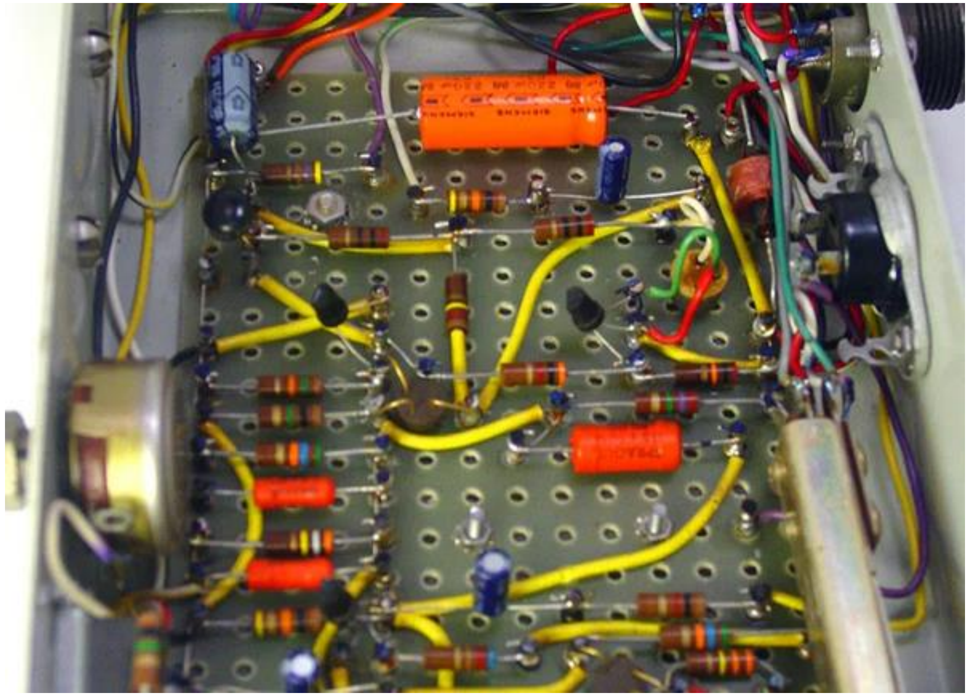


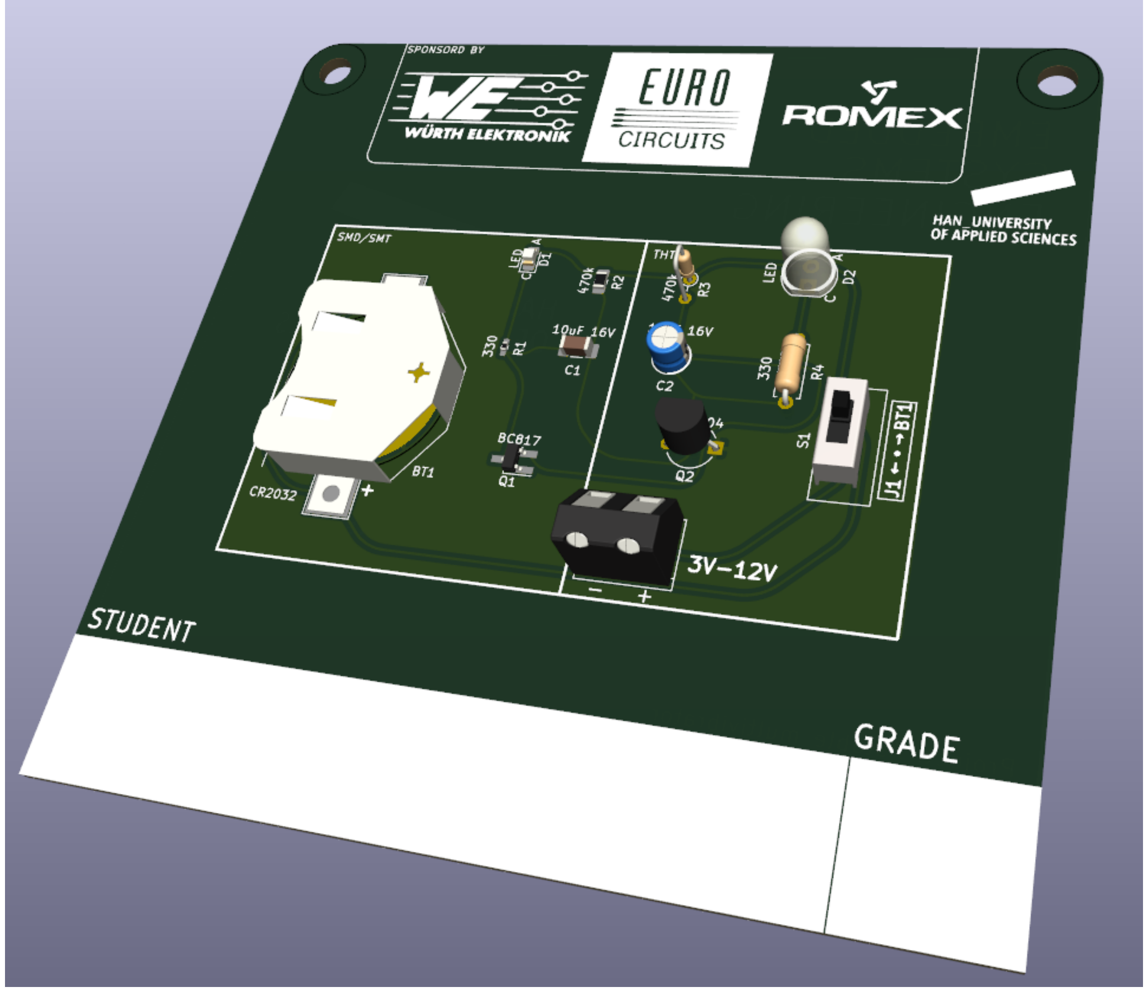
PCB-design practice

Created by: Casper R. Tak

Introduction

So you finished and ordered your first PCB-design

AWESOME!



(Look at that beauty!)

But oh no, what is this?

One LED does not turn on…

Fast forward 2 hours of debugging

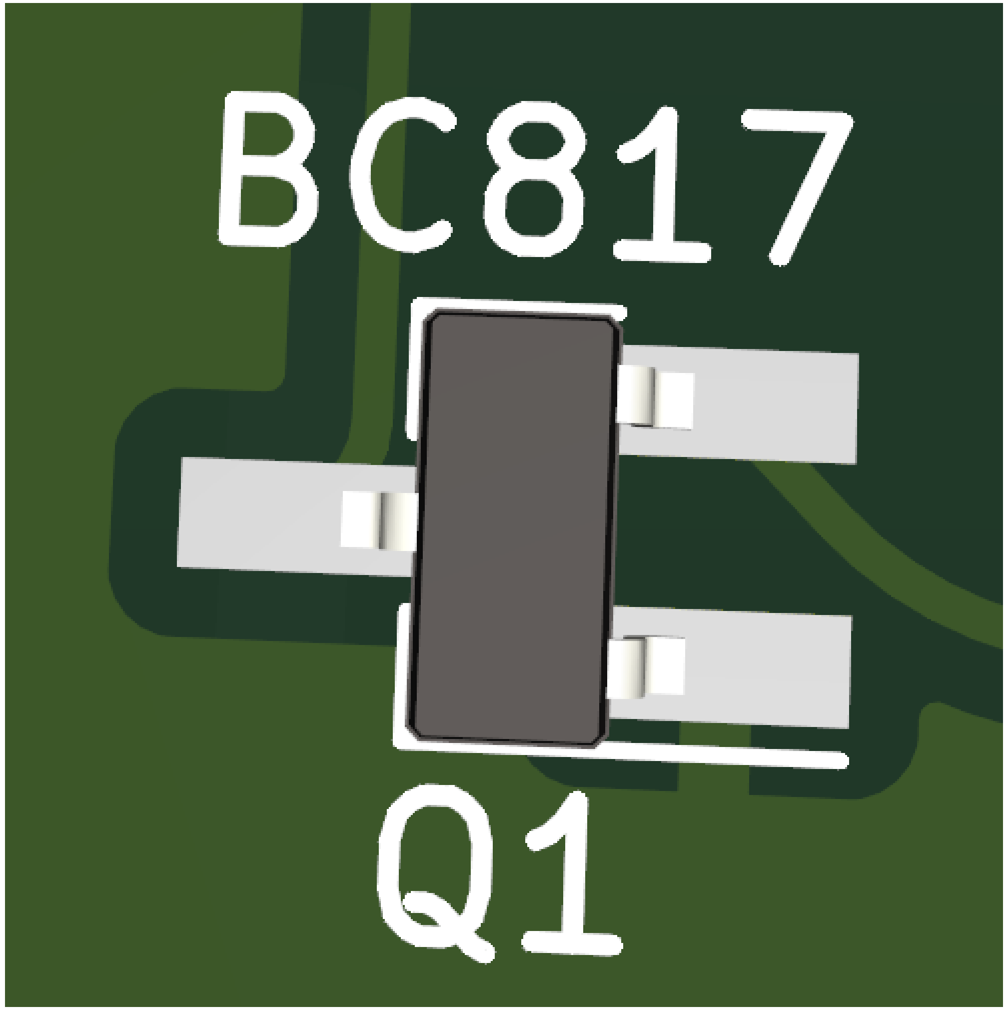
Things we checked:

- Things we checked:
- LED polarity? Double-checked with multimeter ✅
- Correct LED? Forward voltage matches datasheet ✅
- Transistor? Checked datasheet ✅ , checked pinout ✅ , checked footprint... ❌

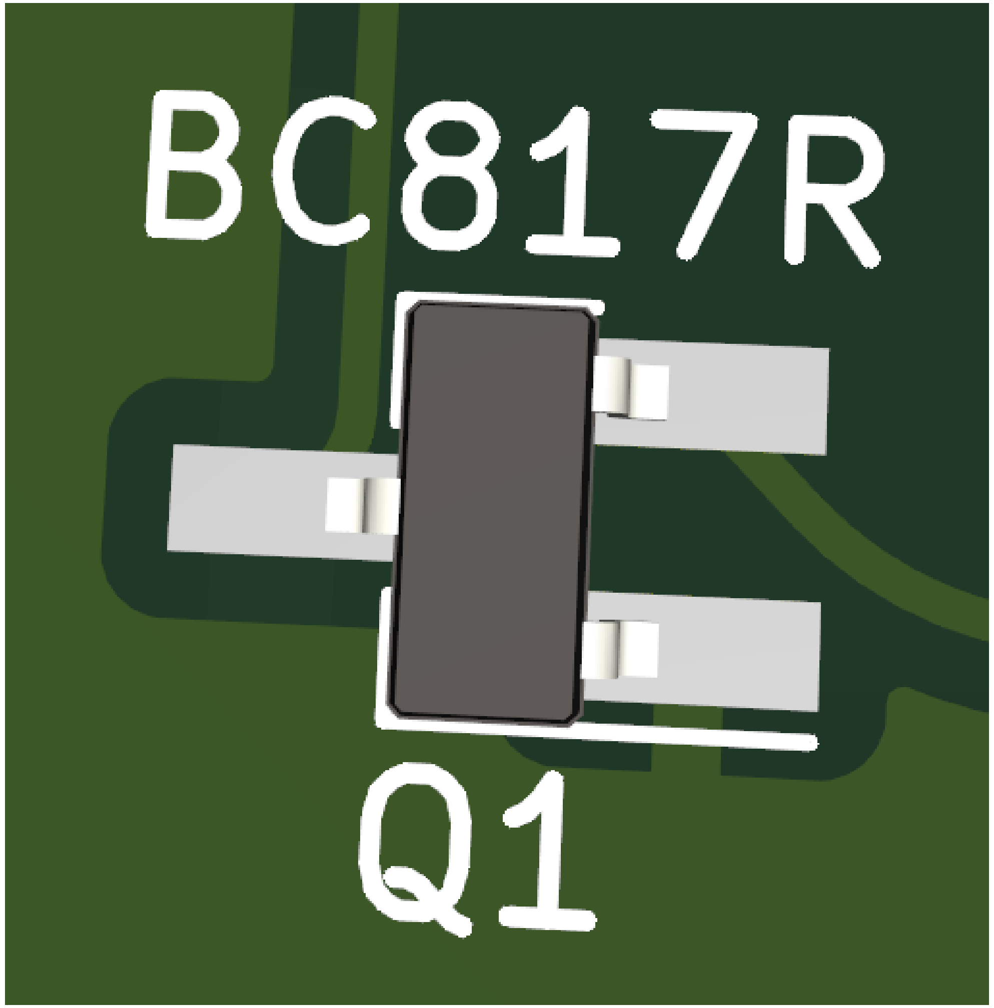
Oops... we forgot to check the footprint!

But I found a solution!

SOLUTION



SOLUTION



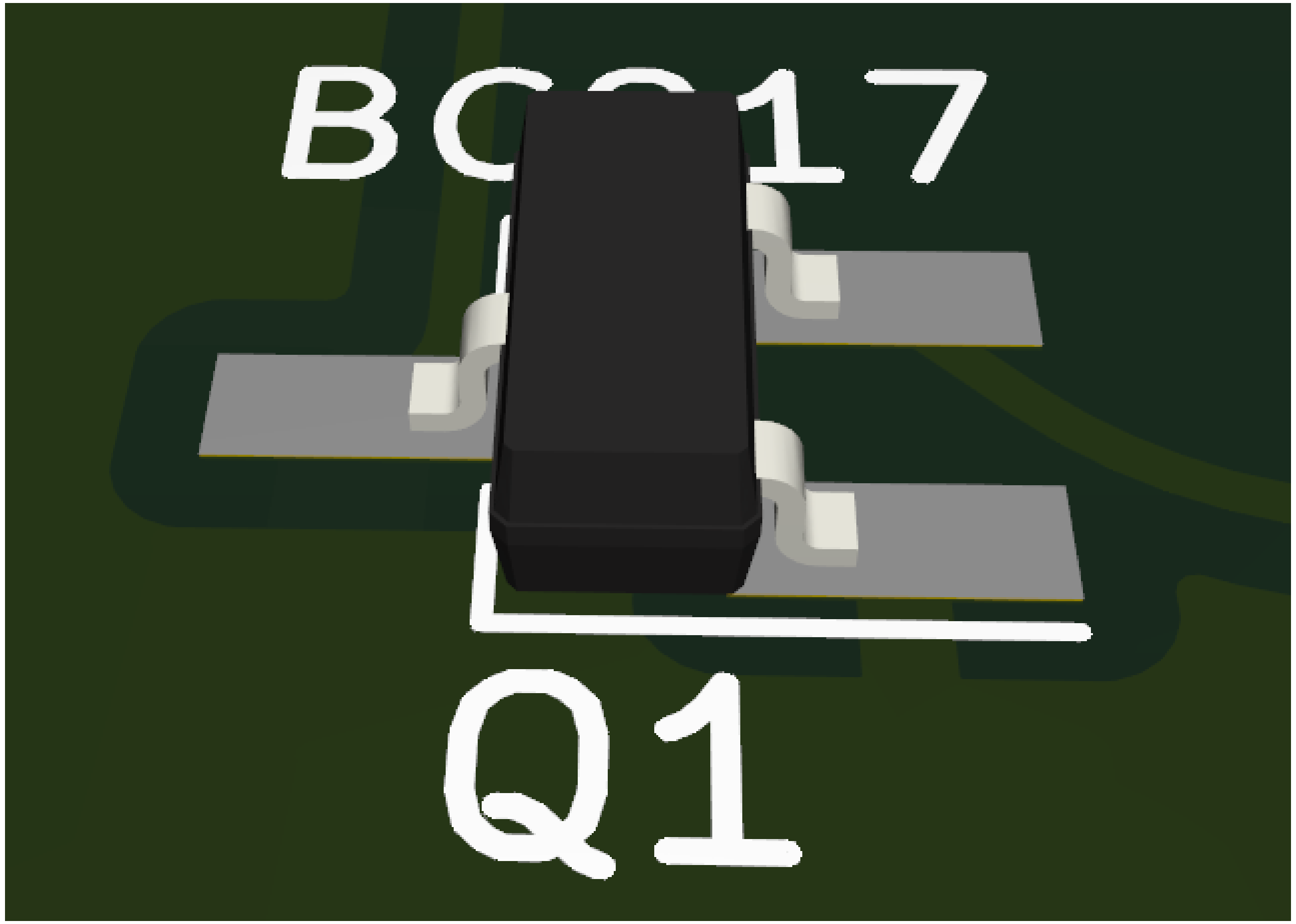
But… now we need to order a new PCB

And throw away the old ones…? No, we can live with a silkscreen error.
But what about the old transistors? Throw them away? Nope, we don’t do e-waste.

