

Essentials of PCB Design

02: Project Design

about this class

schedule

A-Term

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

B-Term

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

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!



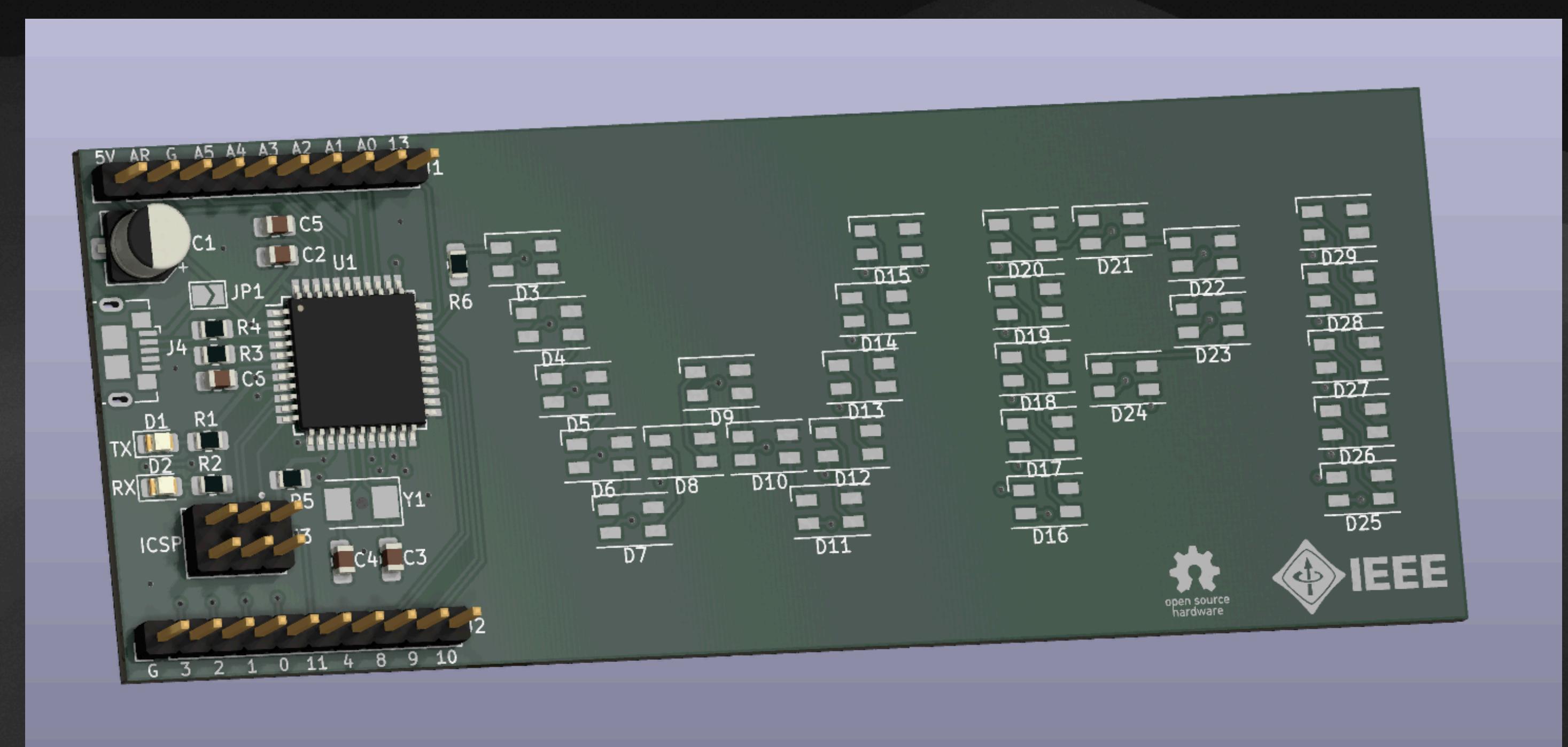
Track Registration

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

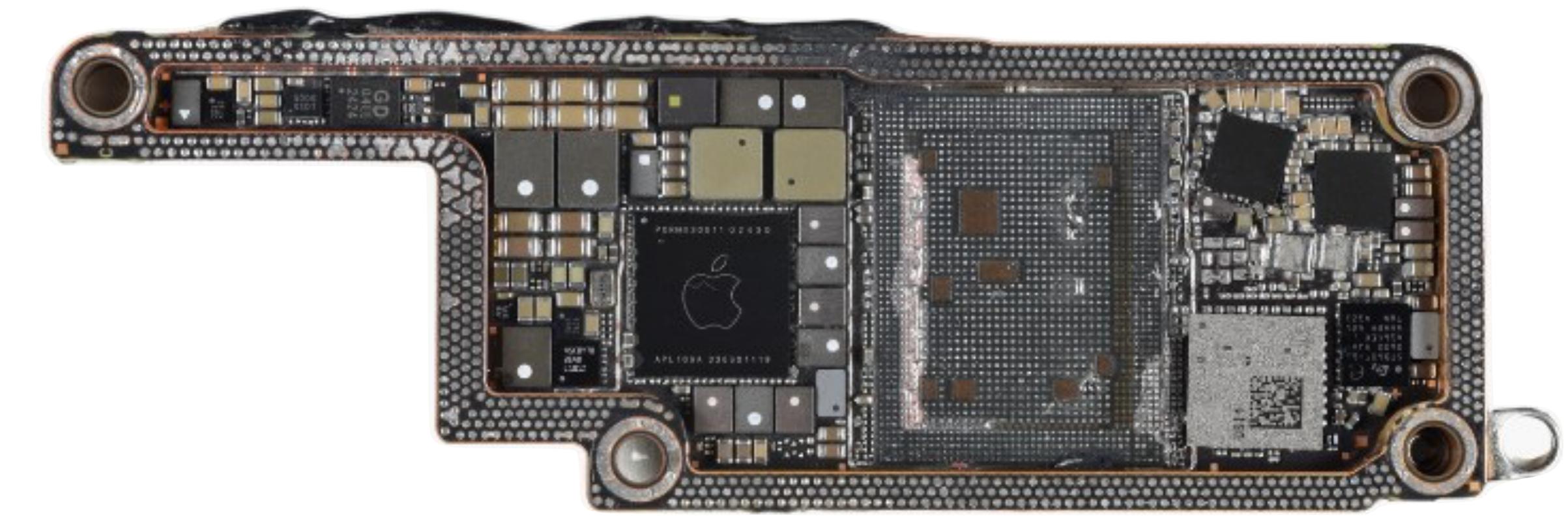
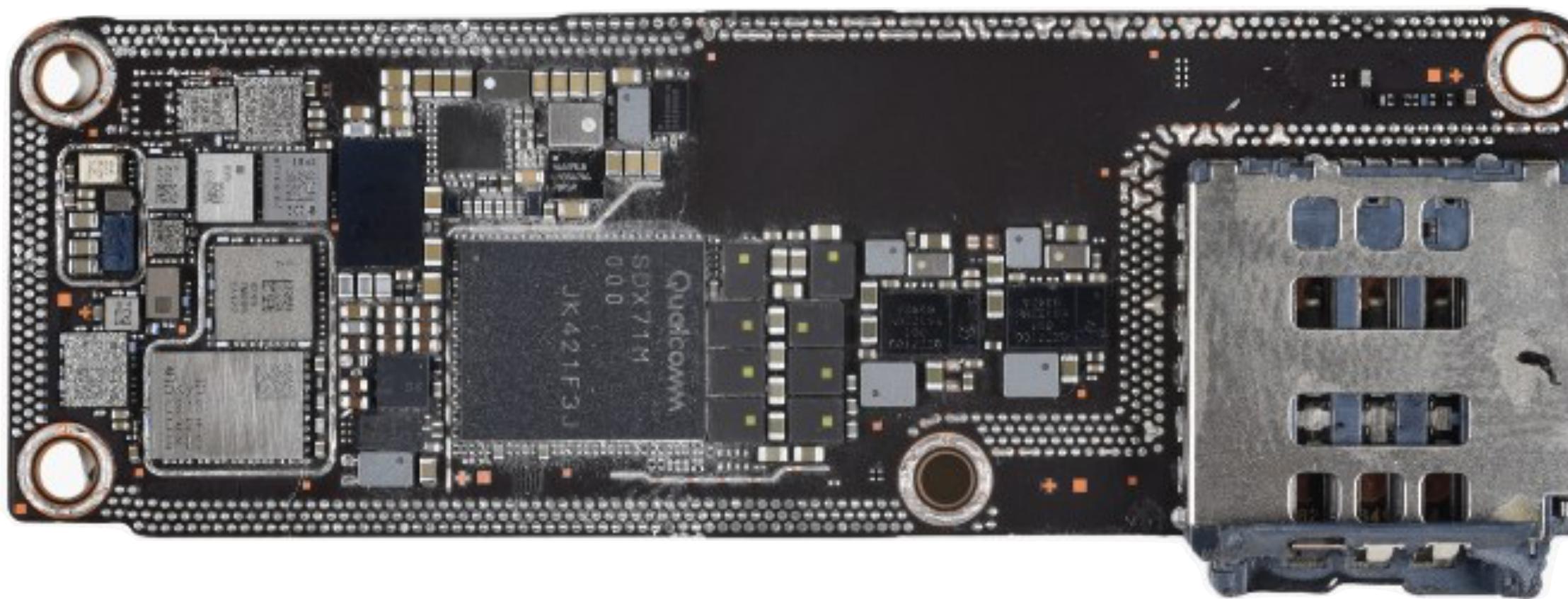
basics of PCBs

