

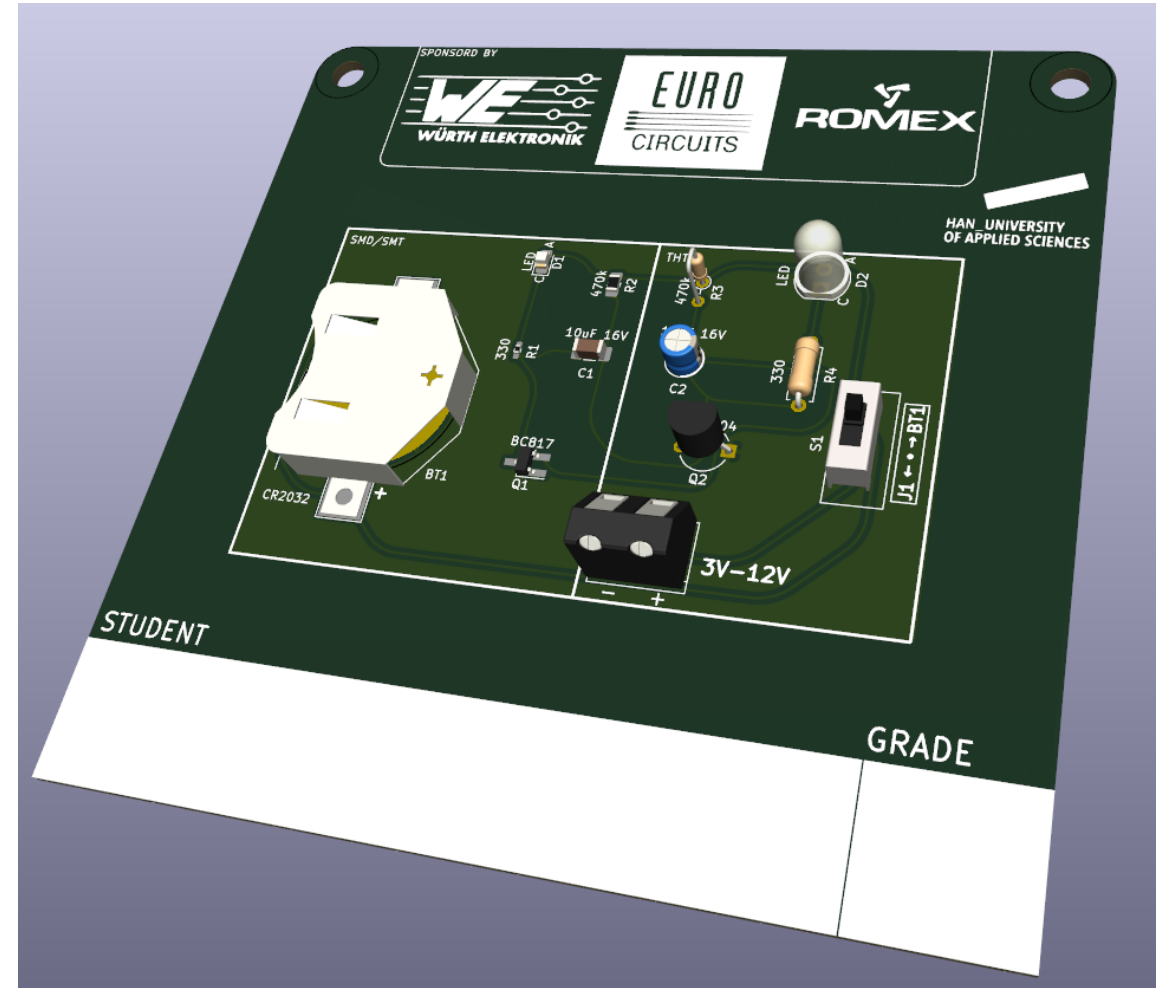
PCB-design practice

Created by: Casper R. Tak

Introduction

So you finished and
ordered your first
PCB-design

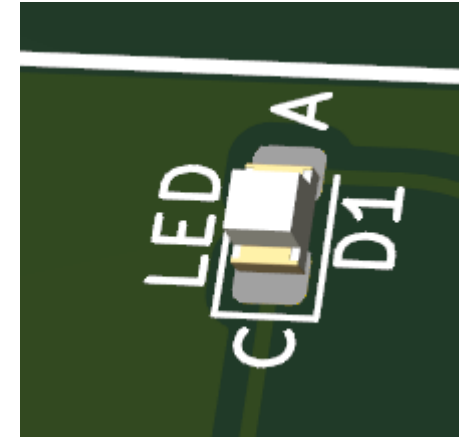
AWESOME!



(Look at that beauty!)






But oh no, what is this?

One LED does not turn on...