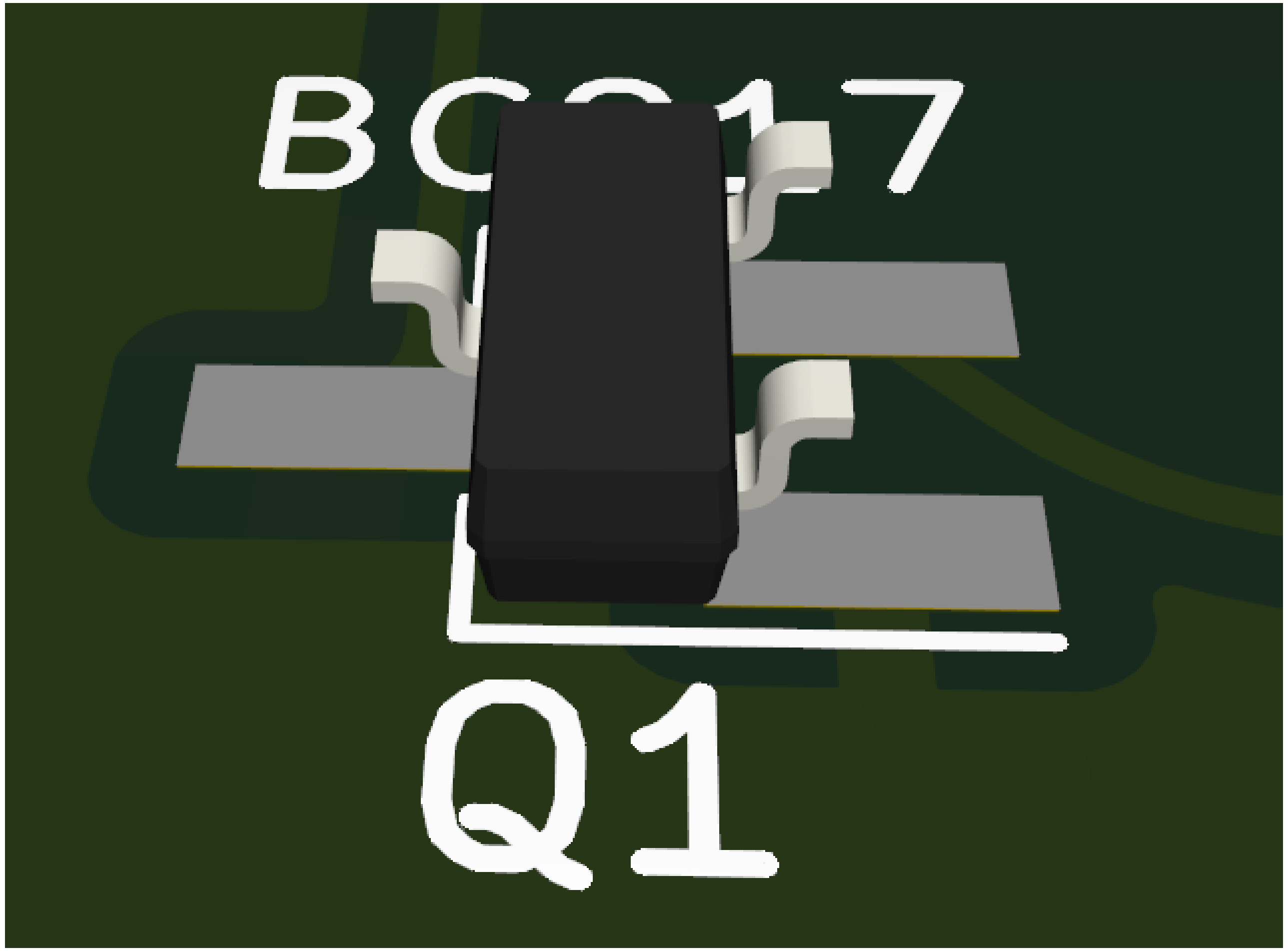
Any better ideas?

Yes :)

SOLUTION 2



SOLUTION 2



Perfect, and thankfully we ordered “only” 500 PCBs

And made it **your** problem to get the LED working.
We actually called it a soldering challenge ;)

In the end, everybody was happy, and the designer only a little embarrassed

The HAN was chill about it

But what about a PCB for a company?

The FIRST company you'll work for.

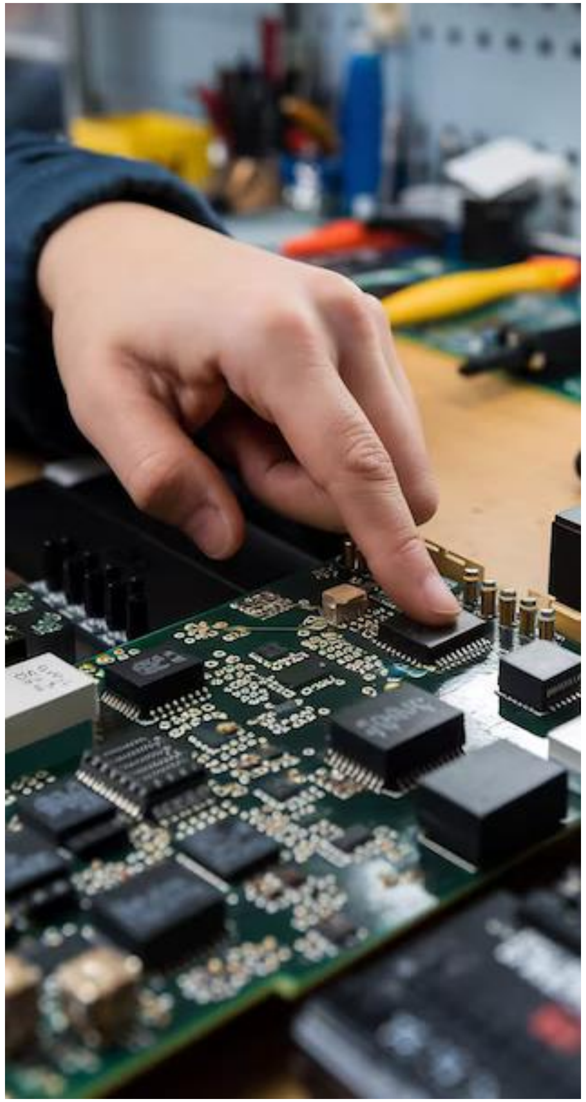
And you are NOT allowed to make a prototype, in fact, every PCB there is a product.

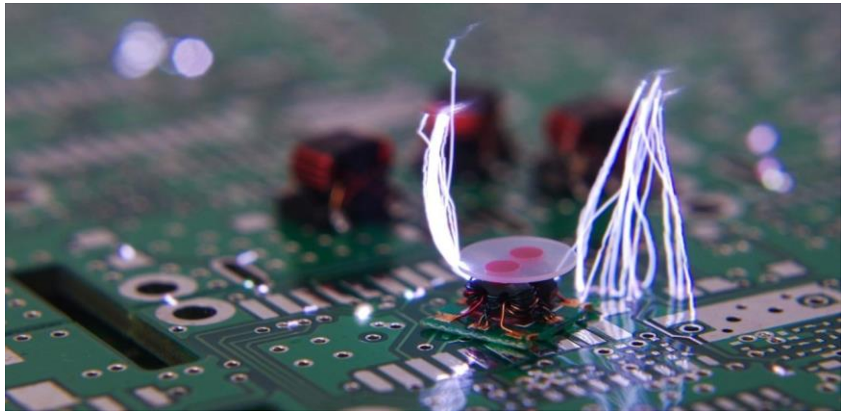
Welcome to my world.