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

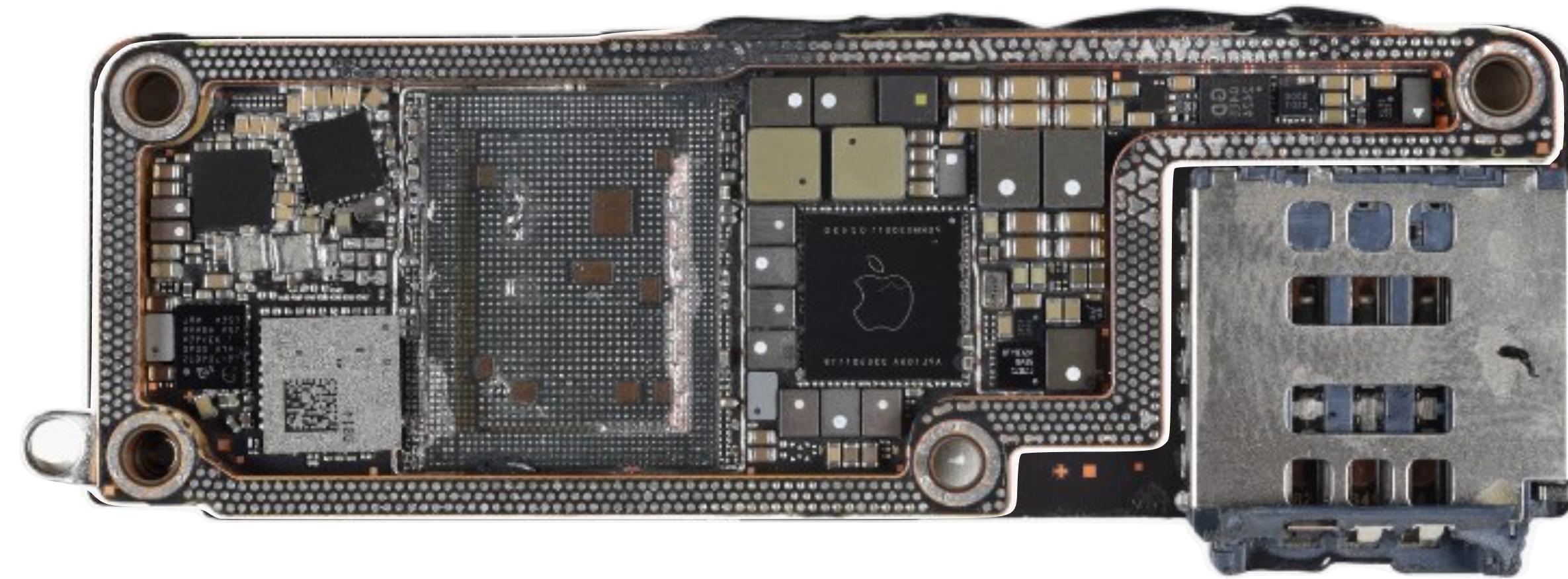
VERY complicated PCB



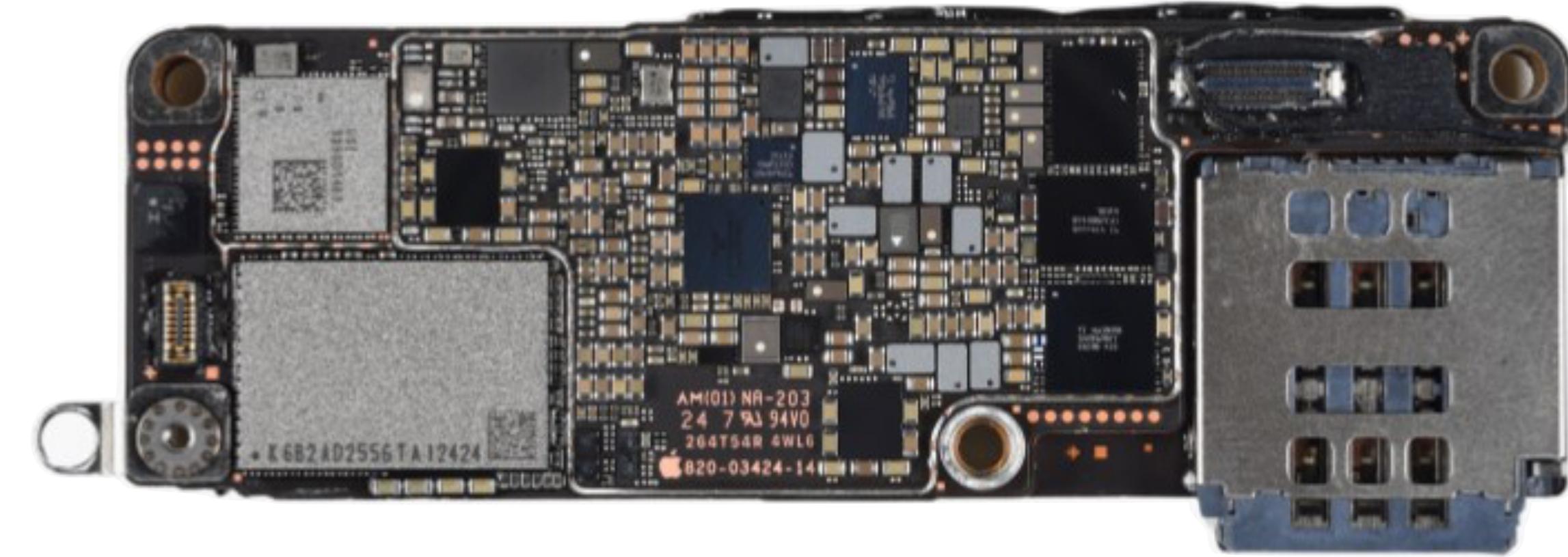
iPhone 16 pro max motherboard



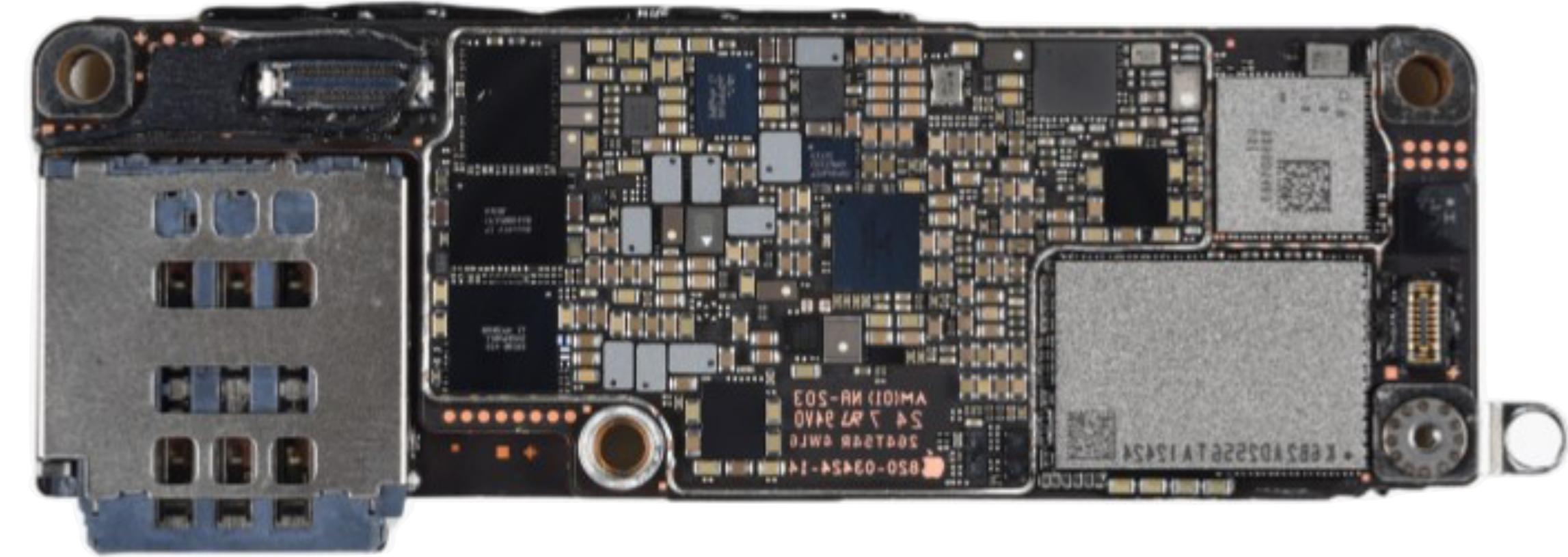
iPhone 16 pro max motherboard



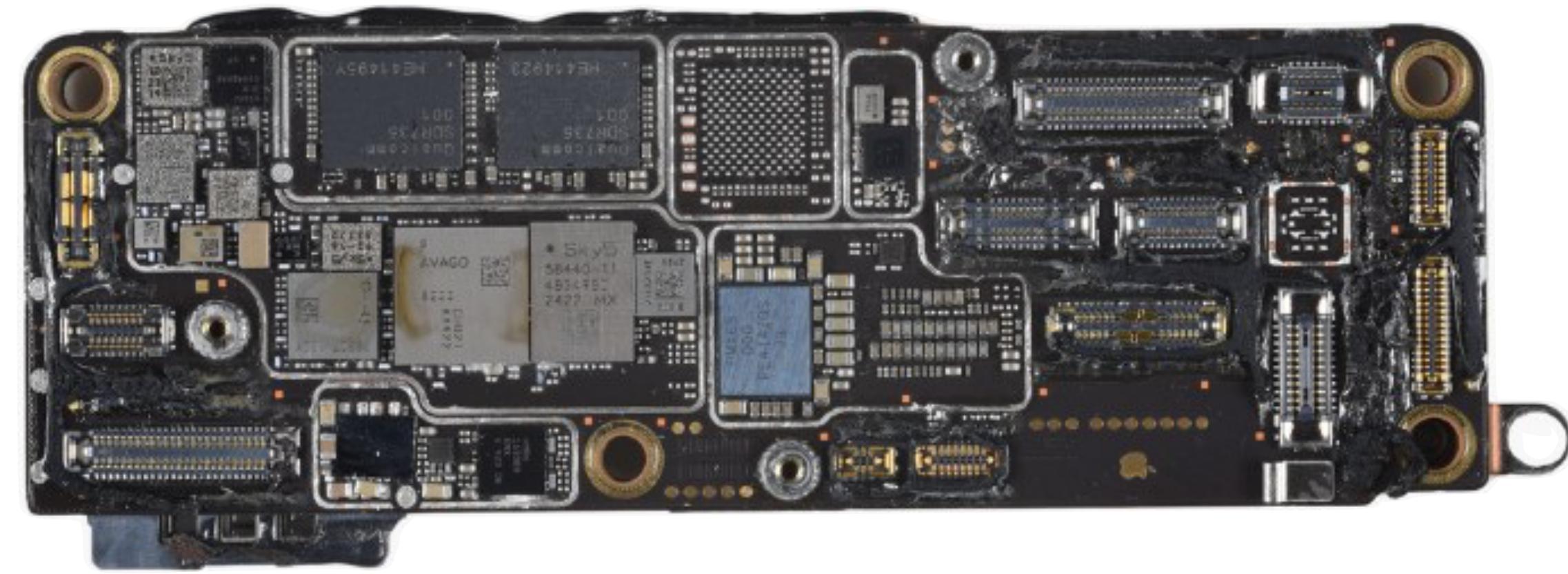
iPhone 16 pro max motherboard



iPhone 16 pro max motherboard



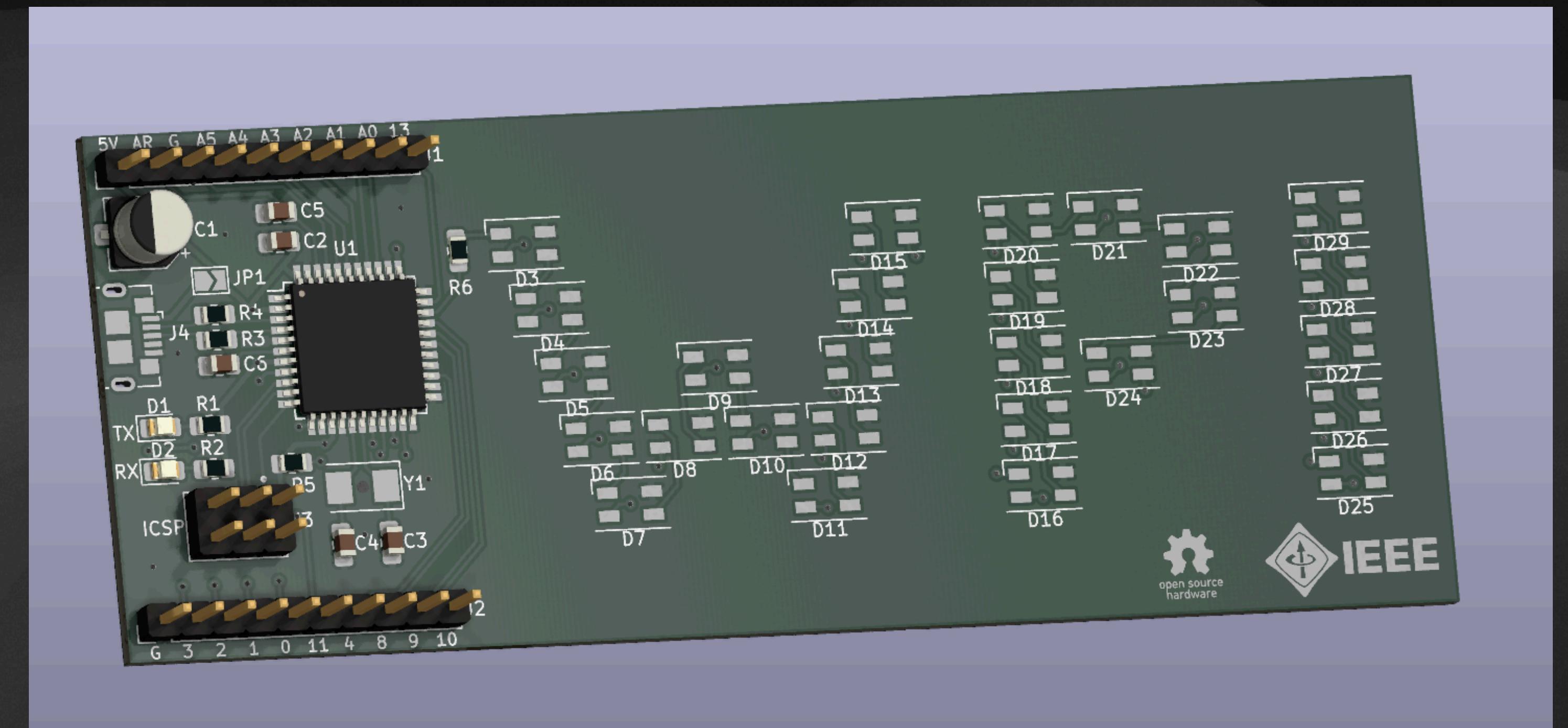
iPhone 16 pro max motherboard



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

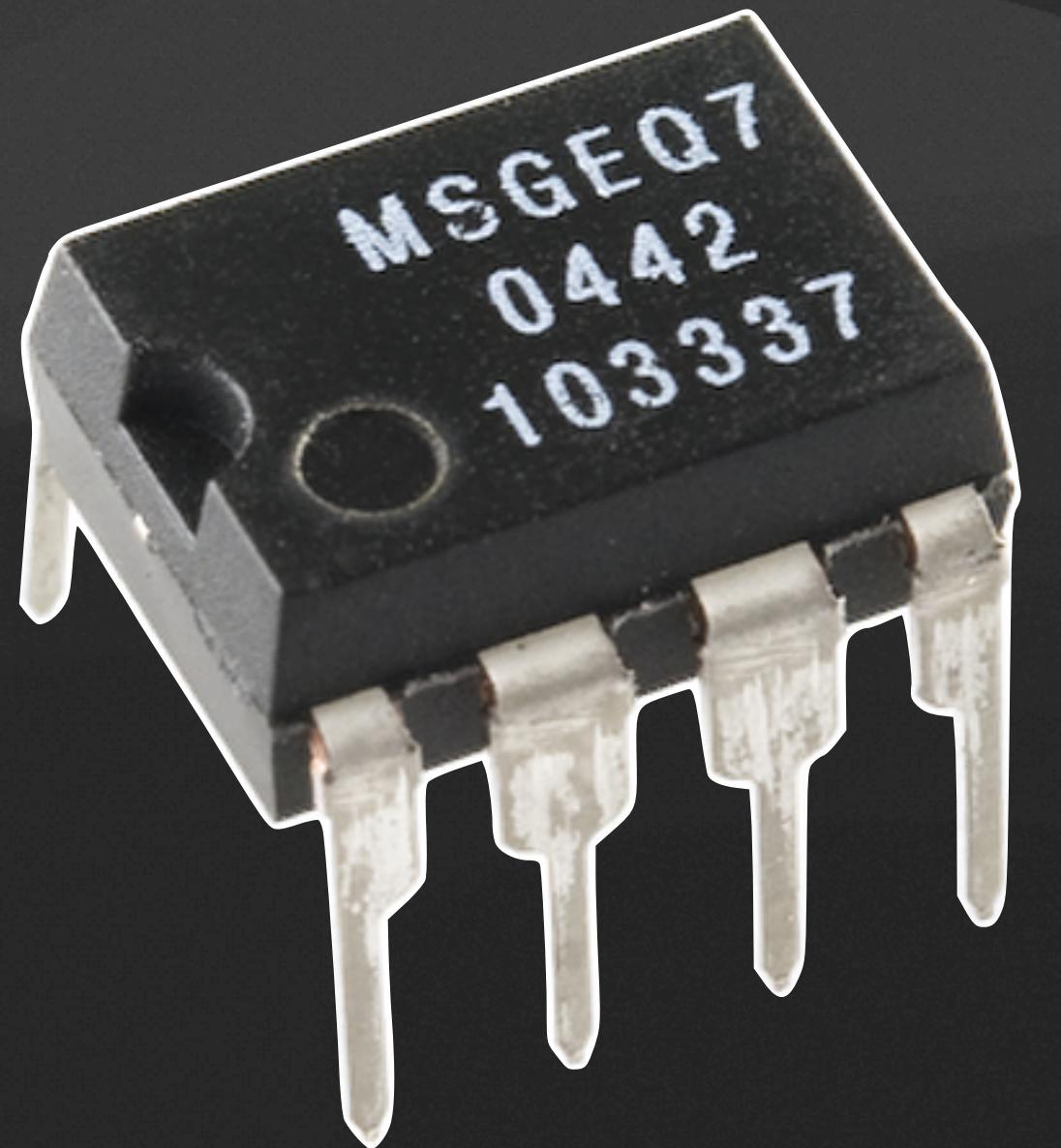
teensy visualizer

inspiration

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

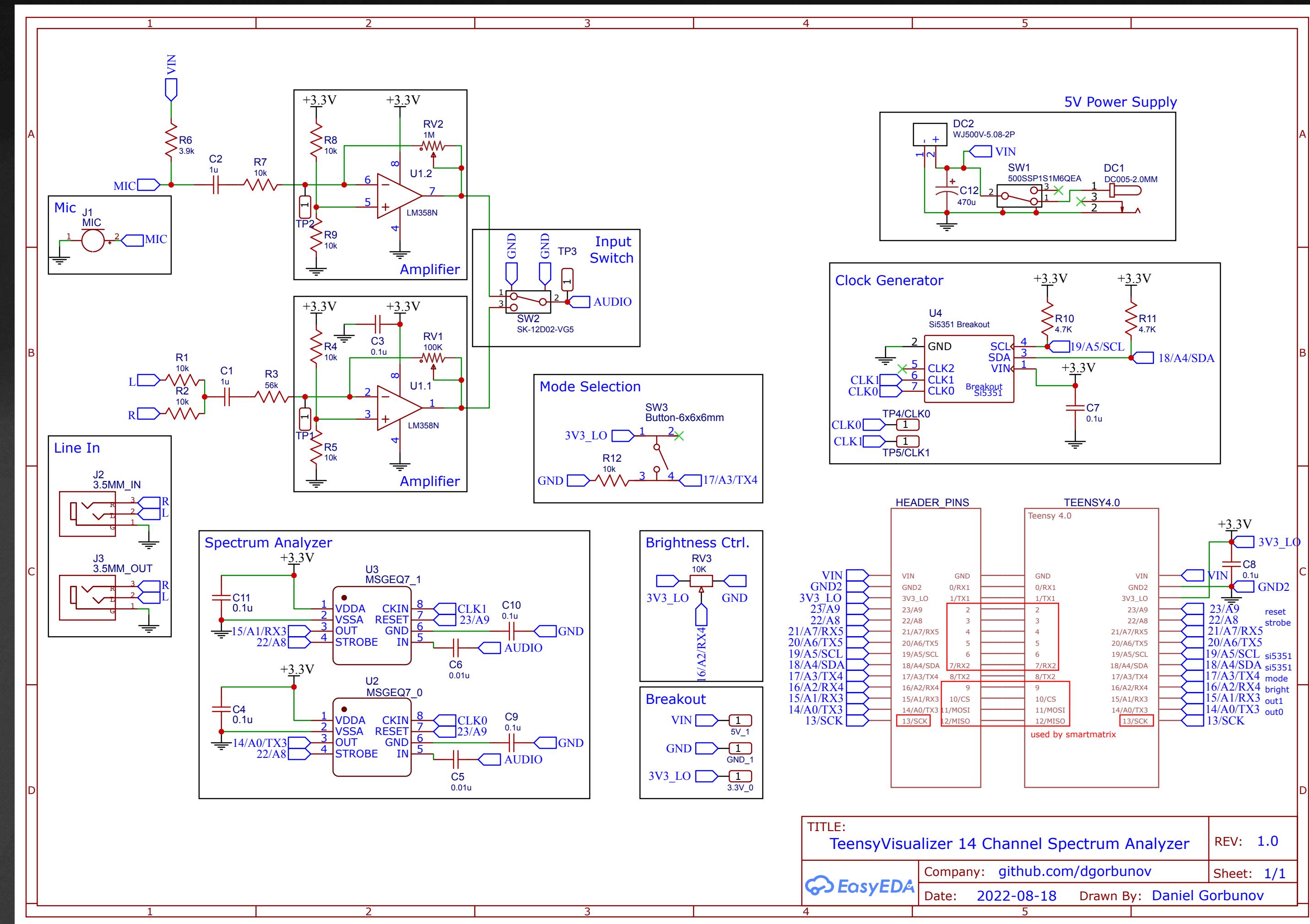
teensy visualizer components?

