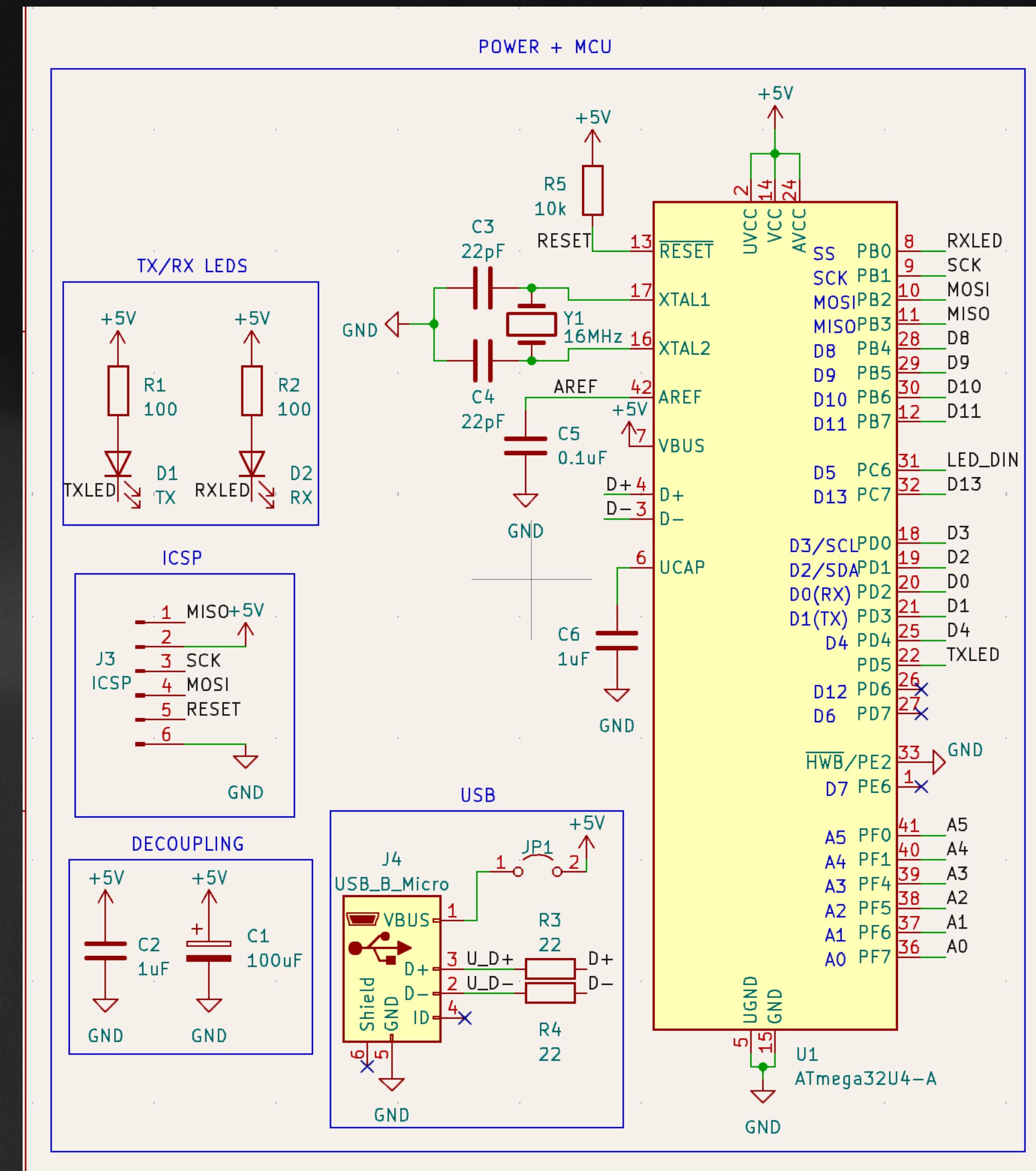
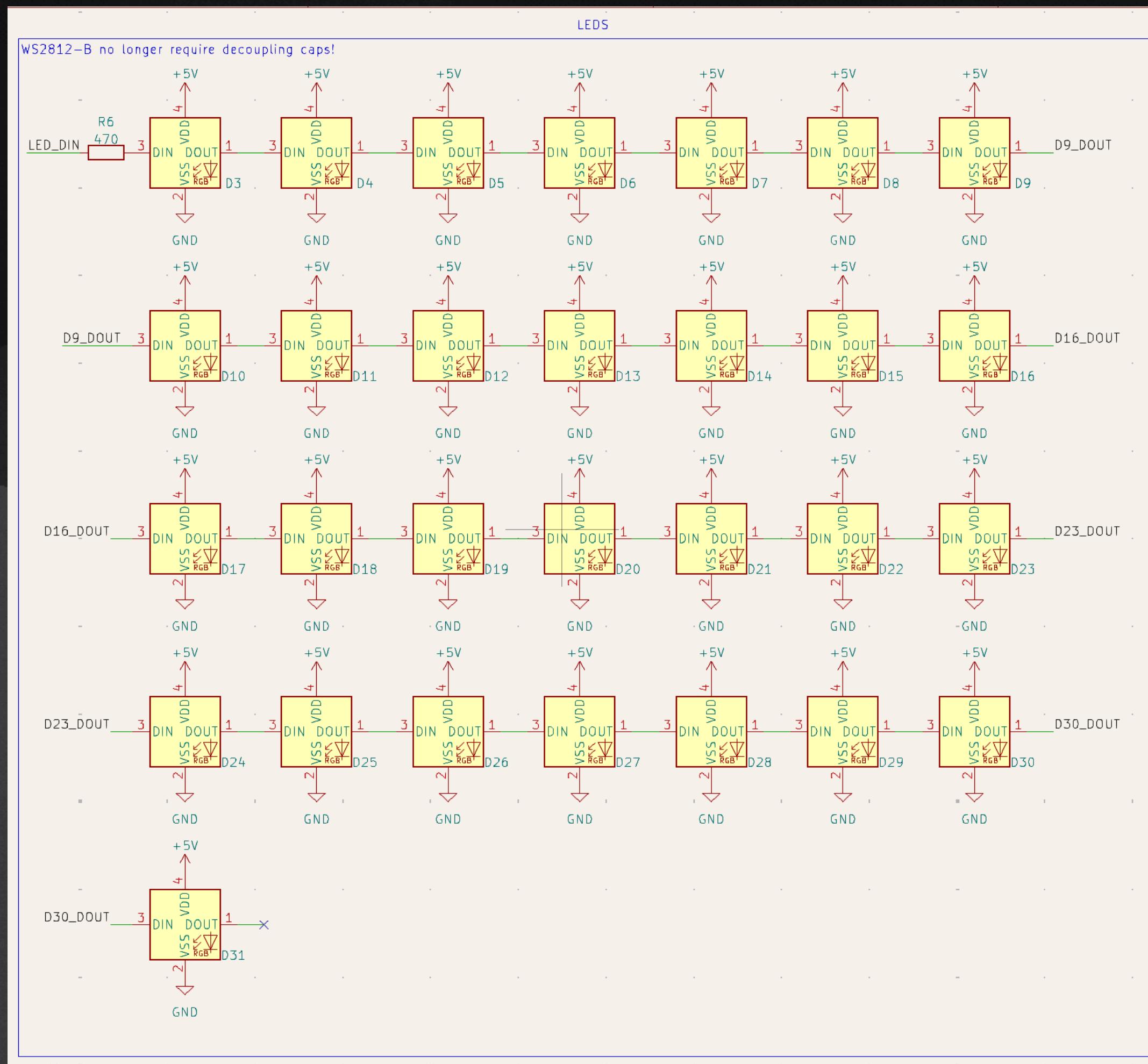
# about the board

## specifics



# about the board

## specifics



# about the board decoupling capacitors