Potential risks and issues:

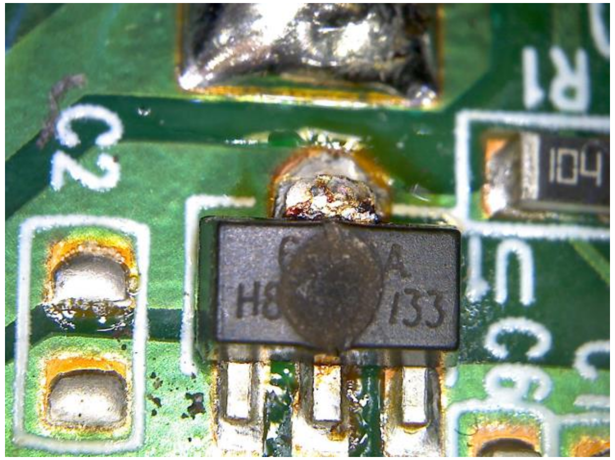
- Have you ever thought of, or even experienced one of these scenarios:

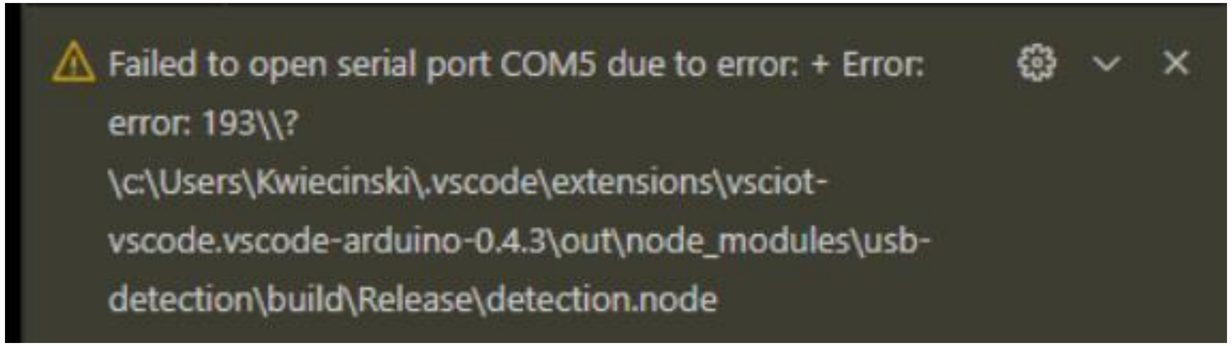
- Magic smoke released by first power up 😶 🌫️
- Programming fails or works only in certain cases (luck) 💻
- Components (almost) desolder themselves 🔥
- It worked, until I touched it 👇 💀
- I touched it, and then it worked 👇 🤗





I did. All of them.





So for today:

Theory:

- But it worked on my machine! (Simulators)
- The magic smoke machines (Heat dissipation)
- Co-Mu-X- ic-a-ti-on lines (“High speed” data transfer)
- You can’t touch this (ESD)
- Final design checks (Footprints, Availability, 3D models)

Practise:

- Let’s peer review our PCB’s with each other!

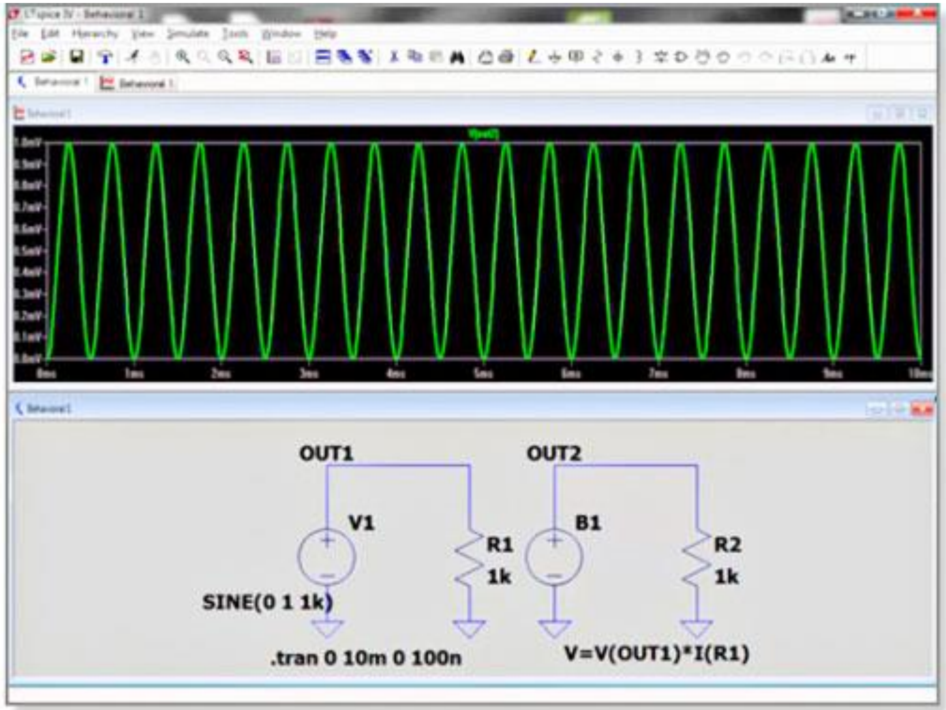
PCB-design in practice

(and how to back up any f#ck ups you made by theory!)

But it worked on my machine! (Simulators)

Theory:

- Why use a simulator?
- How it saved me (and thus my job)
- Free Simulators: LT-Spice, Falstad, Everycircuit*

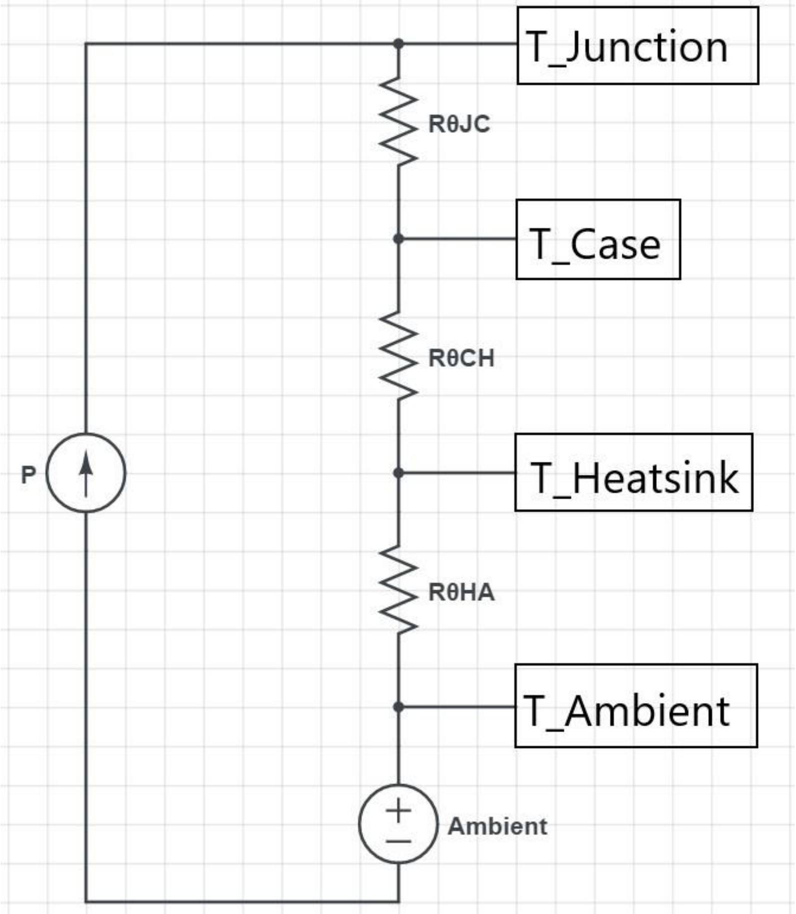


The magic smoke machines (Heat dissipation)

Theory:

- Why take this into account?
- MTBF, Cost, (Board) spacing
- How it saved me
- Thermal resistance, why it is important
- Examples