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

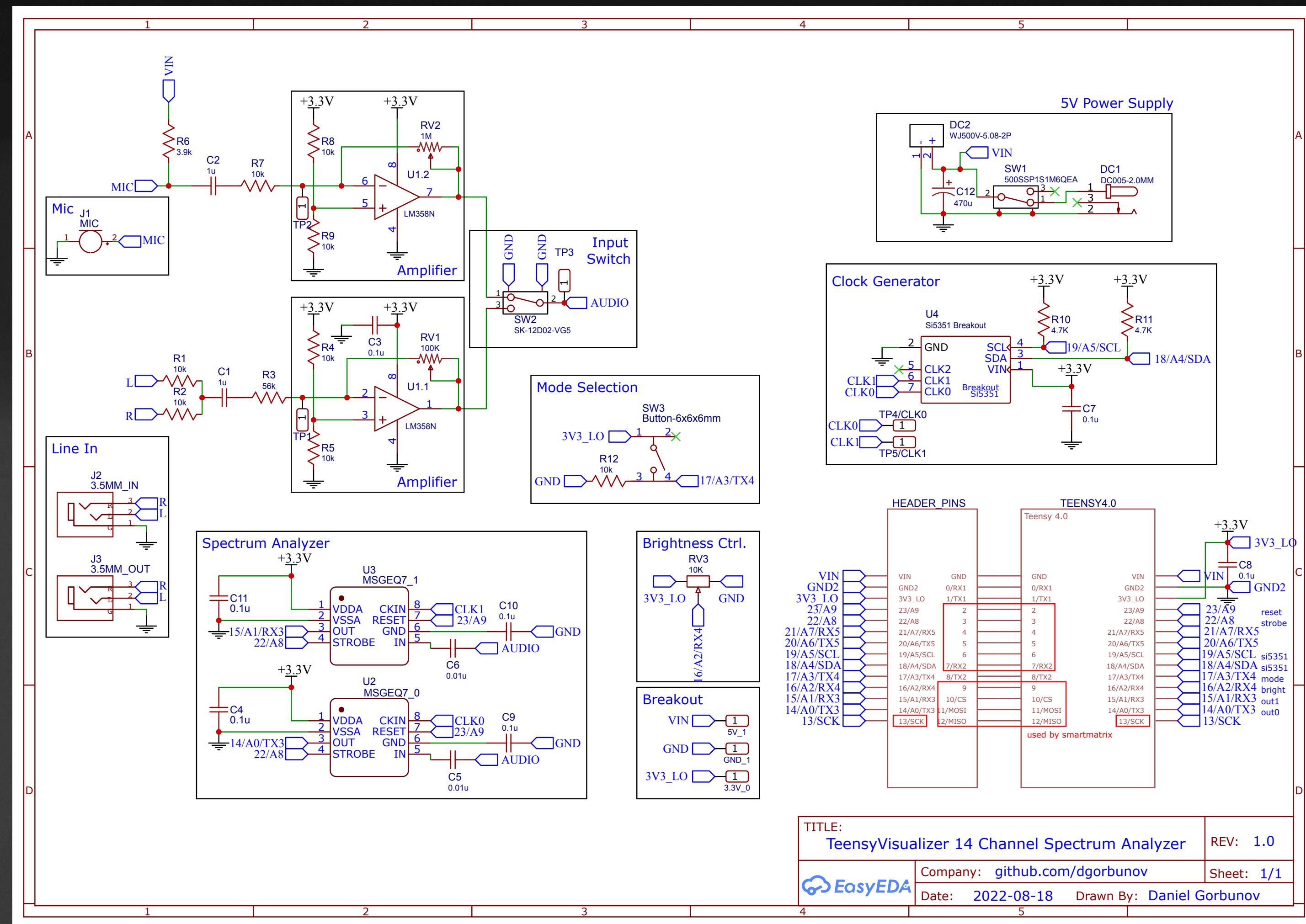


teensy visualizer

schematic

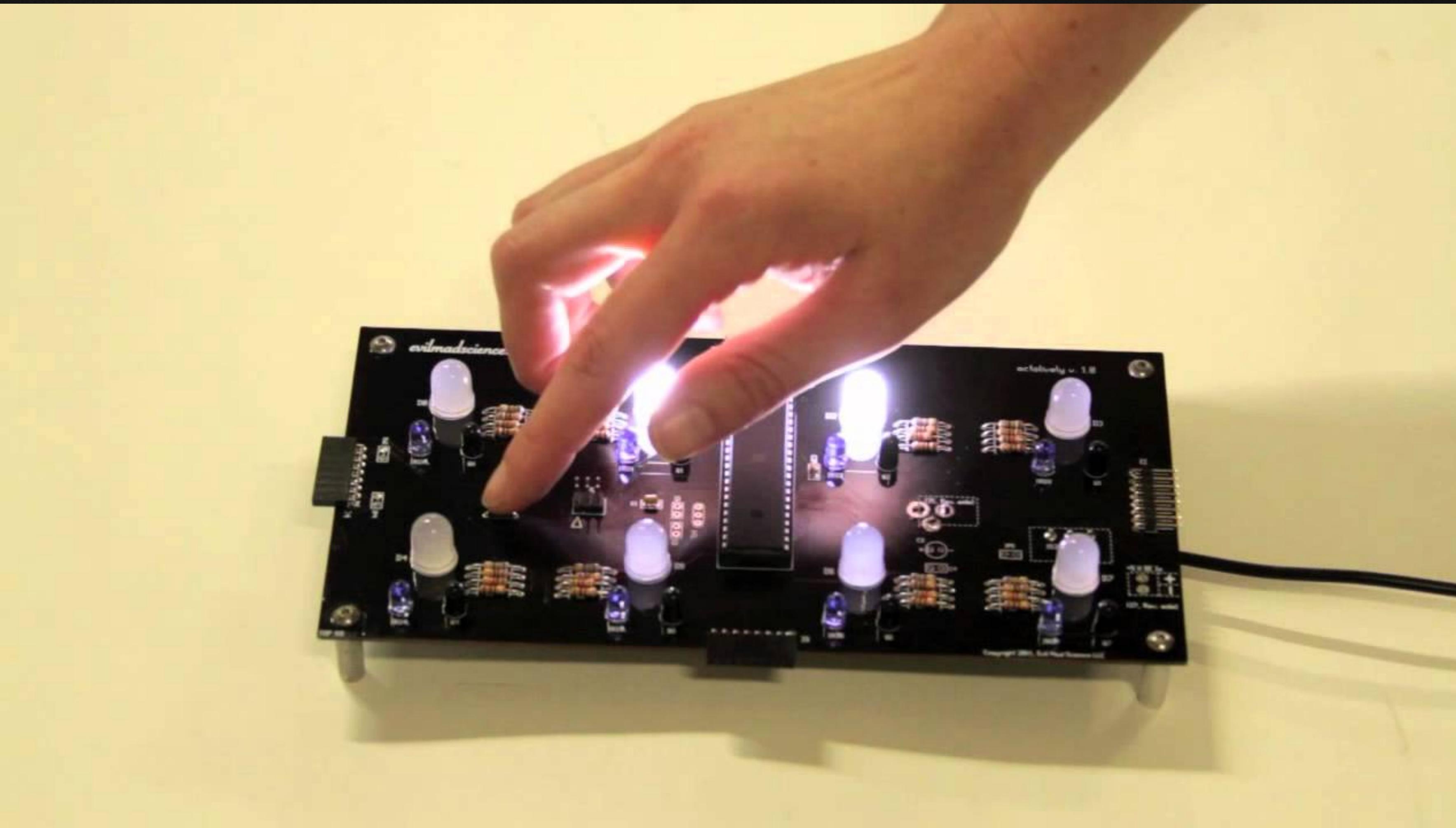


teensy visualizer board



reactive LEDs

inspiration



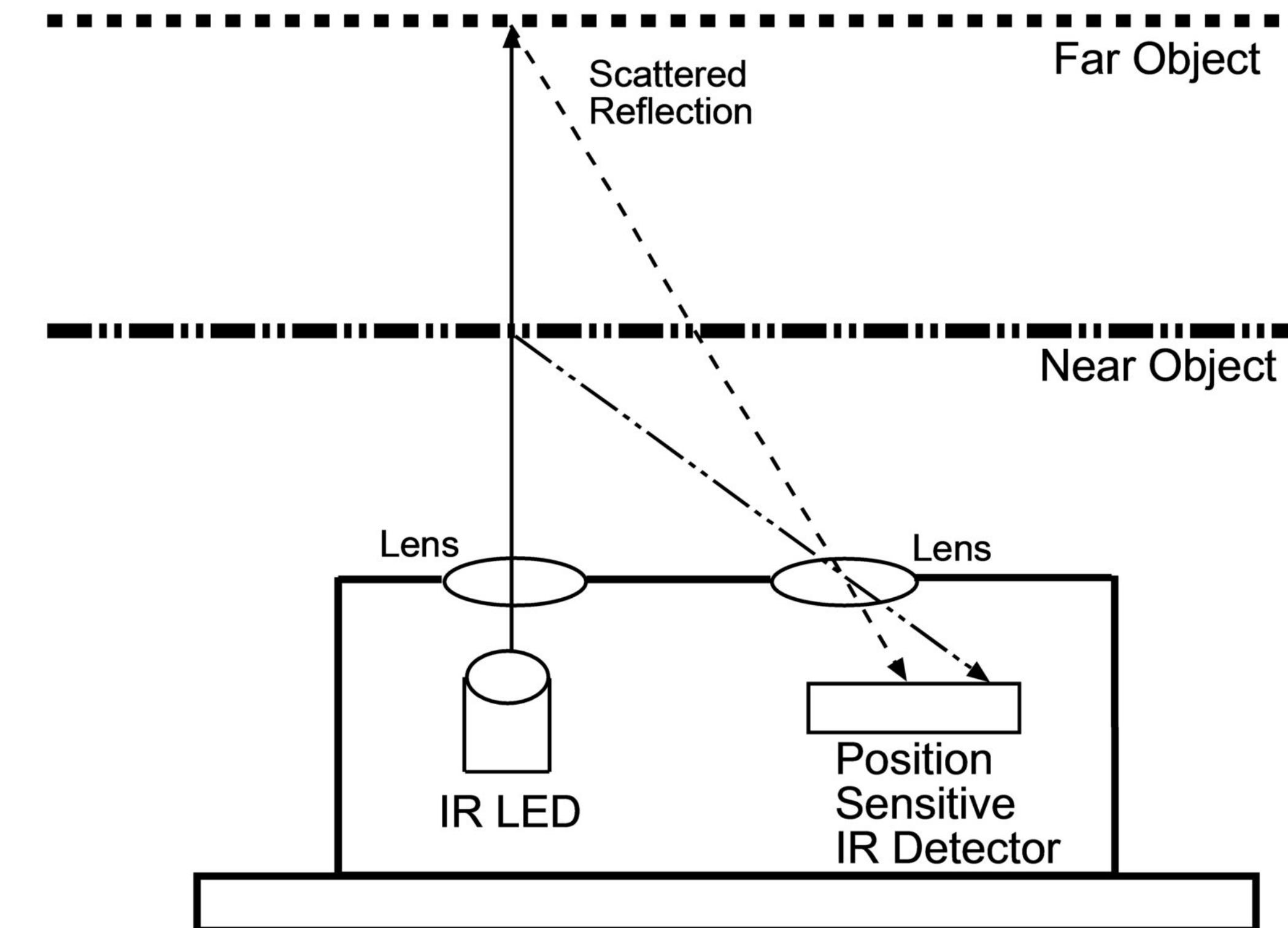
reactive LEDs

components?