Fast forward 2 hours of debugging

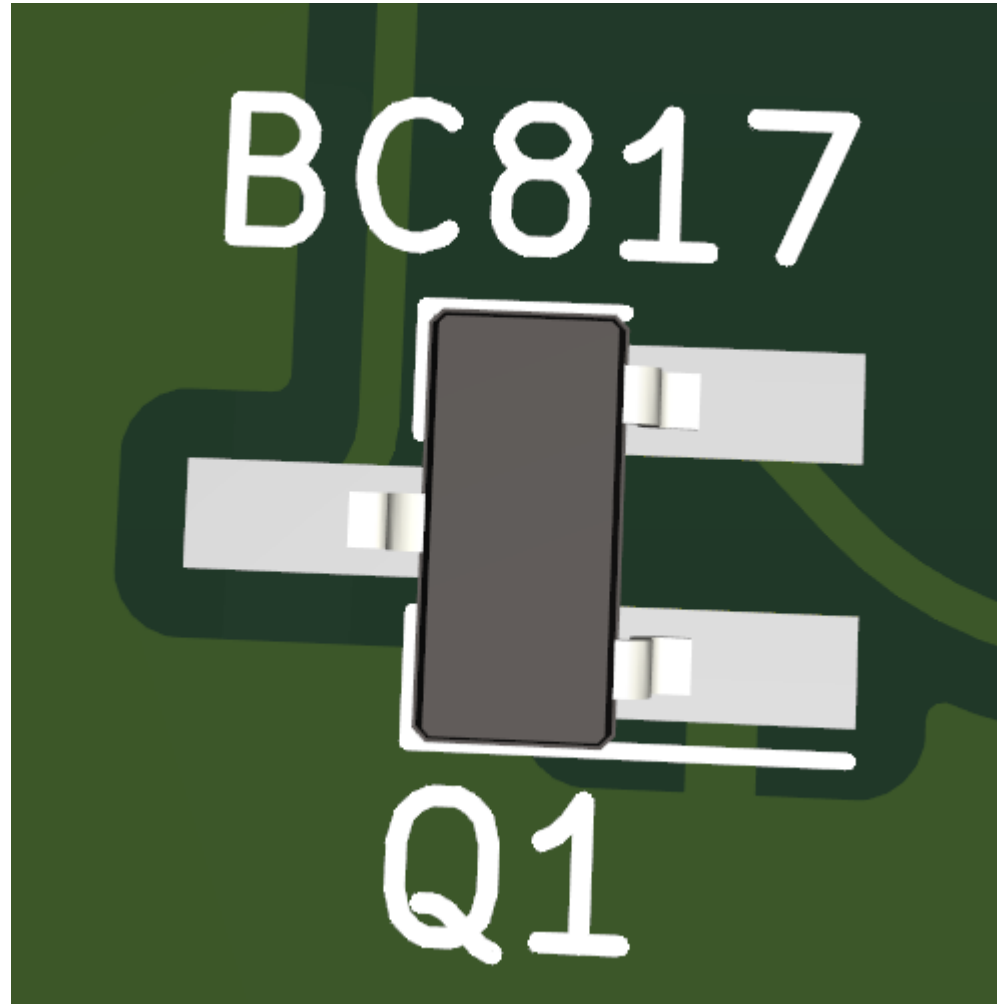
Things we checked:

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

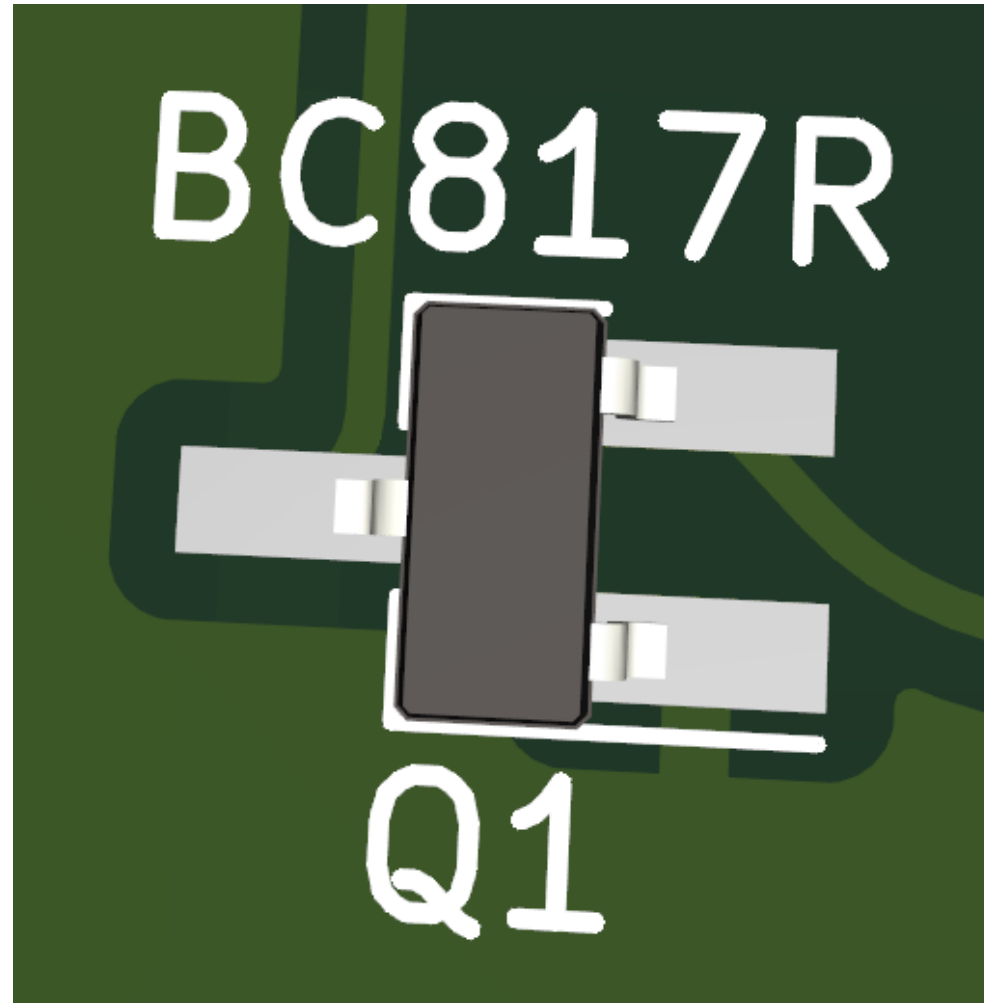
Oops... we forgot to check the footprint!