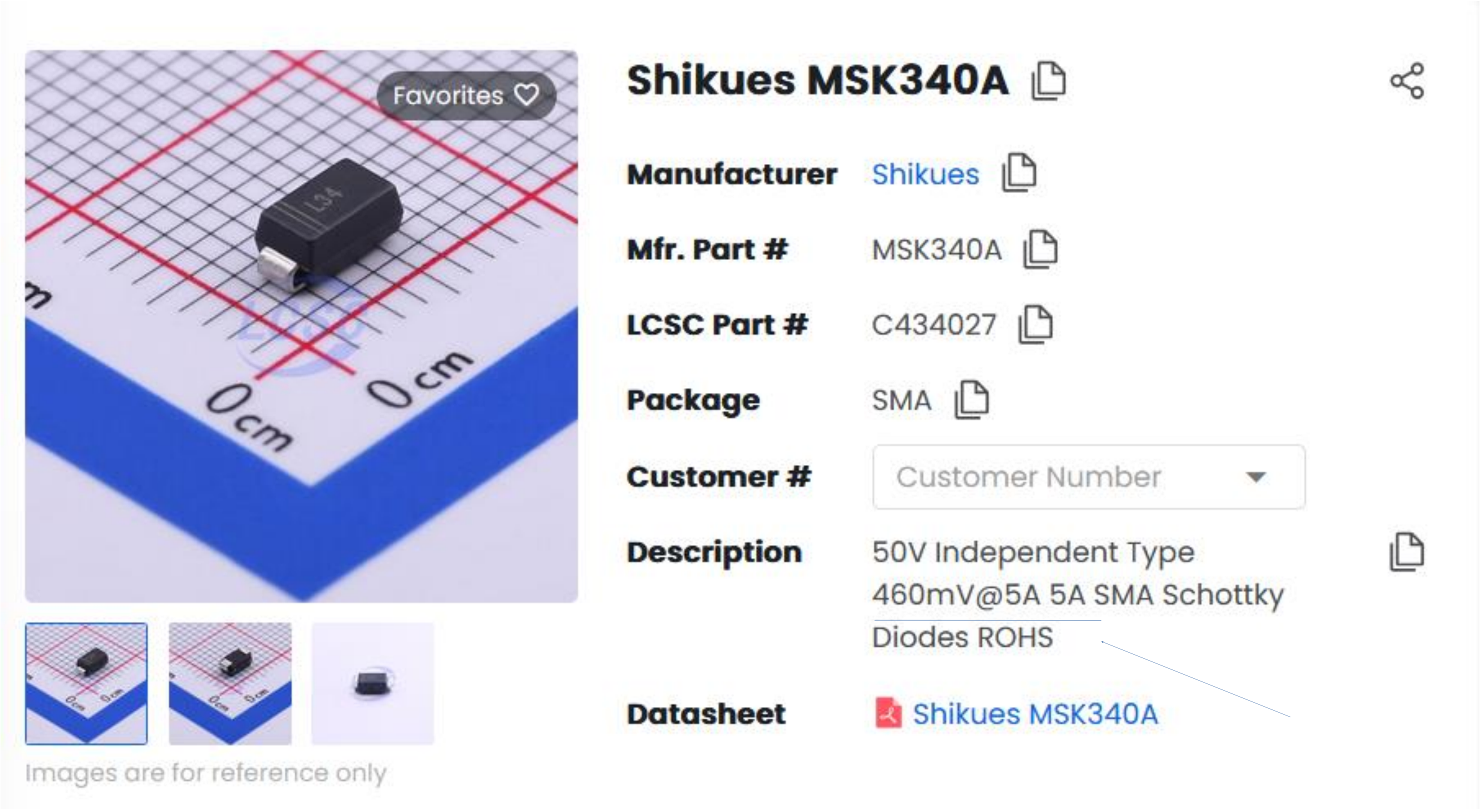
Thermal resistance



Example (Heat dissipation)

Reverse polarity protection diode

- We want to make a reversed polarity protection circuit
- Let’s do the math



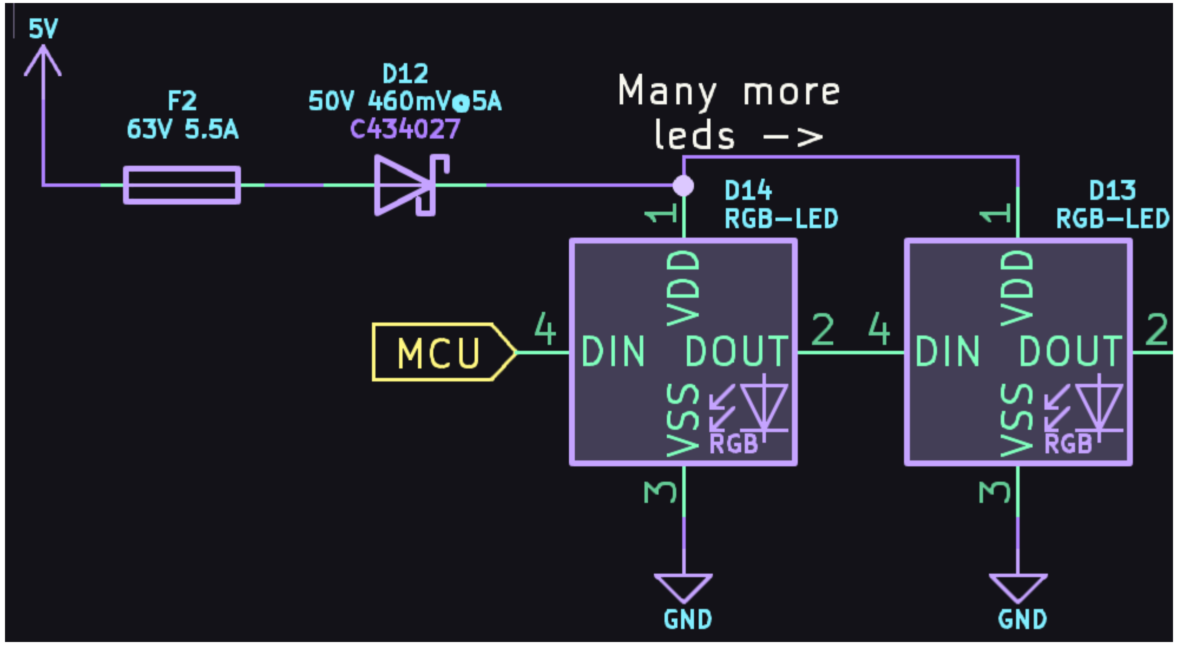
Example (Heat dissipation)

Reverse polarity protection diode

Given: The RGB-leds draw up to 1.8A when all glowing RED

And when fully lid (WHITE) they will draw 5.0A.

Let’s do the math:



P = UI

RED: P = 0.31V x 1.8A = 0.558W of power dissipation

WHITE: P = 0.42V × 5A = 2.10W of power dissipation

With SMA package (RthJA = 85°C/W from datasheet)

For RED:

P = 0.558W Temperature rise = 0.558W × 85°C/W = 47.4°C

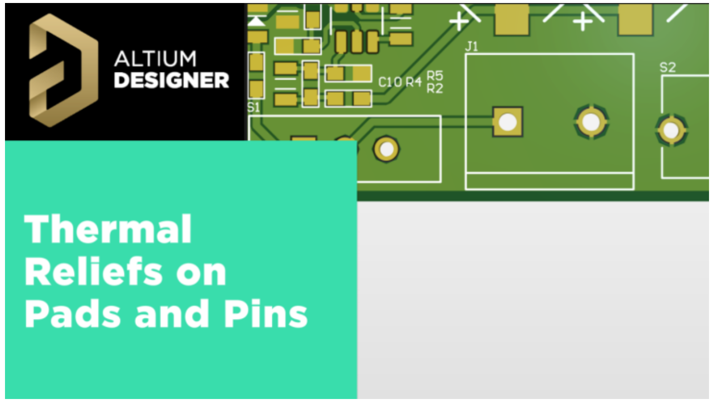
Junction temperature = 25°C + 47.4°C = 72.4°C

For WHITE:

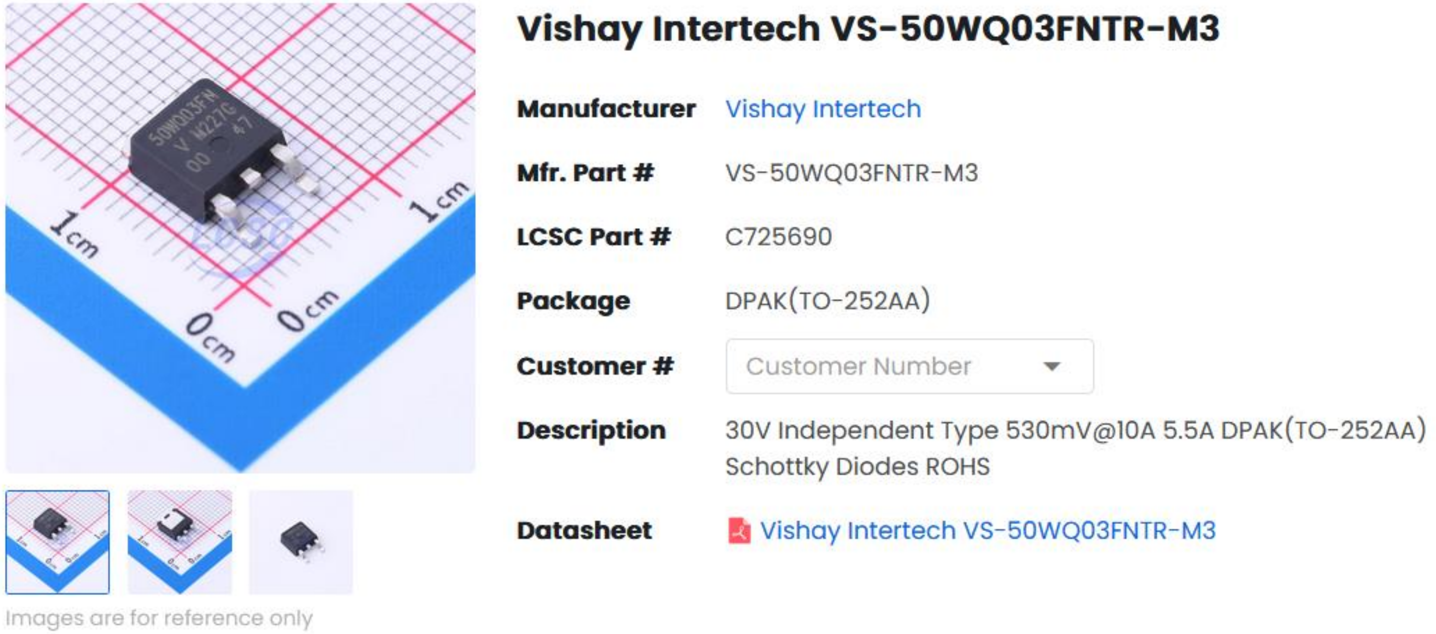
P = 2.10W Temperature rise = 2.10W × 85°C/W = 178.5°C

Junction temperature = 25°C + 178.5°C = 203.5°C

Solution to problem?



- Overspeccify the component (5A requirement? Try 8A diode)
- Choose a component with lower thermal resistance (SMA vs TO-252AA)
- Find other ways to lower thermal resistance to heatink or ambient



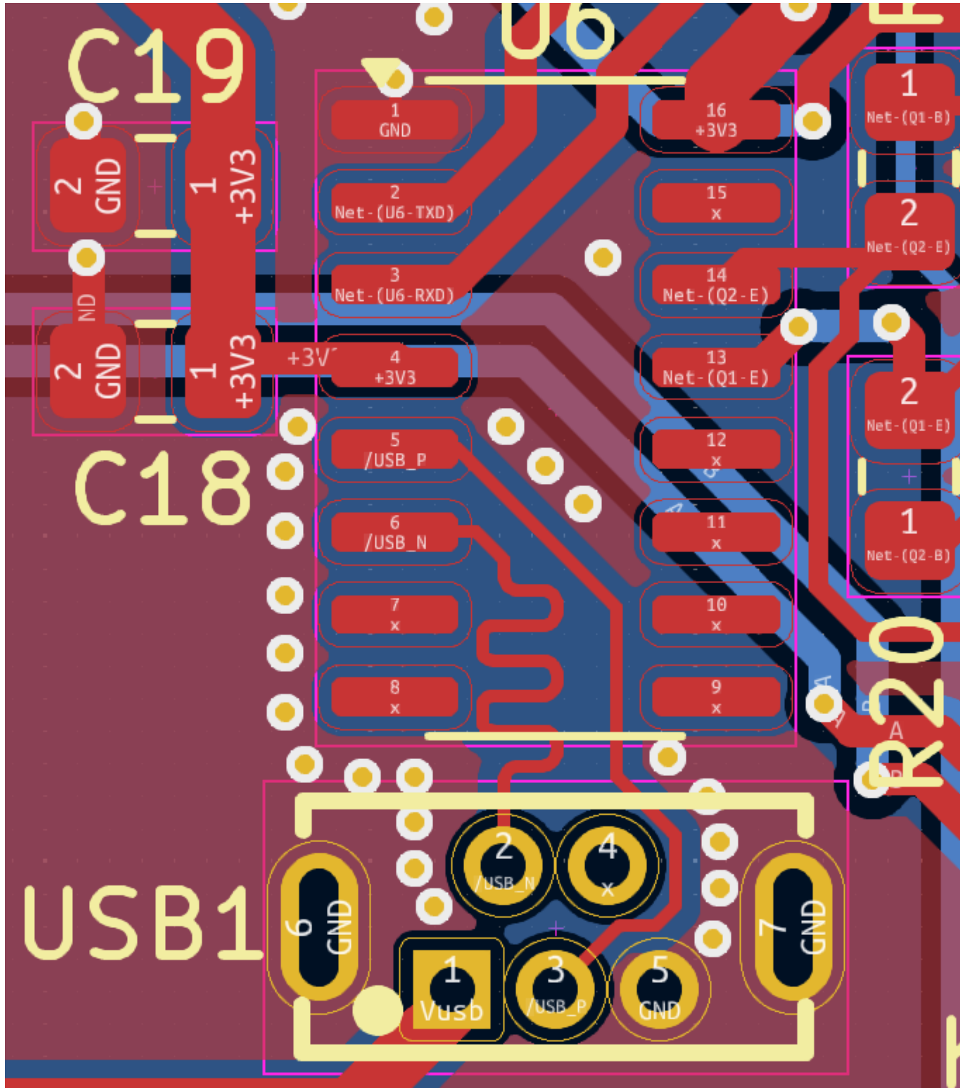
In short

- Keep (ambient) temperature specs in mind for requirements and overall component stress

- Lowering thermal resistance will result in lower stress on components meaning: longer MTBF/product life and therefore better design

- Overspecified/Underspecified (Consider cost trade-off)

Co-Mu-X- ic-a-ti-on lines (High speed Data transfer)



- Who programmed an AT328P with one of these? →
- CH340 or CP2102 USB to UART converter
- USB 2.0: 480 Mbps data rate
- Importance of:
  - Keeping D+/D- parallel (differential pair in KiCad)
  - Length matching/tuning (max of 3mm difference!)
  - No 90° angles
  - Ground plane (stitching for extra stability)
- Result? Good communication/stable.

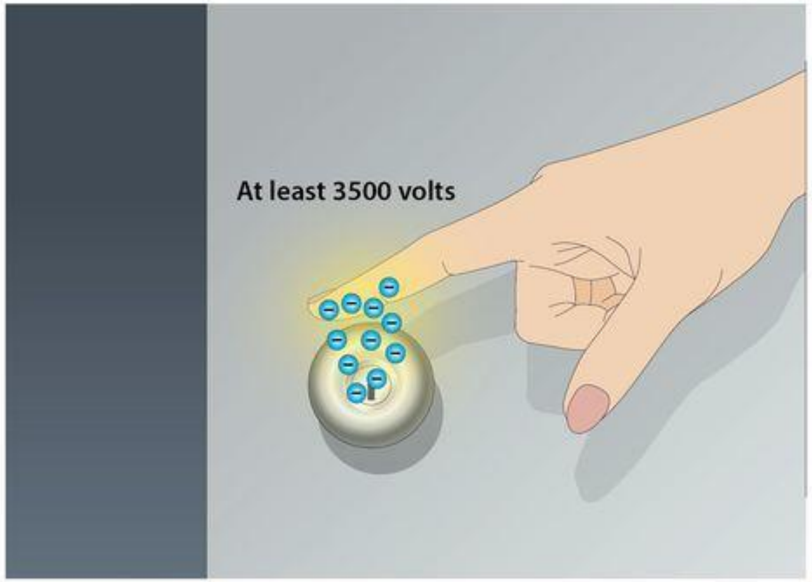
But what if we where bold and just didn't bother?