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

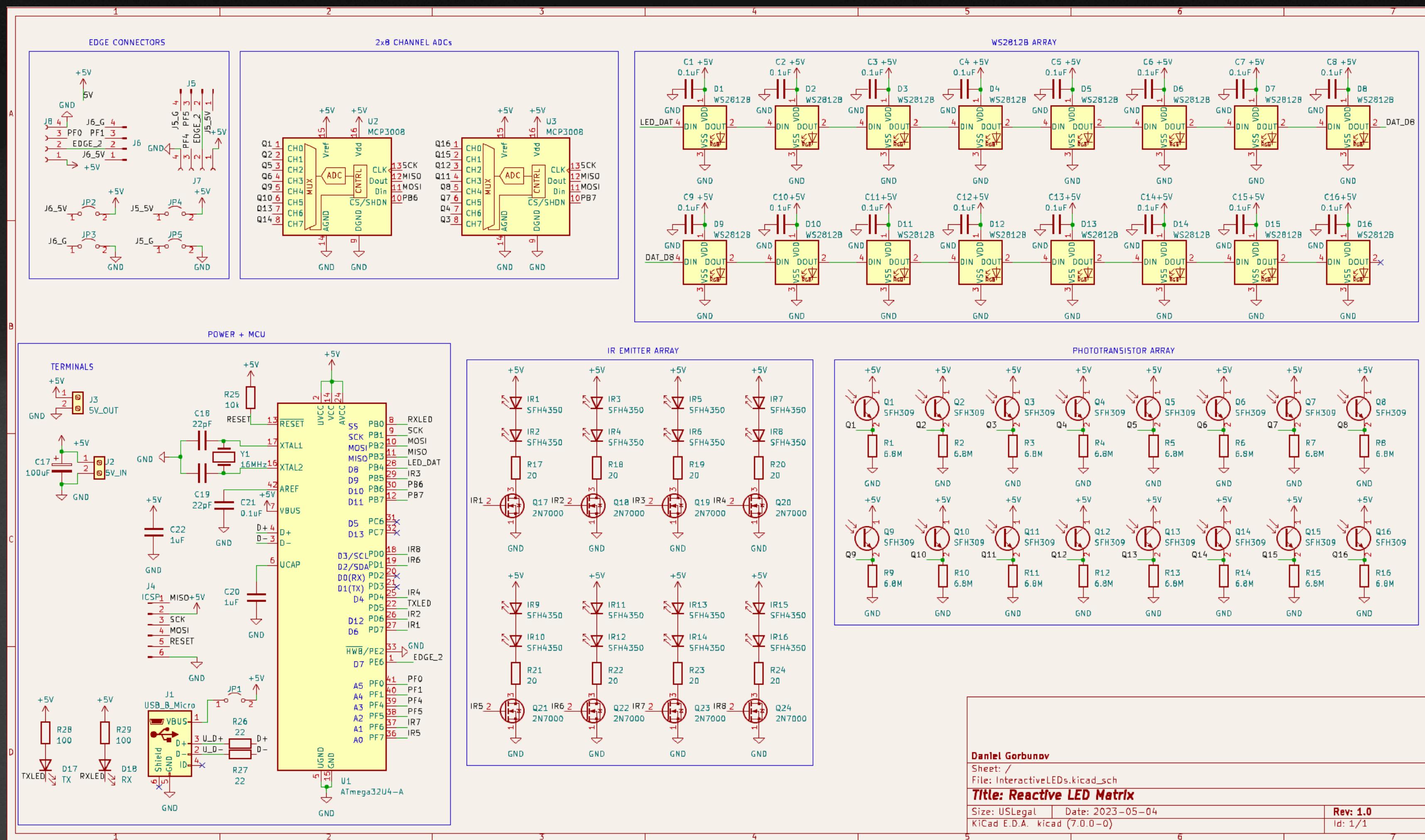
reactive LEDs

infrared sensing

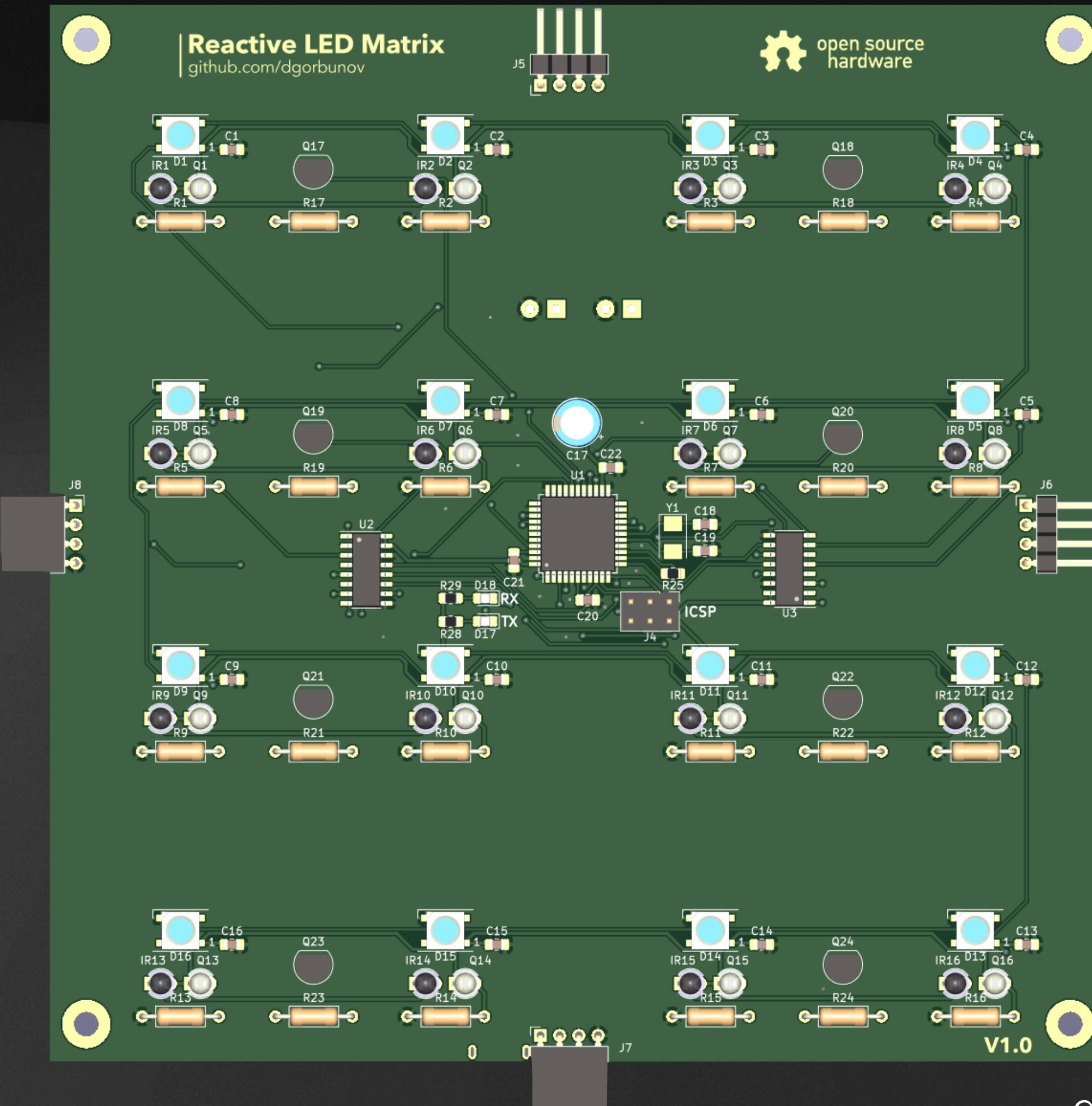


reactive LEDs

schematic



reactive LEDs board



github.com/dgorbunov/ReactiveLEDMatrix

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

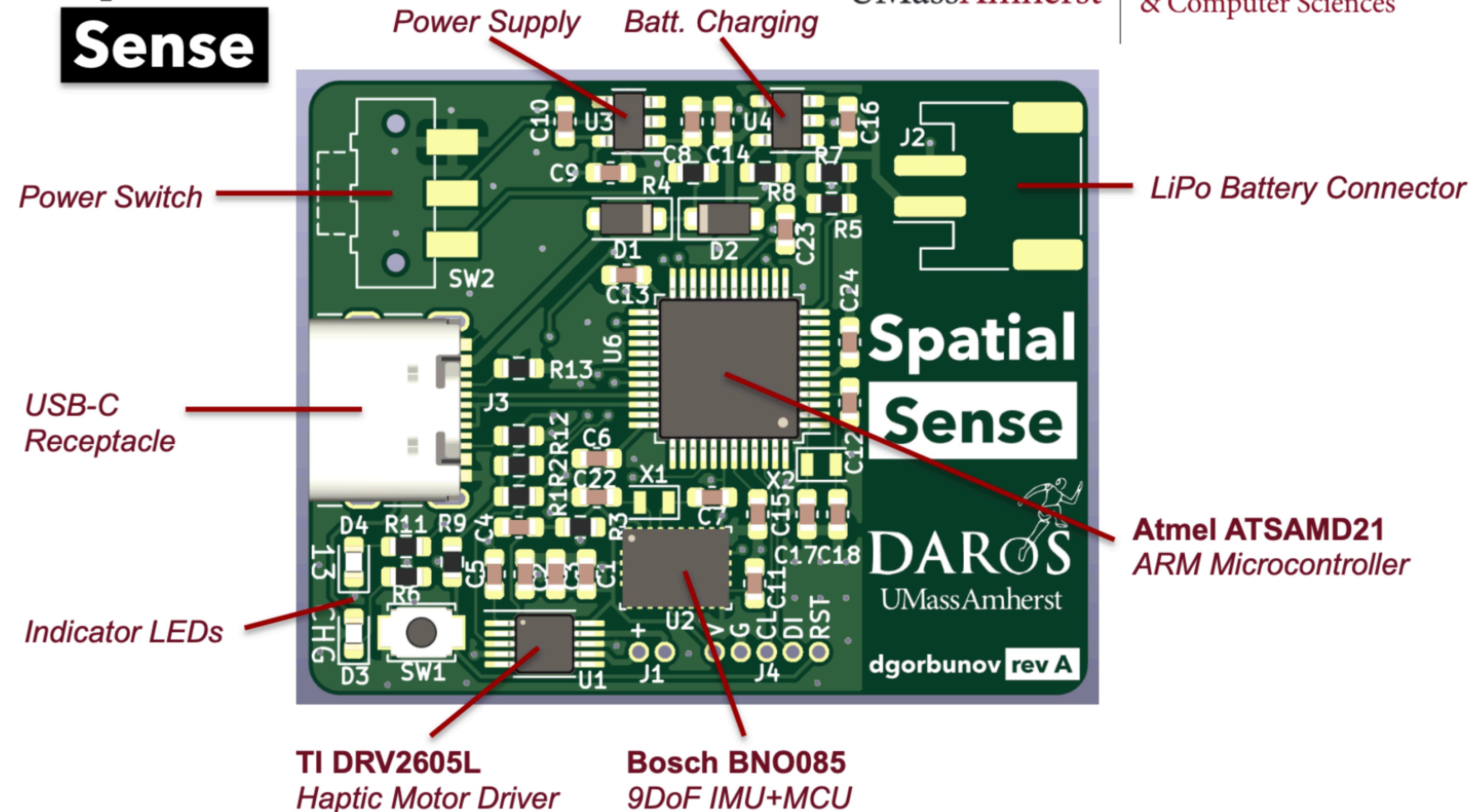
components?

- 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

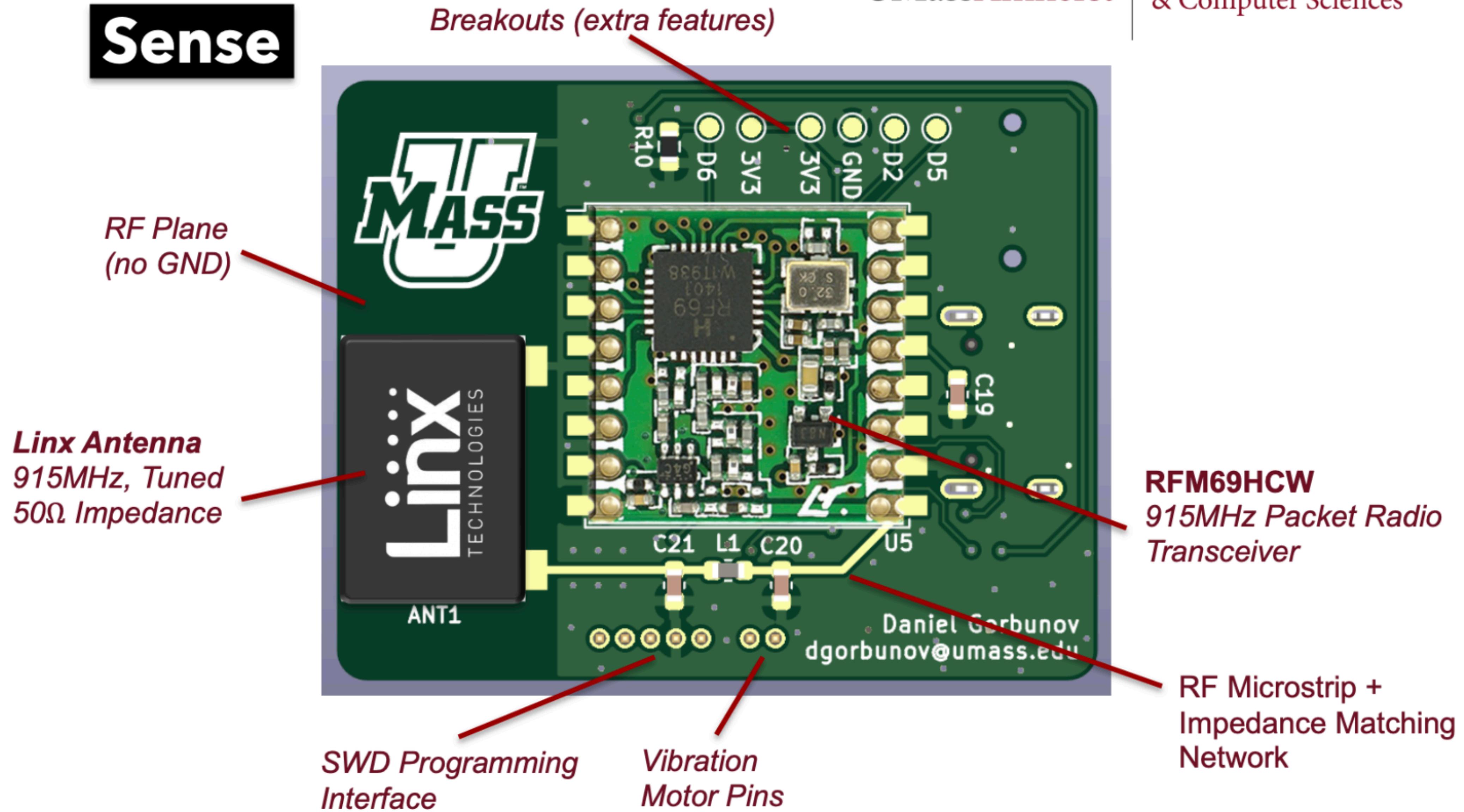
Manning College of Information
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Spatial Sense

UMassAmherst

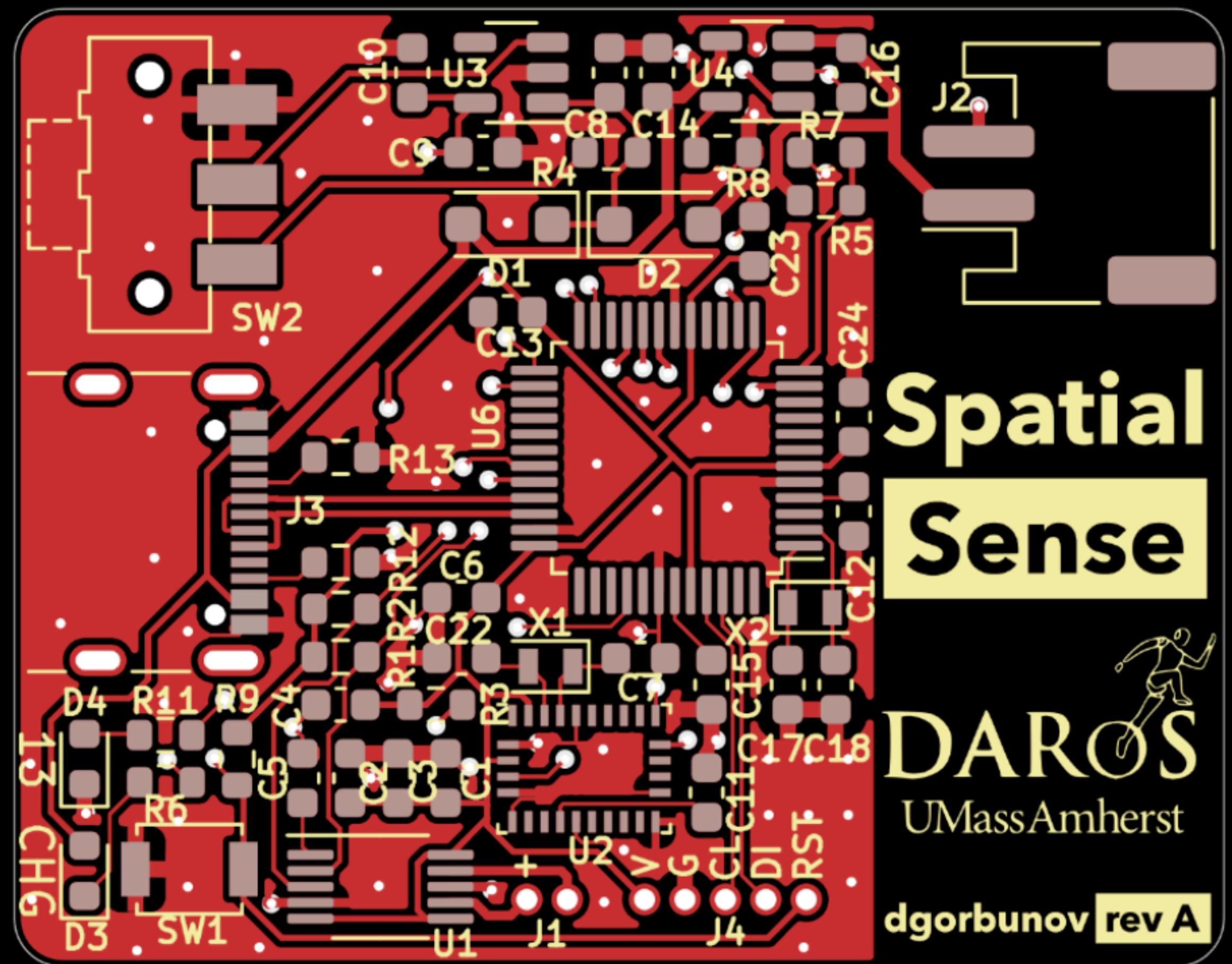
Manning College of Information
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PCB Layout