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



it's not
a bug
it's an
undocumented
feature

The HAN was chill about it

But what about a PCB for a company?

The FIRST company you'll work for.

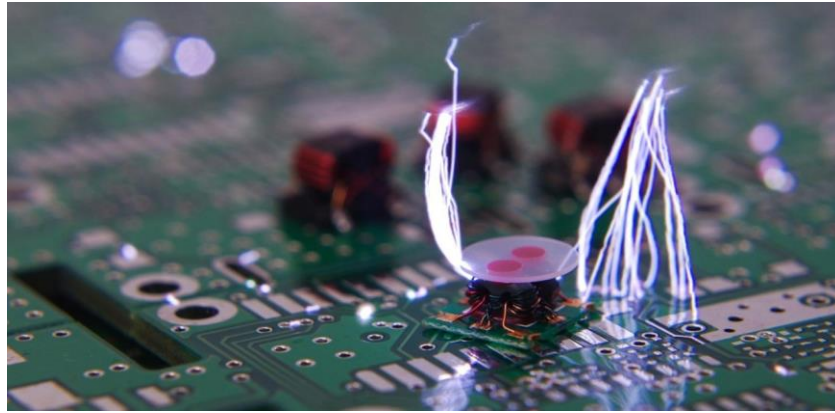
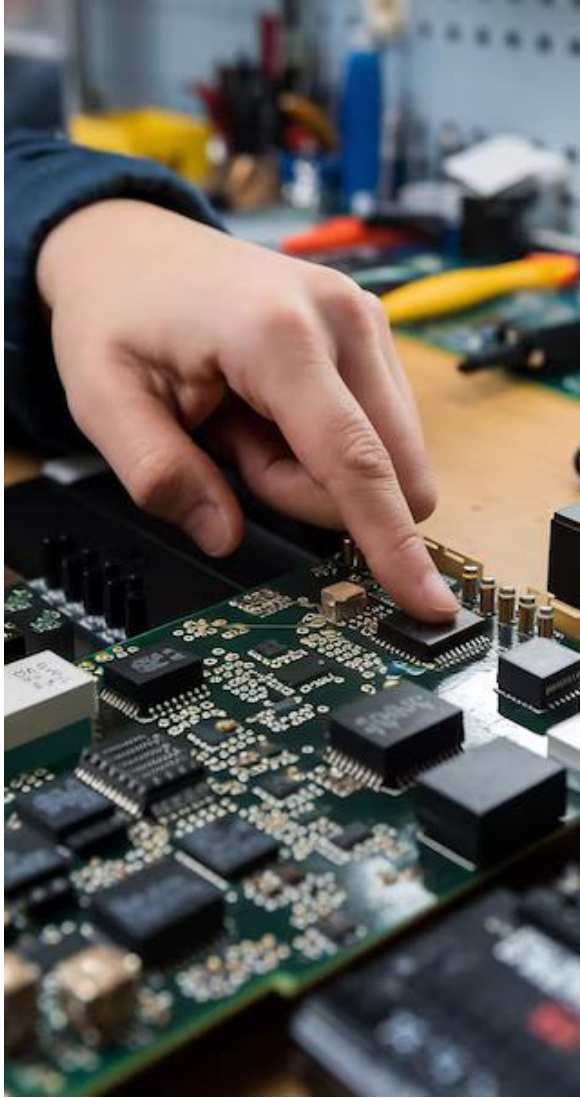
And you are NOT allowed to make a prototype, in fact, every PCB there is a product.

Welcome to my world.