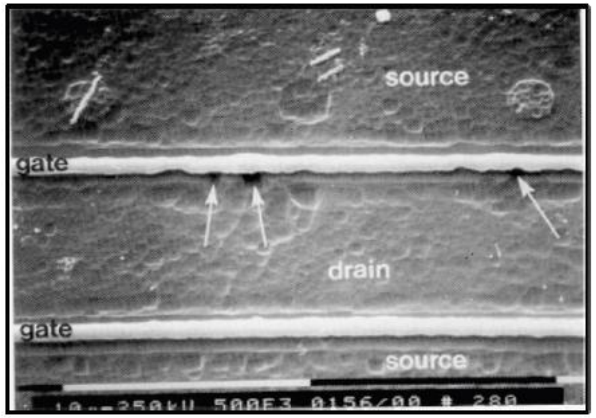
- No communication at all
- Timeout errors
- Loads of frustrations and endless debugging
- Reduced maximum speed

You can’t touch this (ESD)

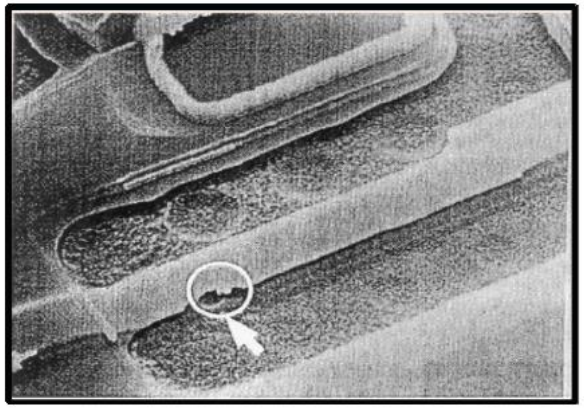
- Hello fellow capacitor friend :)
- ESD-damage
  - Sometimes very apparent
    - Complete device breakdown
    - Device does not turn on or heats up
  - Sometimes not… (image)
    - Reduced lifespan
    - Partial degradation
    - Intermittent failures

Human Threshold of Sensitivity From a Static Discharge





Drain junction damage in an NMOS after HBM stress. Note the thermal damage to silicon.



Gate oxide damage to an input buffer after CDM stress. Note the rupture to gate oxide.

Figure 1. Typical ESD Damage

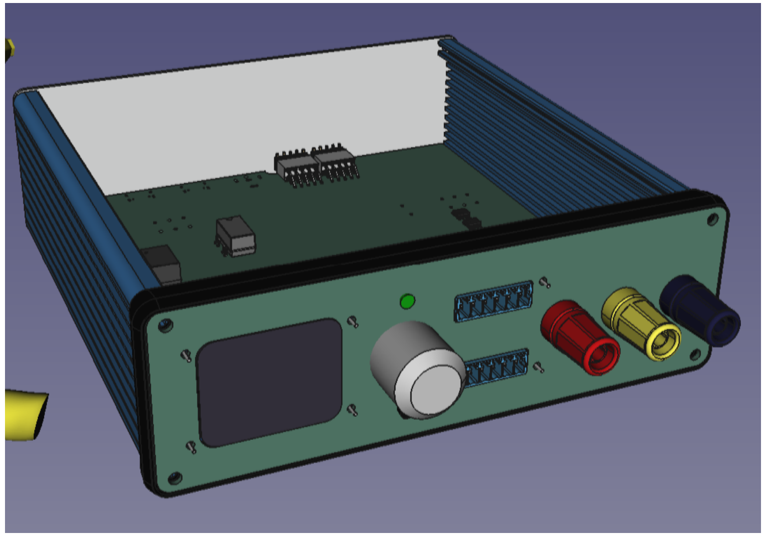
Solution

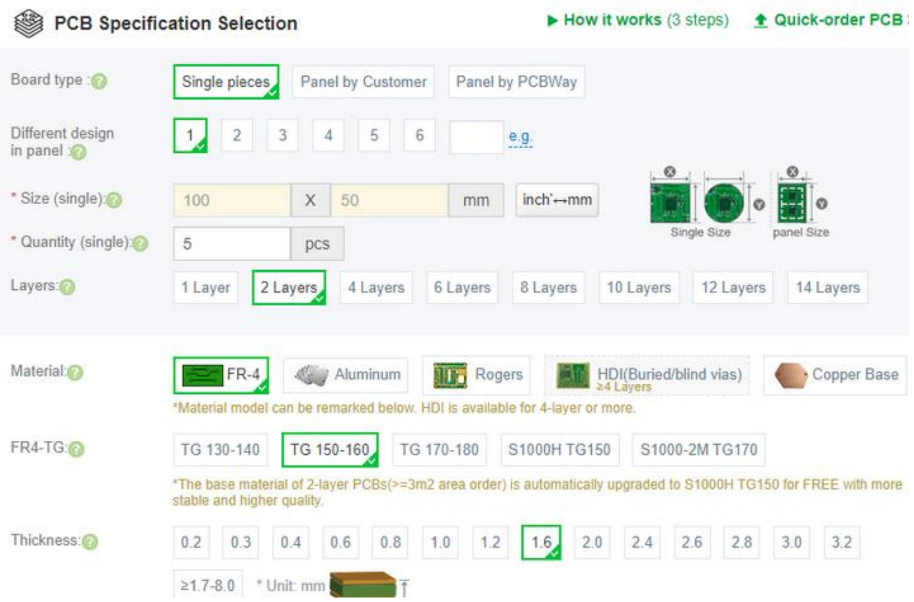
- TVS diodes on I/O lines (I2C line for example)
- ESD protection diodes
- Ground planes (“catches” large ESD currents)
- Proper component selection with built-in ESD-protection (Think about mosfets)
- Protection rings around sensitive ICs
- Keep traces away from board edges
- Add guard rings
- Use ground planes
- Minimize loop areas
- Place protection devices close to connectors