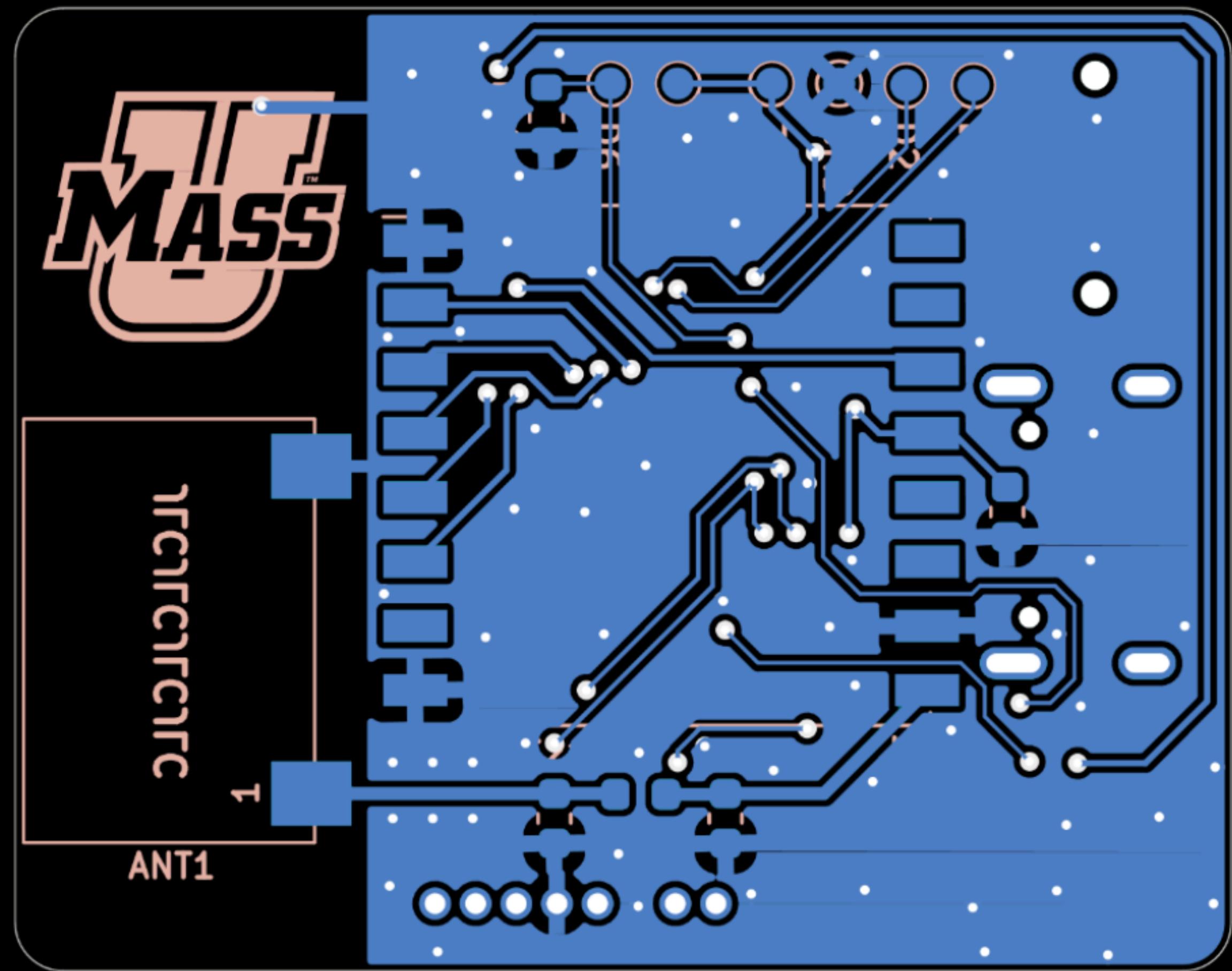
30mm

Front



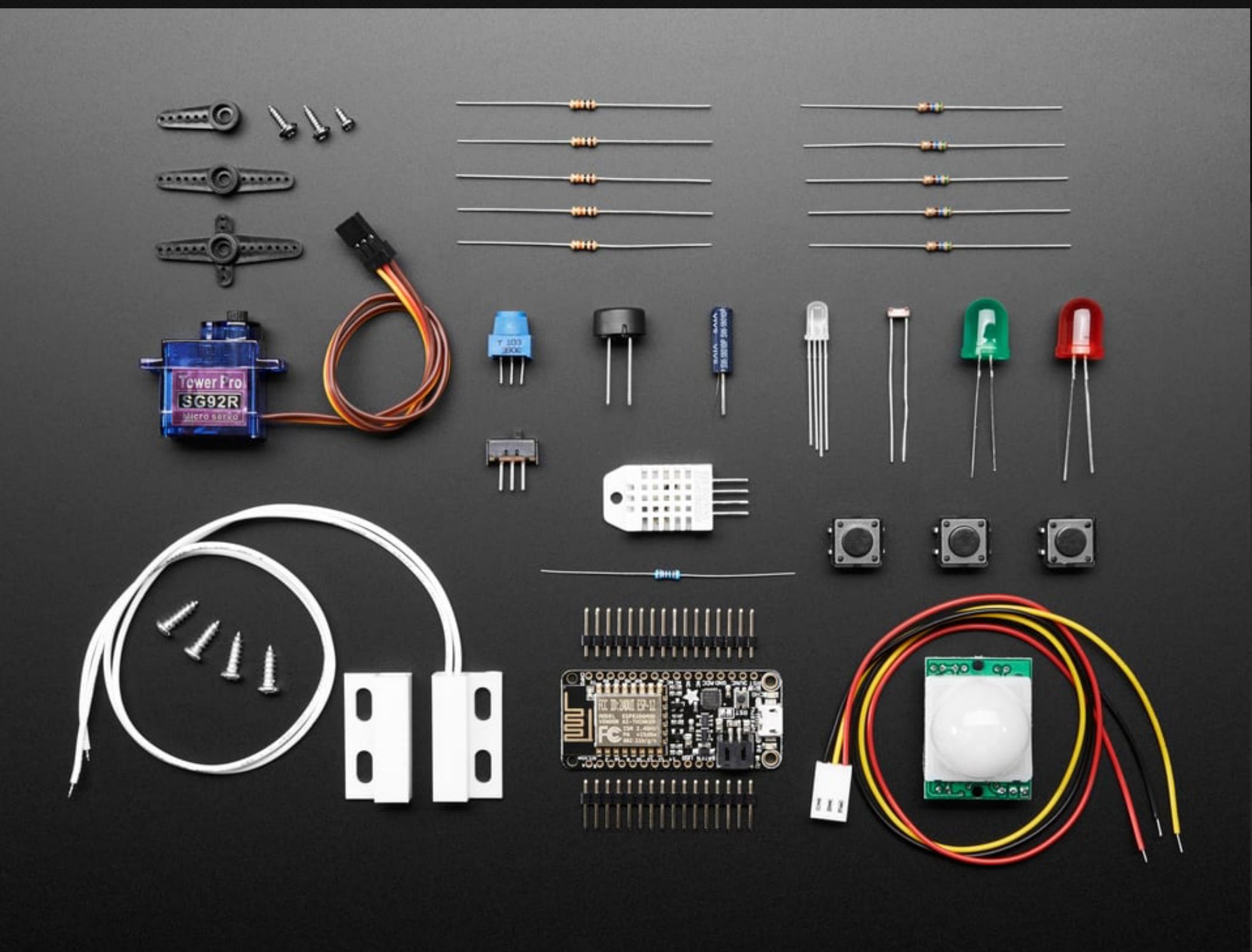
38mm

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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Batteries	Sensors
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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 'Code' tab is selected, showing a list of recent commits:

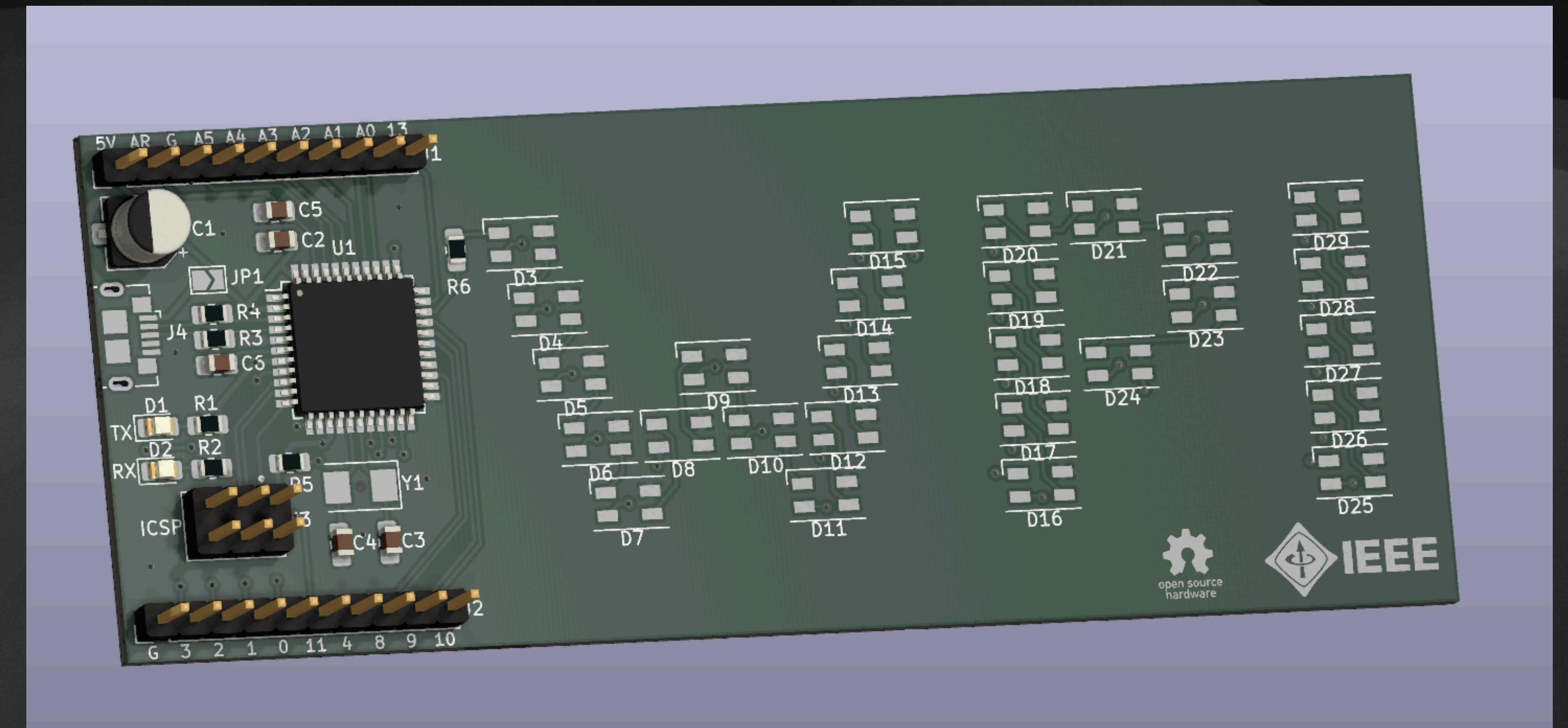
File / Commit Message	Time Ago
dgorbunov add d24 gerbers and update readme	a986431 · 4 hours ago
datasheets add datasheets and new sample board ...	4 hours ago
sample_board add d24 gerbers and update readme	4 hours ago
slides cleanup	2 days ago
starter_board update board files for A24	4 hours ago
starter_code 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

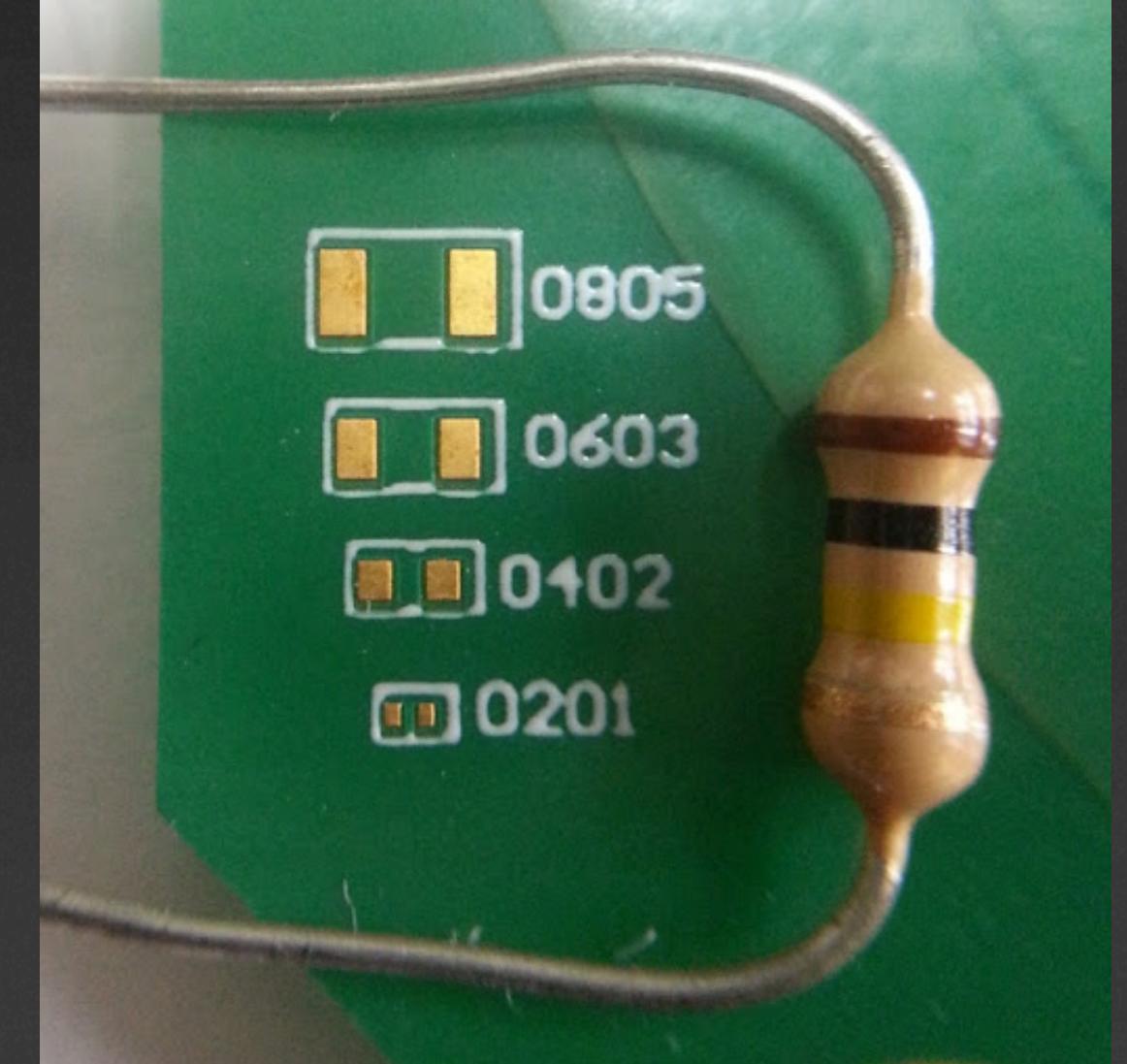
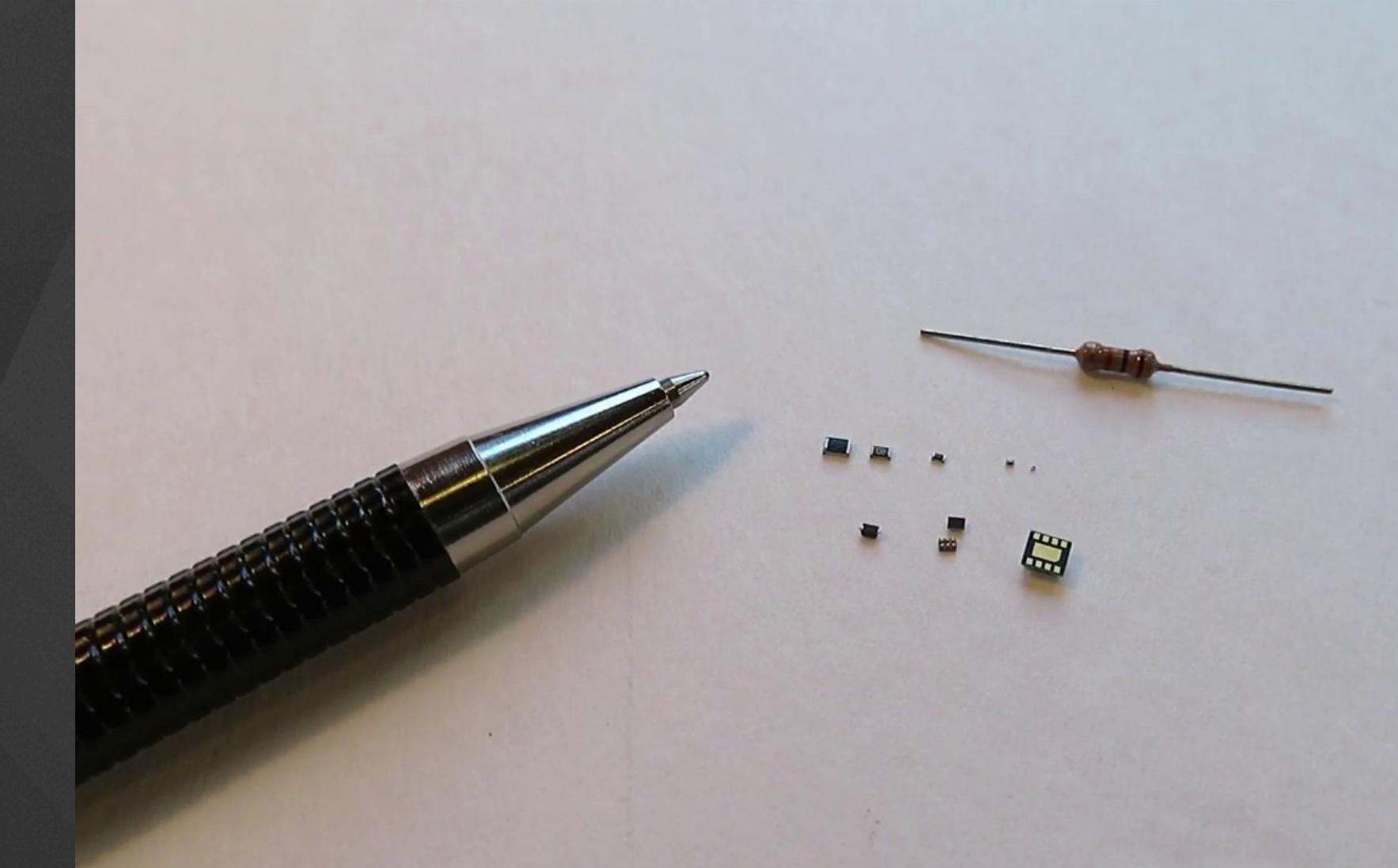
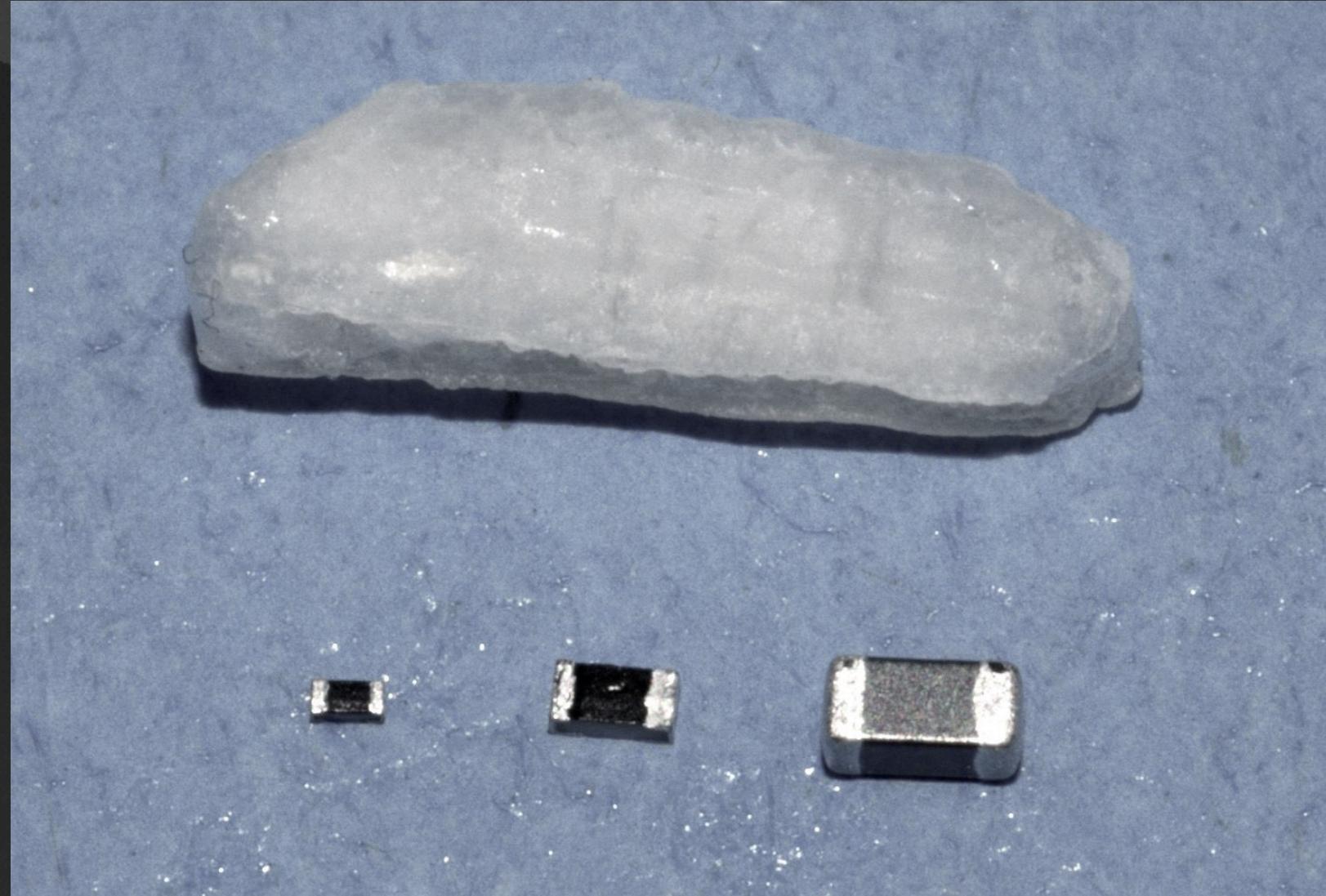
1. Research and Design
2. Schematic Capture (?)
3. Layout
4. Routing
5. Order
6. Assembly