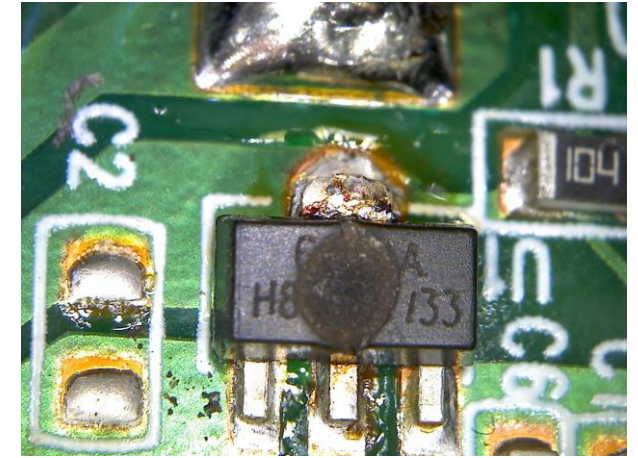
Potential risks and issues:

- **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.



```
⚠ Failed to open serial port COM5 due to error: + Error:
error: 193\\?
\\c:\Users\Kwiecinski\.vscode\extensions\vsciot-
vscode.vscode-arduino-0.4.3\out\node_modules\usb-
detection\build\Release\detection.node
```

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!

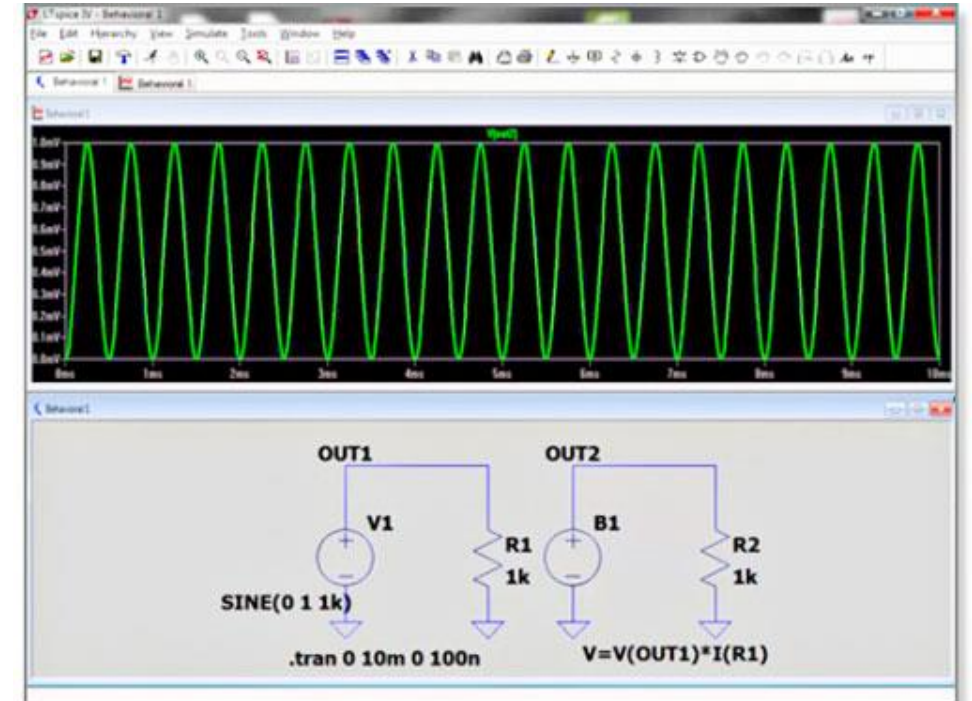
PCB-design in practice

(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*

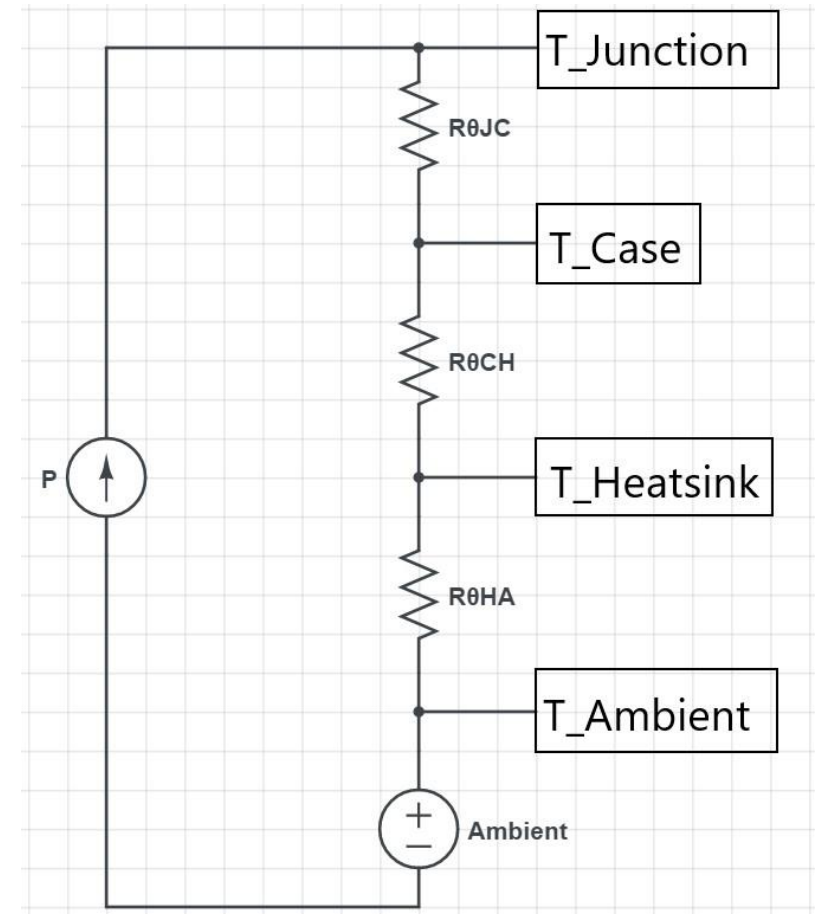


The magic smoke machines (Heat dissipation)