Final design checks

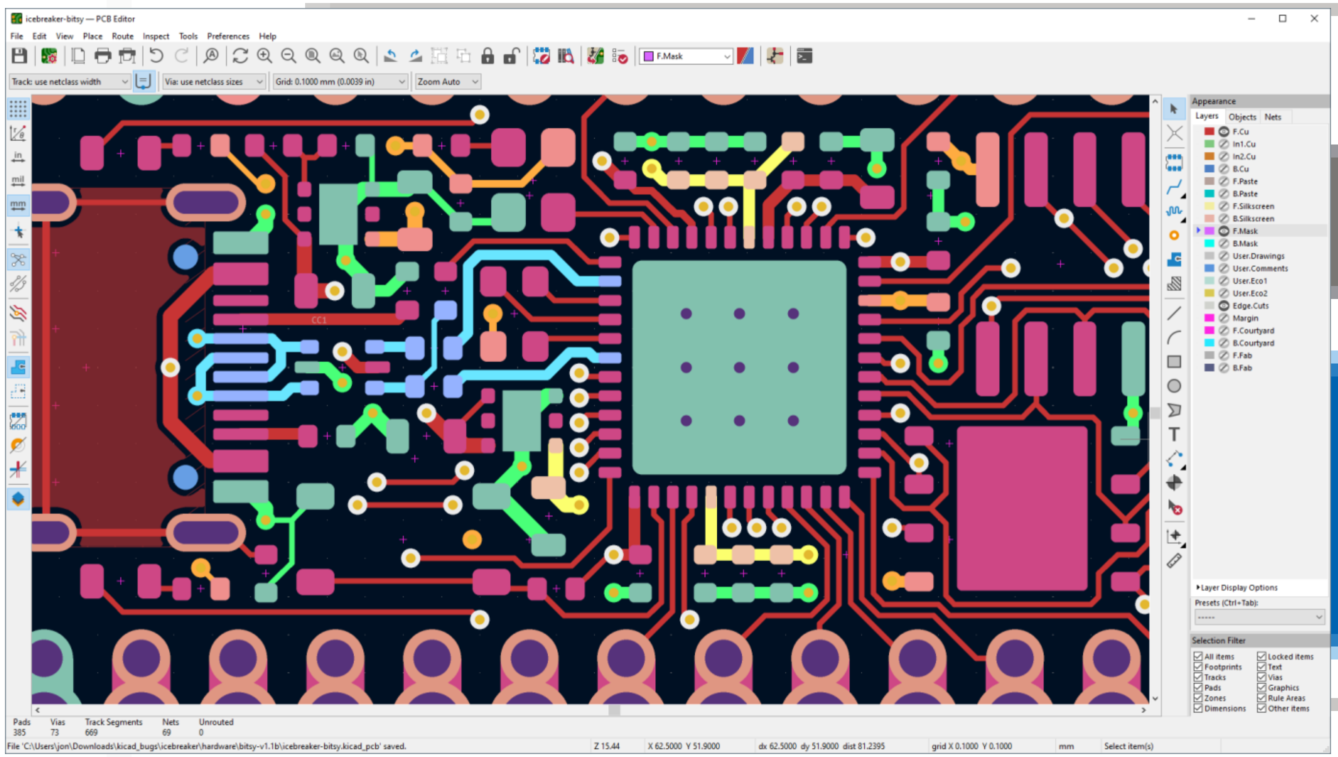
- Does it fit? (3D-models, FreeCAD)
- Check your footprints (if you got the from the internet)
- Check component availability while designing!
- What specifications do you need for your PCB?
  - PCB thickness, gold plated, etc.
  - Material: FR-4, aluminum (heat dissipation!)

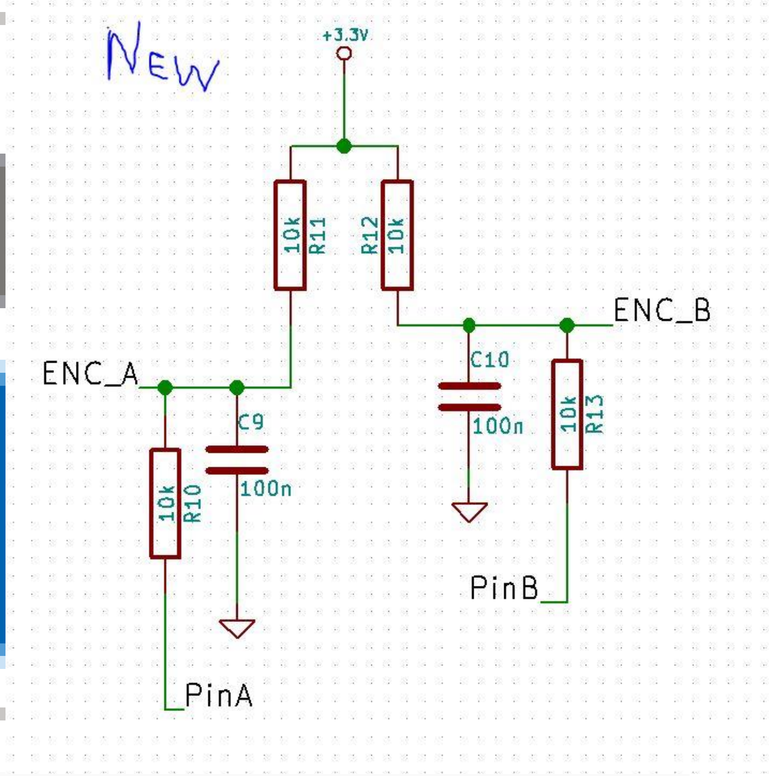
- And also very important: Peer reviews!





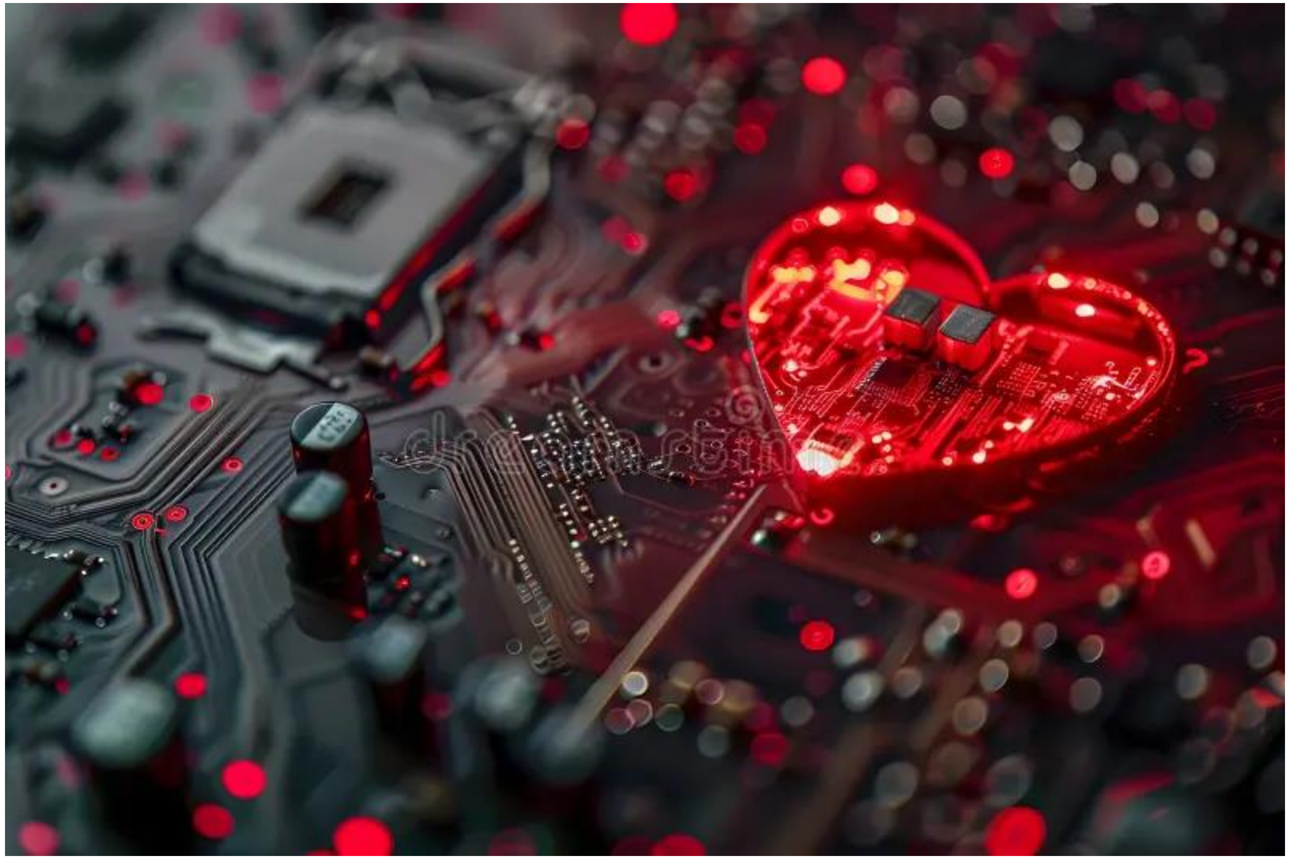
Let’s peer review each others PCBs (and schematics)!





End of this presentation

- Thank you for attending!
- Feel free to ask more questions about the design process, KiCad etc.



Useful Links

- https://fscdn.rohm.com/en/products/databook/applinote/discrete/diodes/list_of_diode_package_thermal_resistance_an-e.pdf
- https://www.protoexpress.com/blog/importance-pcb-line-spacing-creepage-clearance/
- https://resources.altium.com/p/routing-requirements-usb-20-2-layer-pcb
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