Packages

An aside

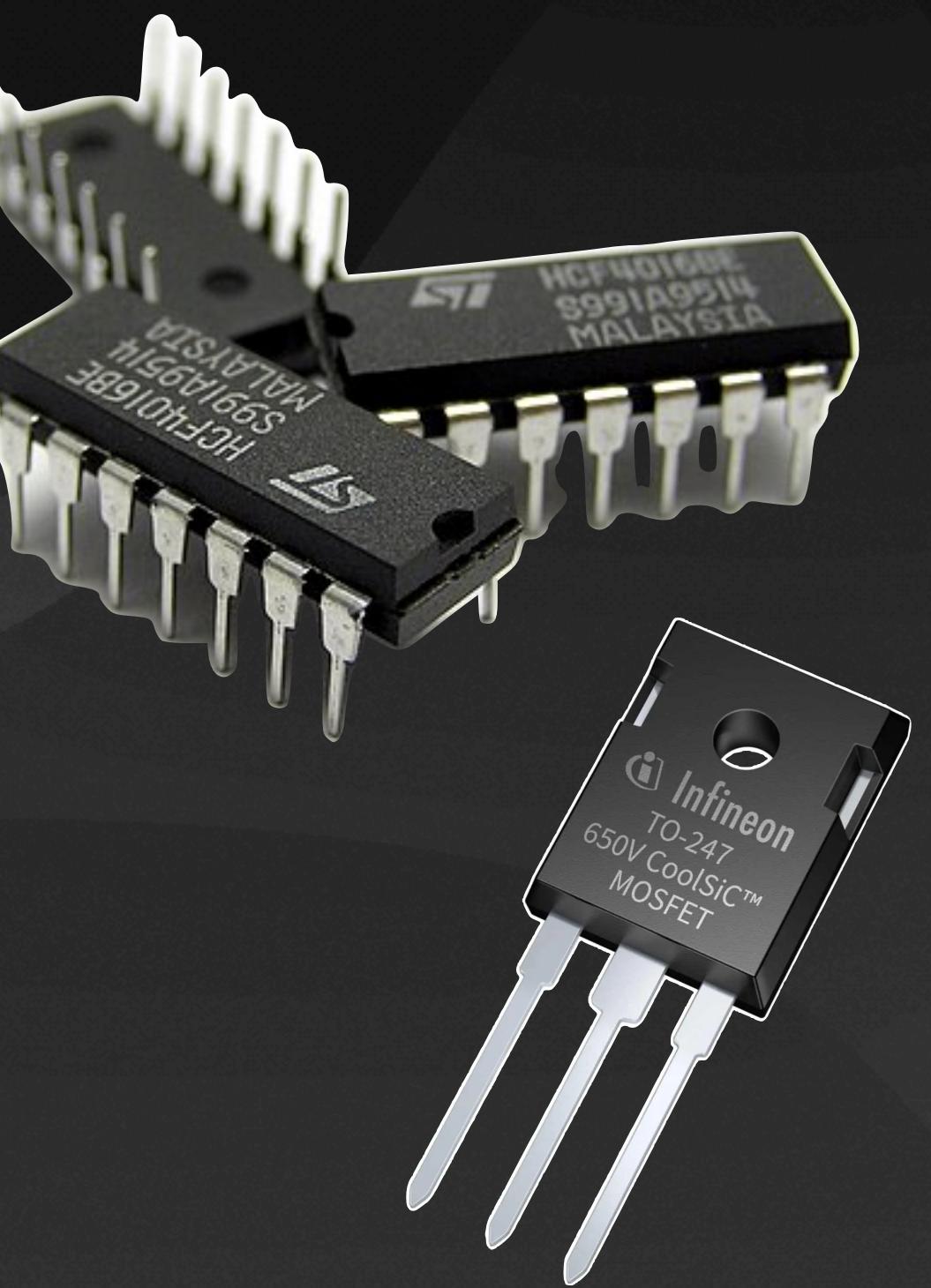
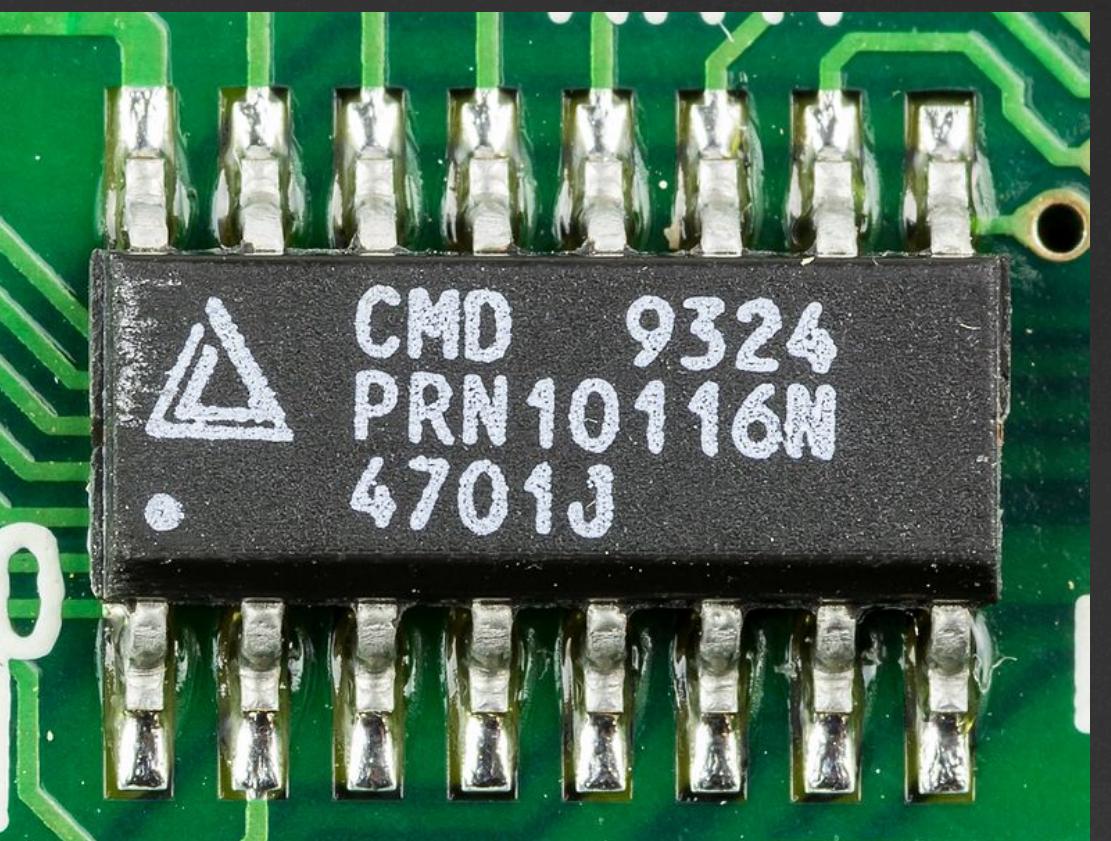
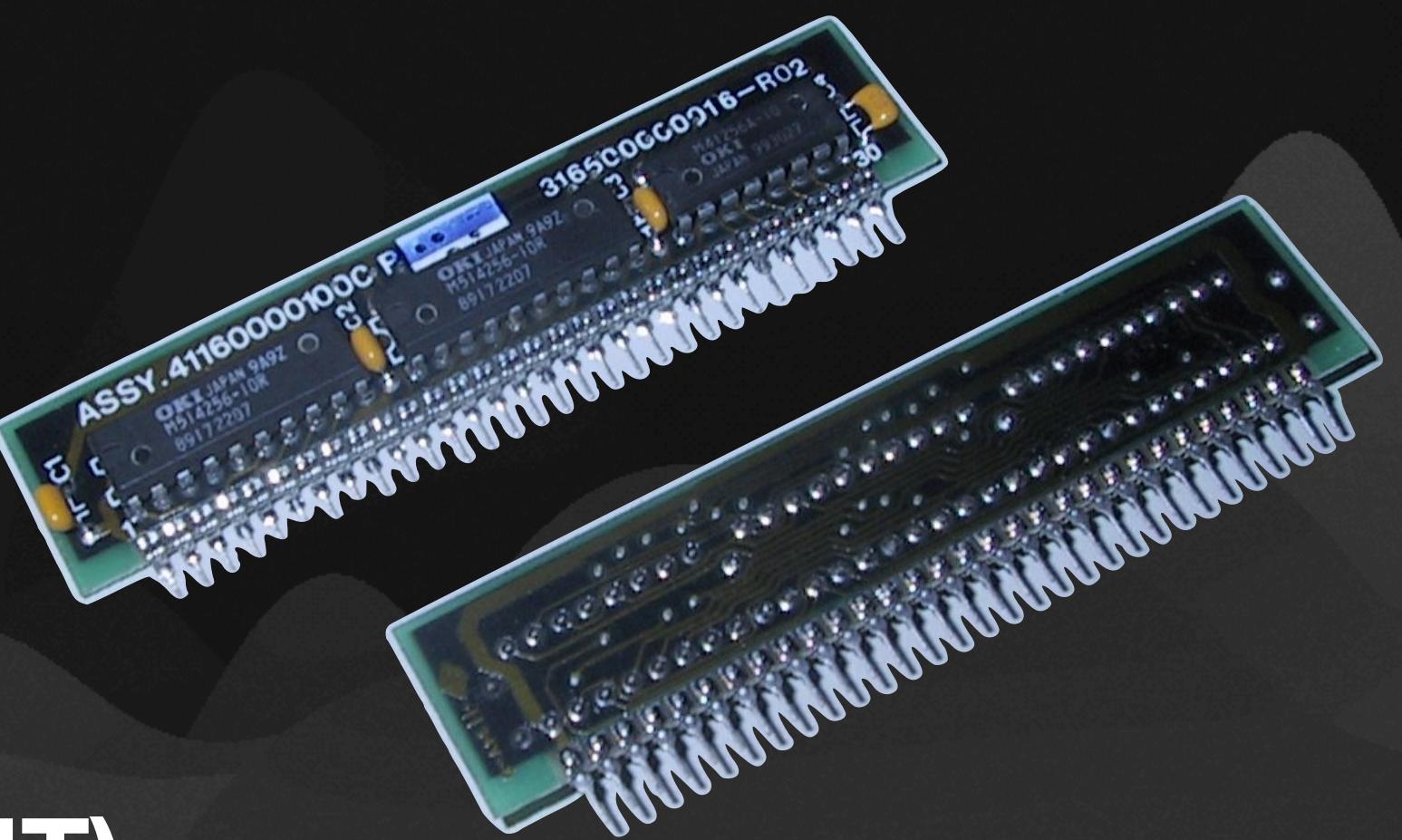
- Size matters -- don't make your life miserable



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)