Theory:

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

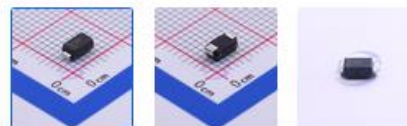
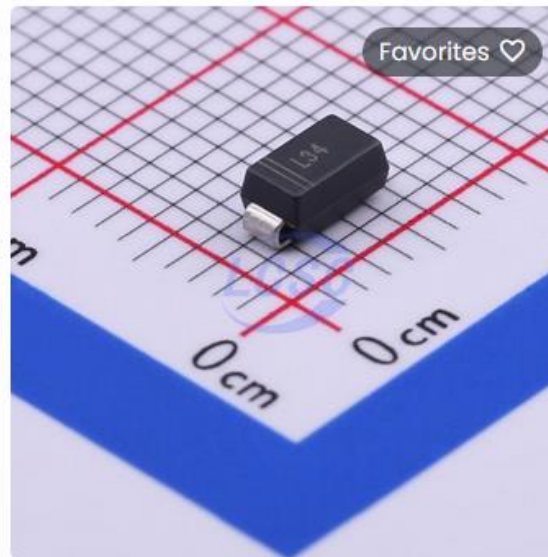
Thermal resistance



Example (Heat dissipation)

Reverse polarity protection diode

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



Images are for reference only

Shikues MSK340A


Manufacturer [Shikues](#) 

Mfr. Part # MSK340A 

LCSC Part # C434027 

Package SMA 

Customer #

Description 50V Independent Type
460mV@5A 5A SMA Schottky
Diodes ROHS 

Datasheet  [Shikues MSK340A](#)



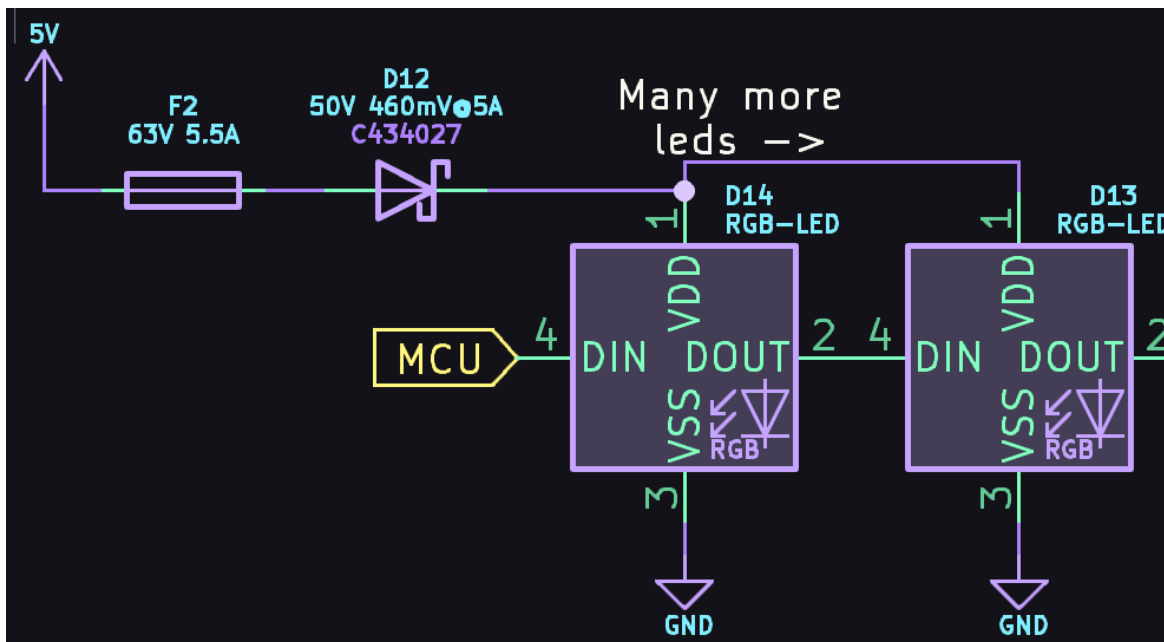
Example (Heat dissipation)

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: $P = 0.31V \times 1.8A = 0.558W$ of power dissipation

WHITE: $P = 0.42V \times 5A = 2.10W$ of power dissipation

With SMA package ($R_{thJA} = 85^{\circ}C/W$ from datasheet)

For RED:

$P = 0.558W$ Temperature rise = $0.558W \times 85^{\circ}C/W = 47.4^{\circ}C$

Junction temperature = $25^{\circ}C + 47.4^{\circ}C = 72.4^{\circ}C$

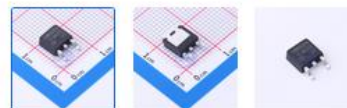
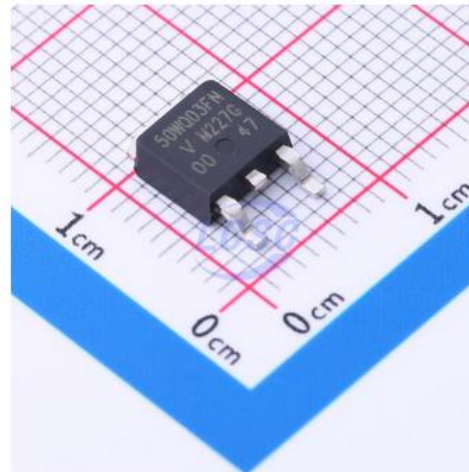
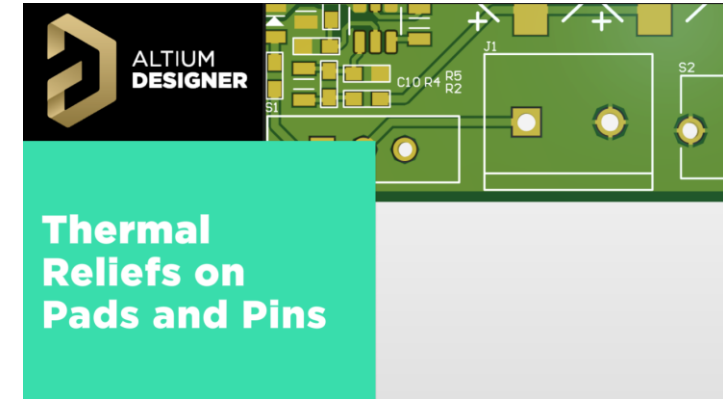
For WHITE:

$P = 2.10W$ Temperature rise = $2.10W \times 85^{\circ}C/W = 178.5^{\circ}C$

Junction temperature = $25^{\circ}C + 178.5^{\circ}C = 203.5^{\circ}C$

Solution to problem?

- Overspecify 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



Images are for reference only

Vishay Intertech VS-50WQ03FNTR-M3

Manufacturer [Vishay Intertech](#)

Mfr. Part # VS-50WQ03FNTR-M3

LCSC Part # C725690

Package DPAK(TO-252AA)

Customer #

Description 30V Independent Type 530mV@10A 5.5A DPAK(TO-252AA) Schottky Diodes ROHS

Datasheet [Vishay Intertech VS-50WQ03FNTR-M3](#)

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)

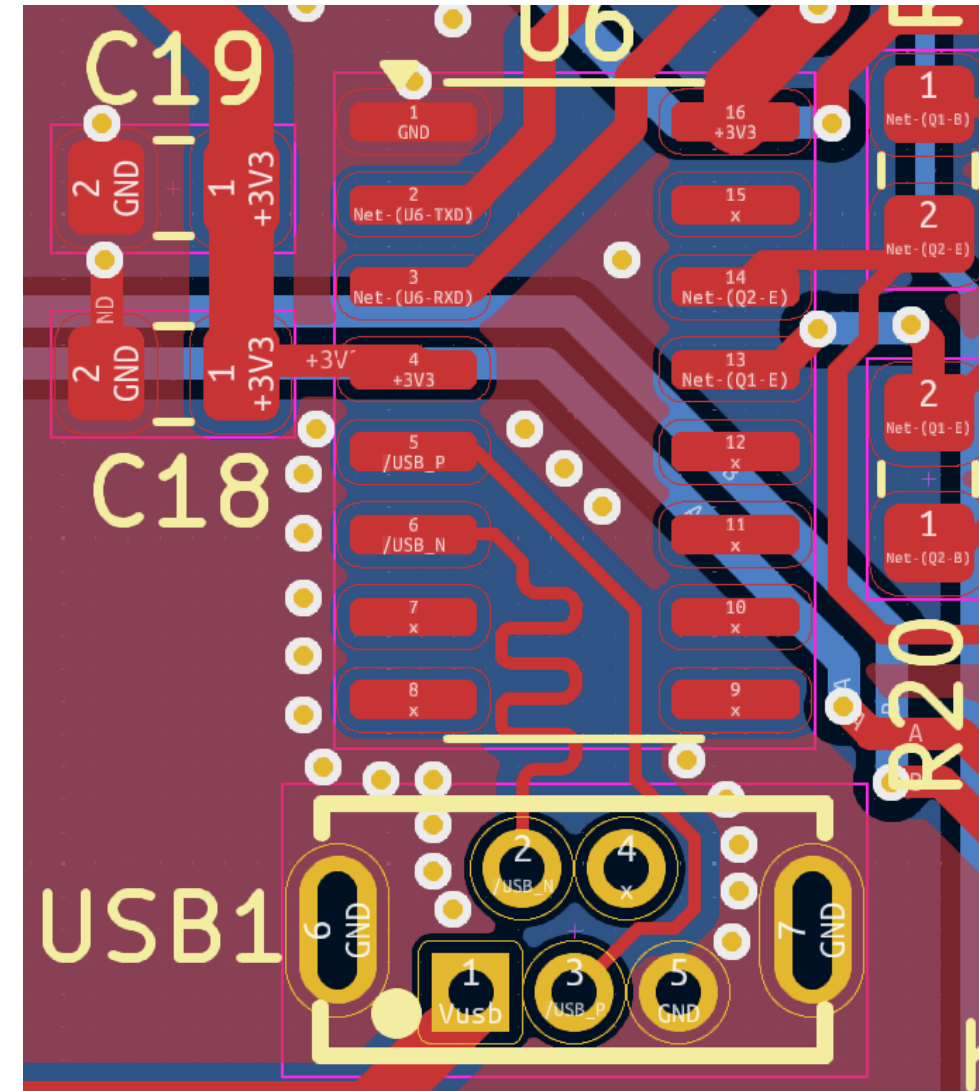
Co-Mu-X-ic-a-ti-on lines (High speed Data transfer)