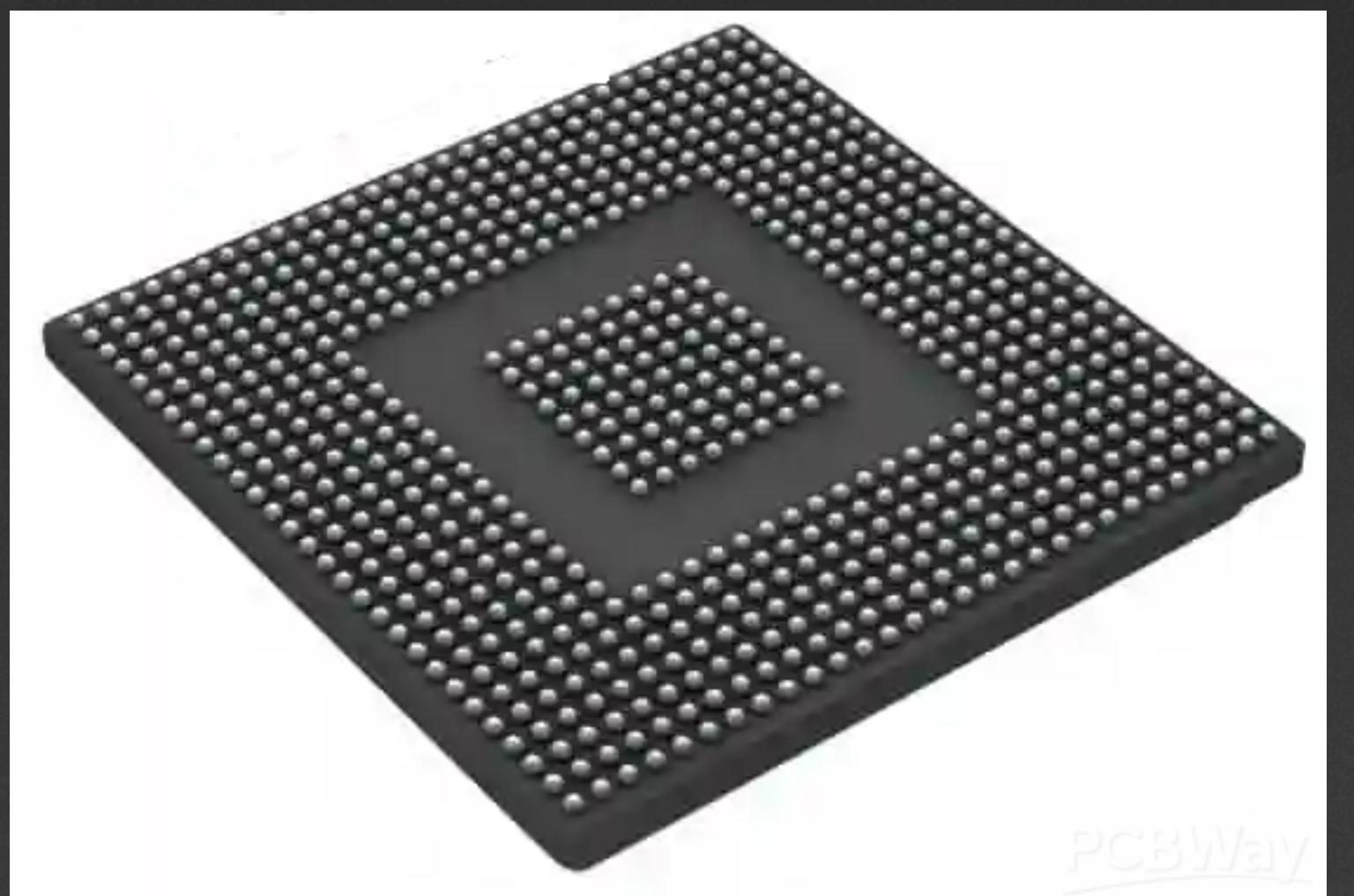


Packages

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

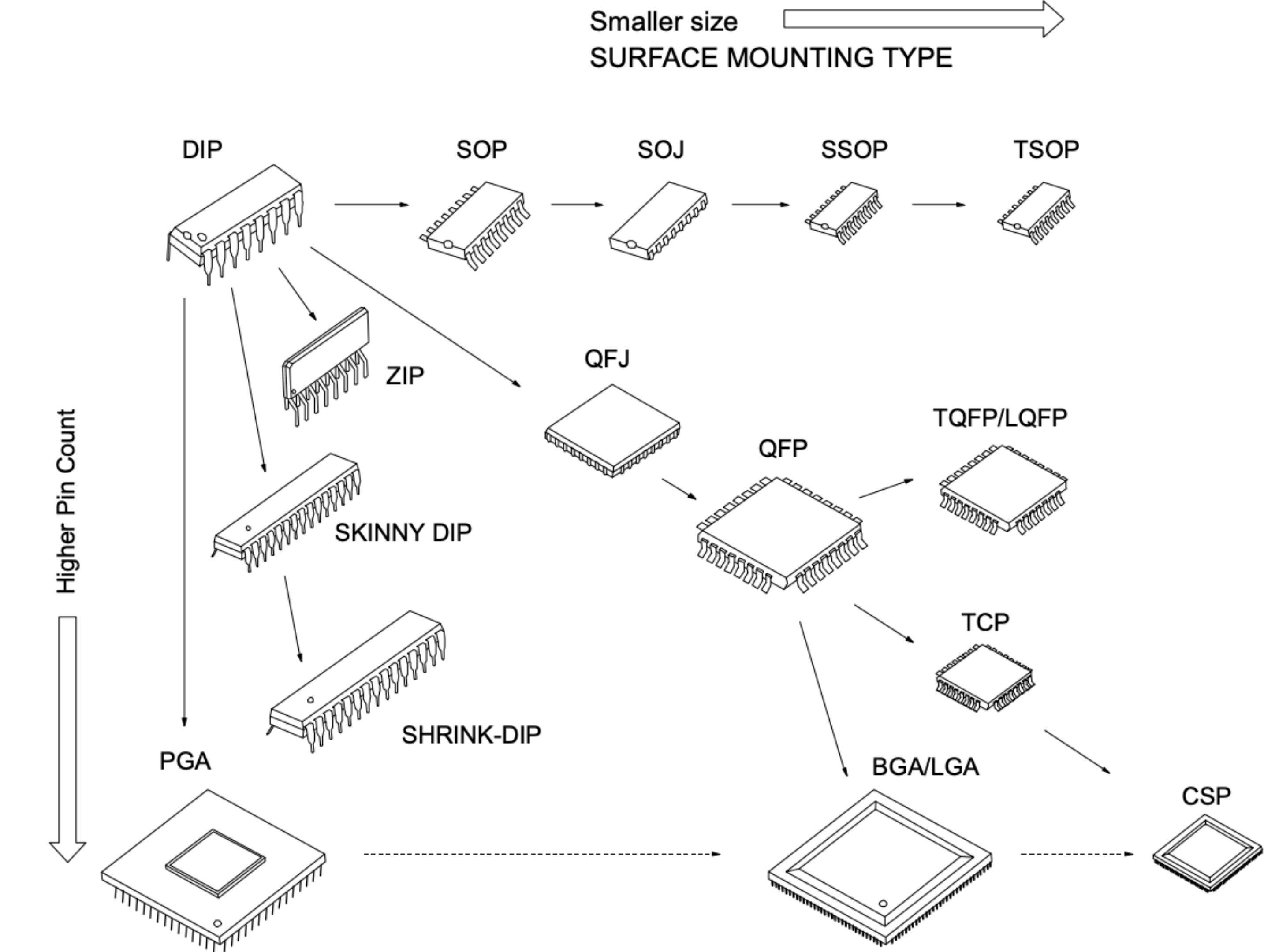
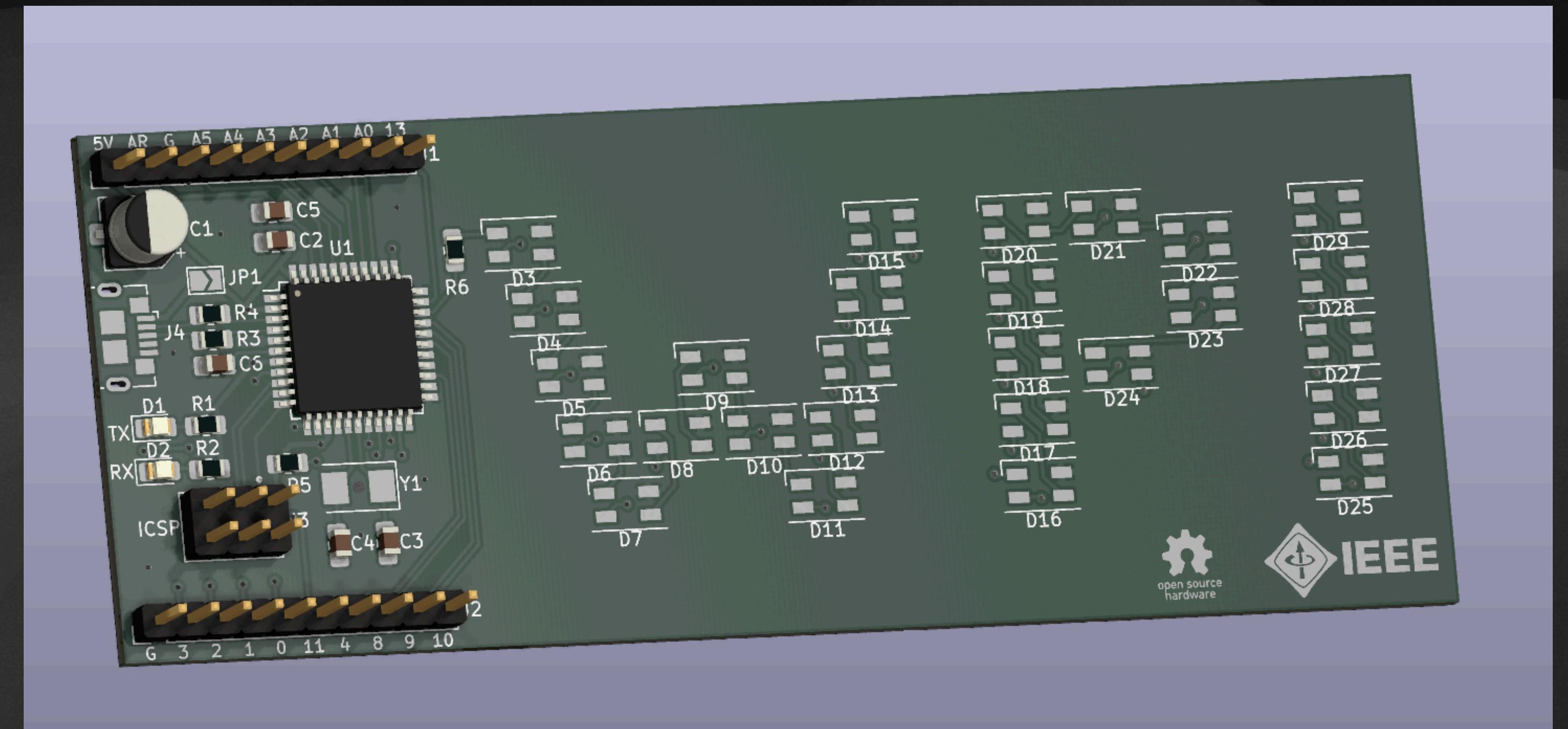


Figure 1.1.1 Packaging Trend

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
	^	^	^	^	^
  ATMEGA32U4-MU IC MCU 8BIT 32KB FLASH 44VQFN <i>Microchip Technology</i>	14,742 In Stock	1 : \$5.26000 Tray	AVR® ATmega	Tray ⓘ	Active
  ATMEGA32U4RC-MU IC MCU 8BIT 32KB FLASH 44VQFN <i>Microchip Technology</i>	10,393 In Stock	1 : \$5.26000 Tray	AVR® ATmega	Tray ⓘ	Active
  ATMEGA32U4-AU IC MCU 8BIT 32KB FLASH 44TQFP <i>Microchip Technology</i>	17,825 In Stock	1 : \$5.29000 Tray	AVR® ATmega	Tray ⓘ	Active
  ATMEGA32U4-AUR 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
  ATMEGA32U4-MUR 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
  ATMEGA32U4RC-AU IC MCU 8BIT 32KB FLASH 44TQFP <i>Microchip Technology</i>	3,336 In Stock	1 : \$5.26000 Tray	AVR® ATmega	Tray ⓘ	Active
  ATMEGA32U4RC-MUR 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
	^	^	^	^	^
 ATMEGA32U4-MU IC MCU 8BIT 32KB FLASH 44VQFN <i>Microchip Technology</i>	14,742 In Stock	1 : \$5.26000 Tray	AVR® ATmega	Tray	Active
 ATMEGA32U4RC-MU IC MCU 8BIT 32KB FLASH 44VQFN <i>Microchip Technology</i>	10,393 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

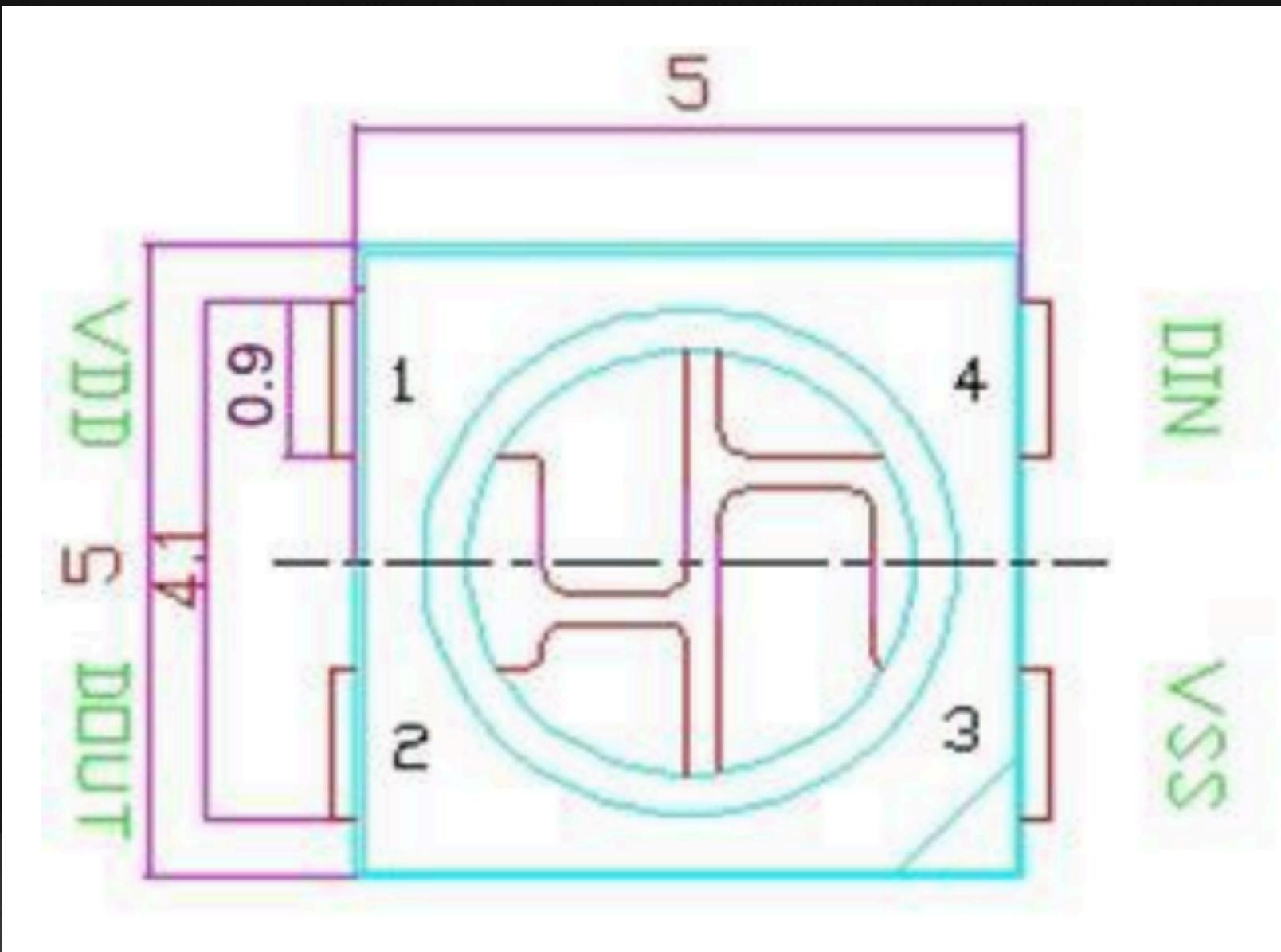
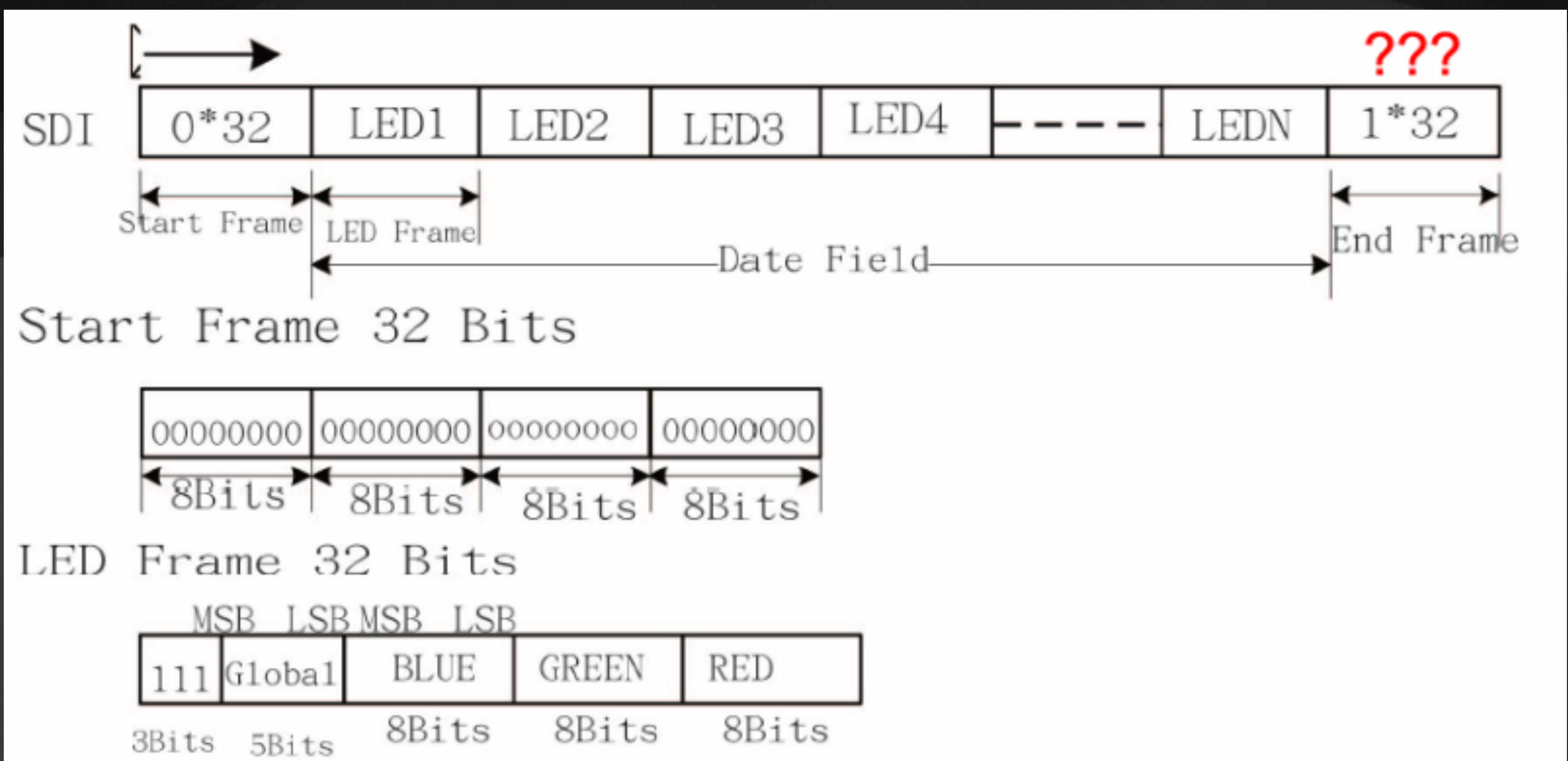
6.2 ATmega32U4

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 ⁽¹⁾⁽²⁾⁽³⁾	External XTAL	44PW		
		ATmega32U4RC-MU ⁽¹⁾⁽²⁾⁽³⁾	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.

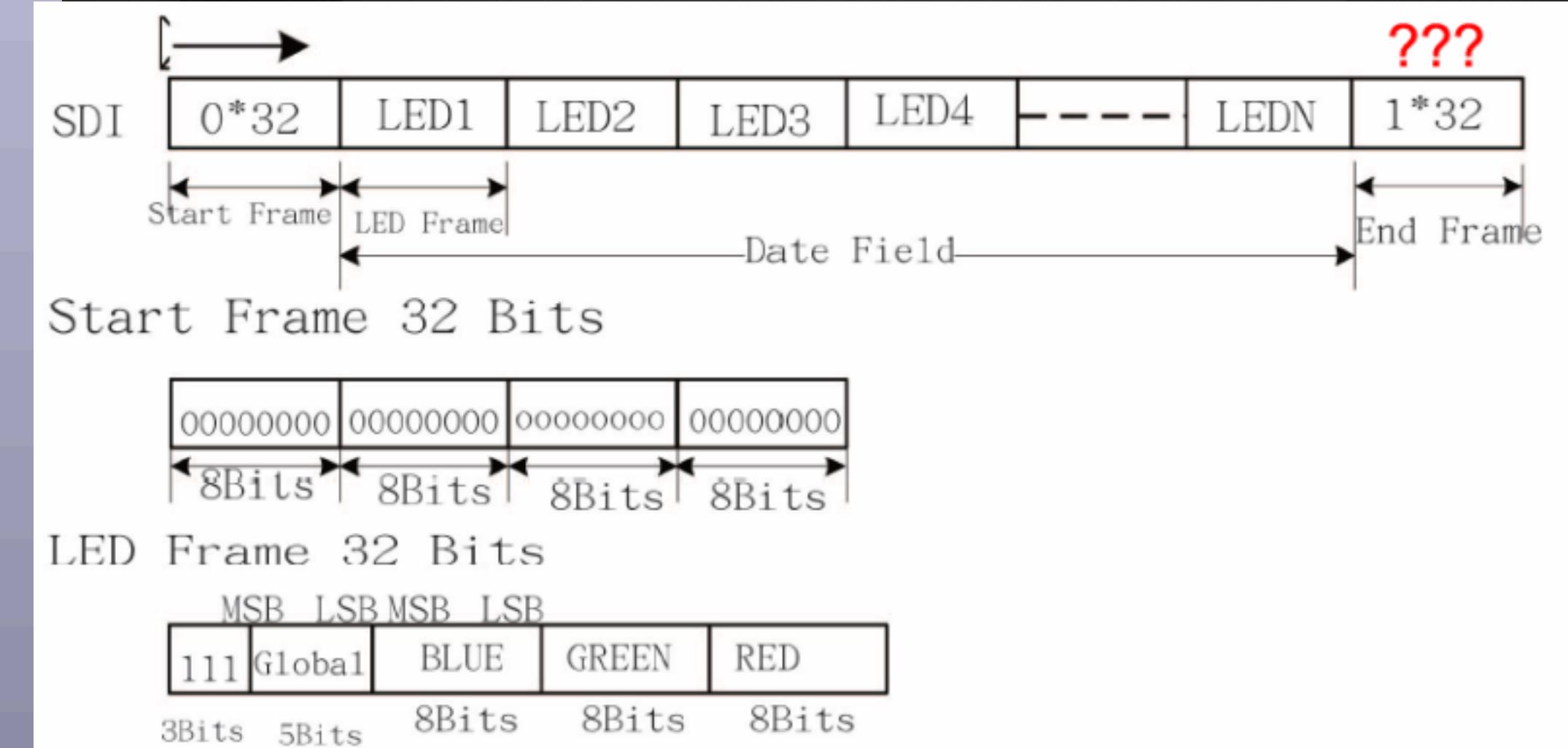
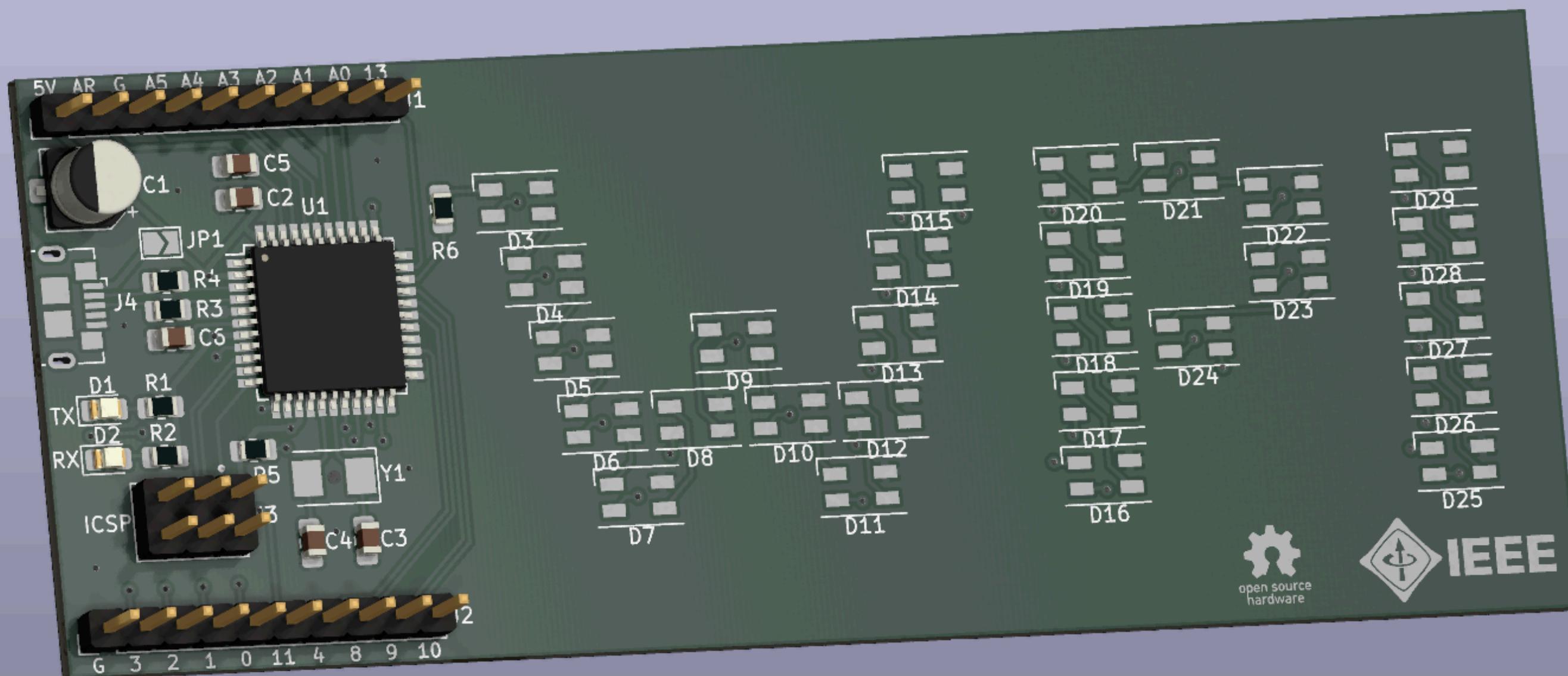
schematic capture

finding parts



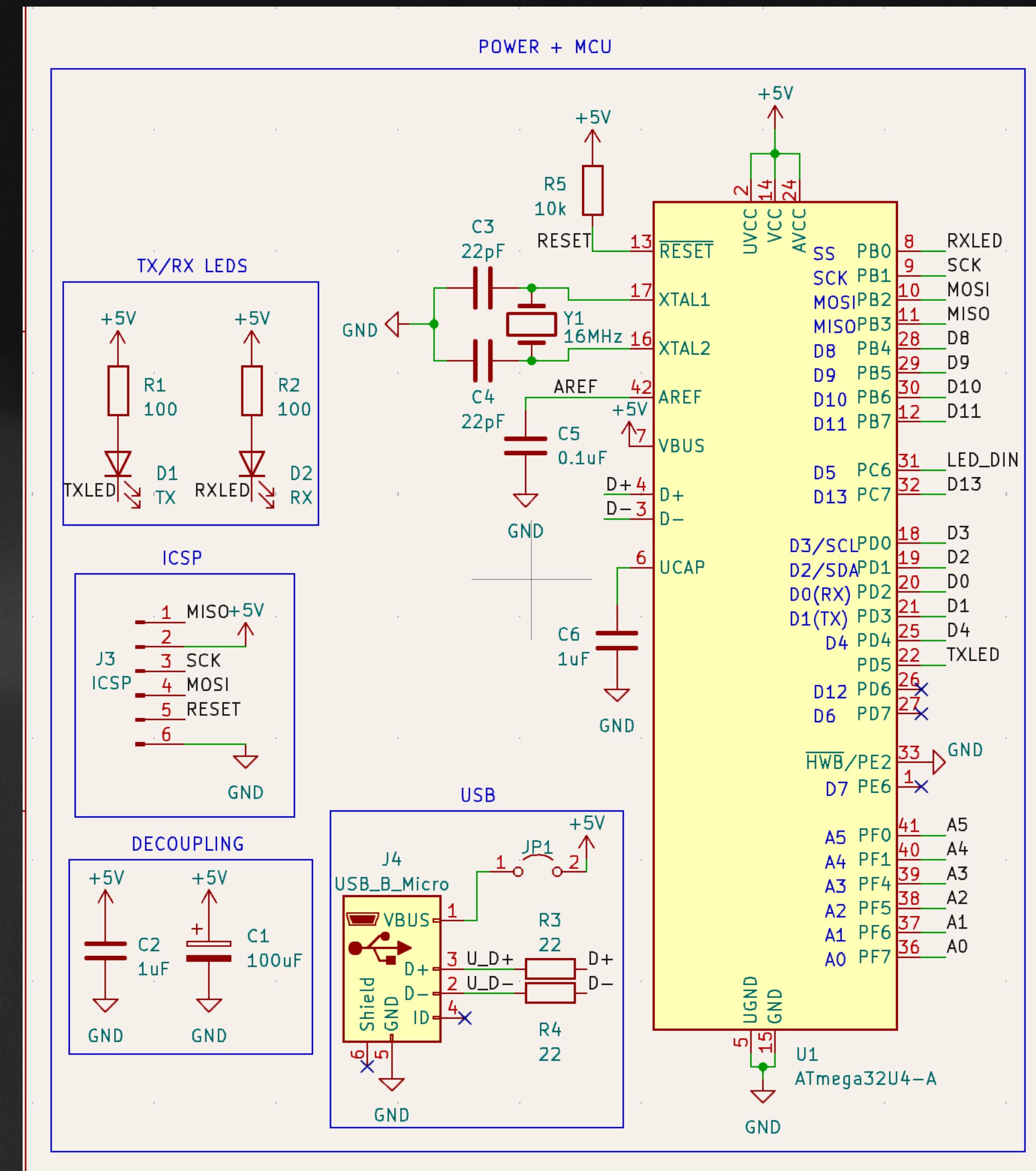
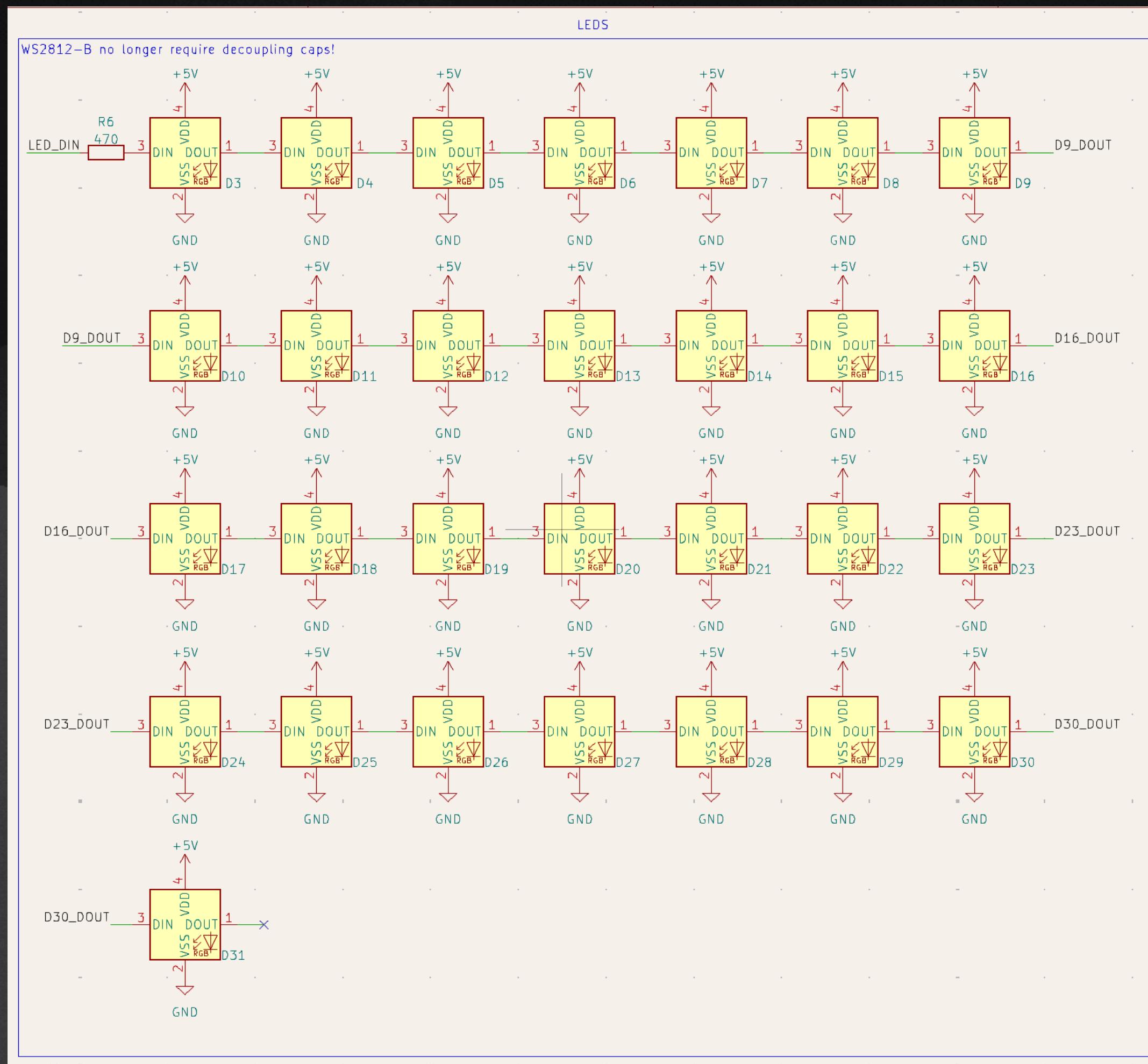
about the board

specifics



about the board

specifics



about the board decoupling capacitors