- 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?

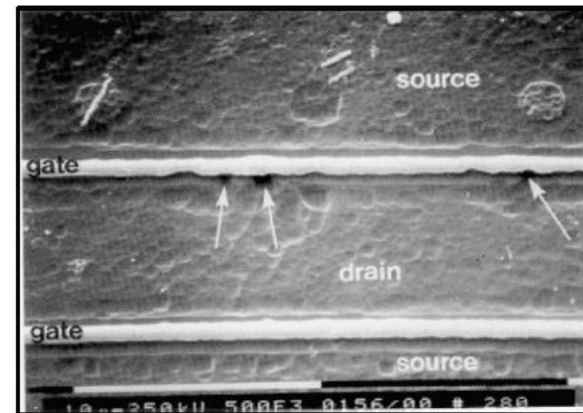
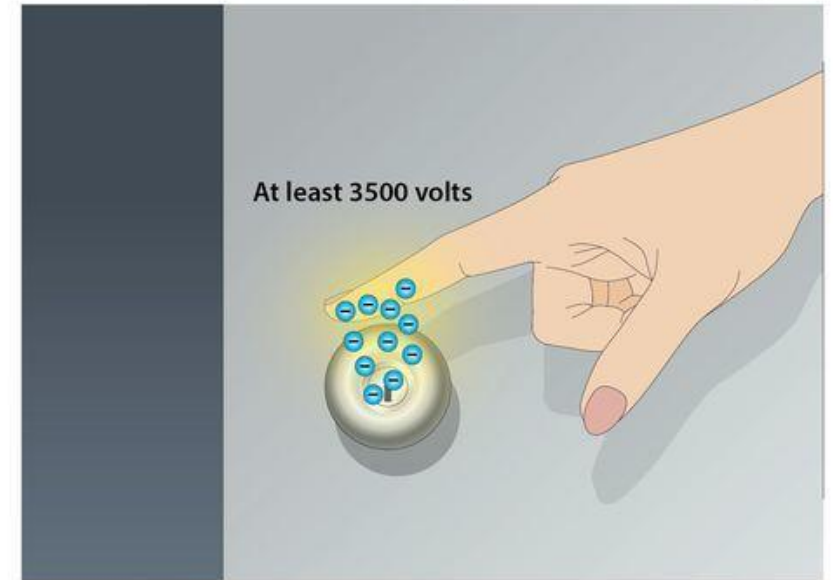
- No communication at all
- Timeout errors
- Loads of frustrations and endless debugging
- Reduced maximum speed



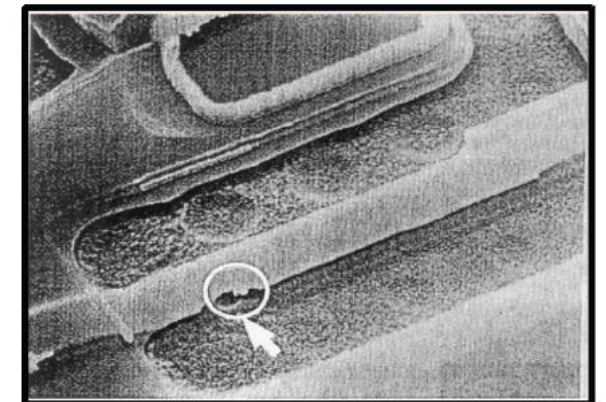
You can't touch this (ESD)

- 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.

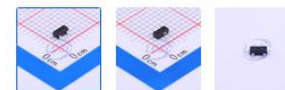
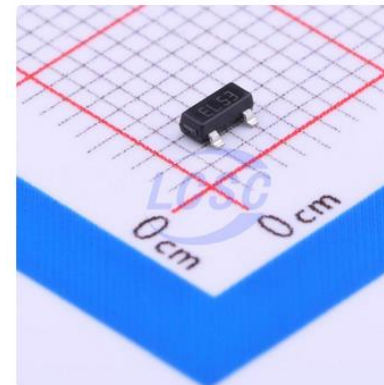
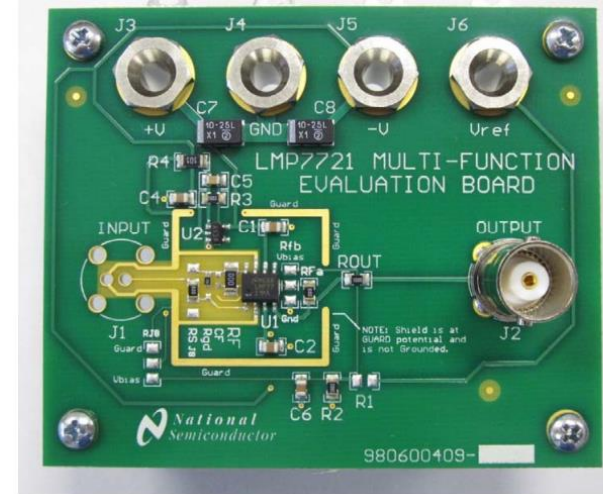


Gate oxide damage to an input buffer after CDM stress. Note the rupture to gate oxide.

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



Images are for reference only

STMicroelectronics ESDA5V3L

Manufacturer [STMicroelectronics](#)

Mfr. Part # ESDA5V3L

LCSC Part # C87911

Package SOT-23

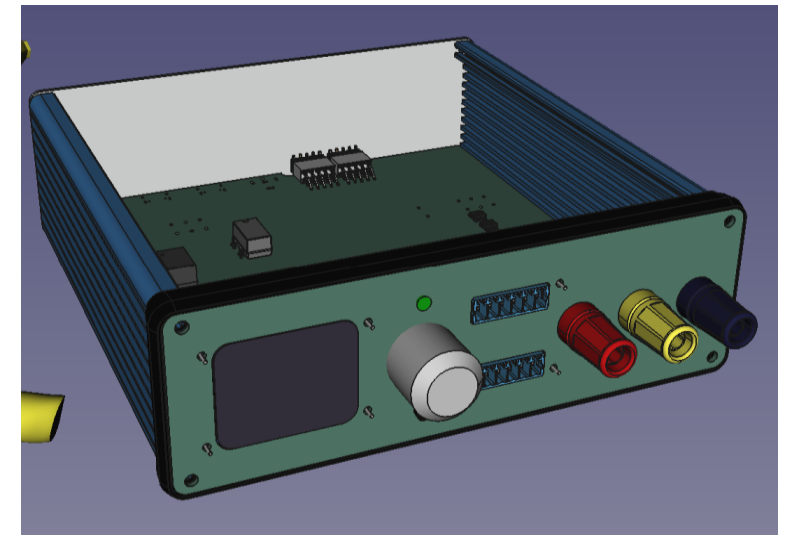
Customer #

Description 5.3V 300W 5.3V 3V SOT-23 ESD and Surge Protection (TVS/ESD) ROHS

Datasheet [STMicroelectronics ESDA5V3L](#)

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!



PCB Specification Selection ▶ How it works (3 steps) [↑ Quick-order PCB](#)

Board type: Single pieces Panel by Customer Panel by PCBWay

Different design in panel: 1 2 3 4 5 6


* Size (single): X mm  

* Quantity (single): pcs

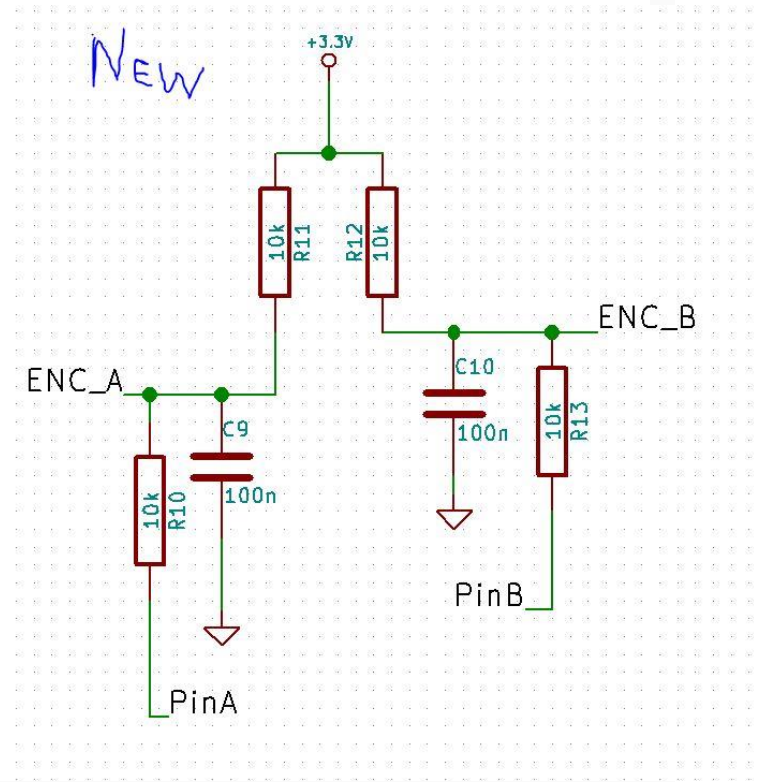
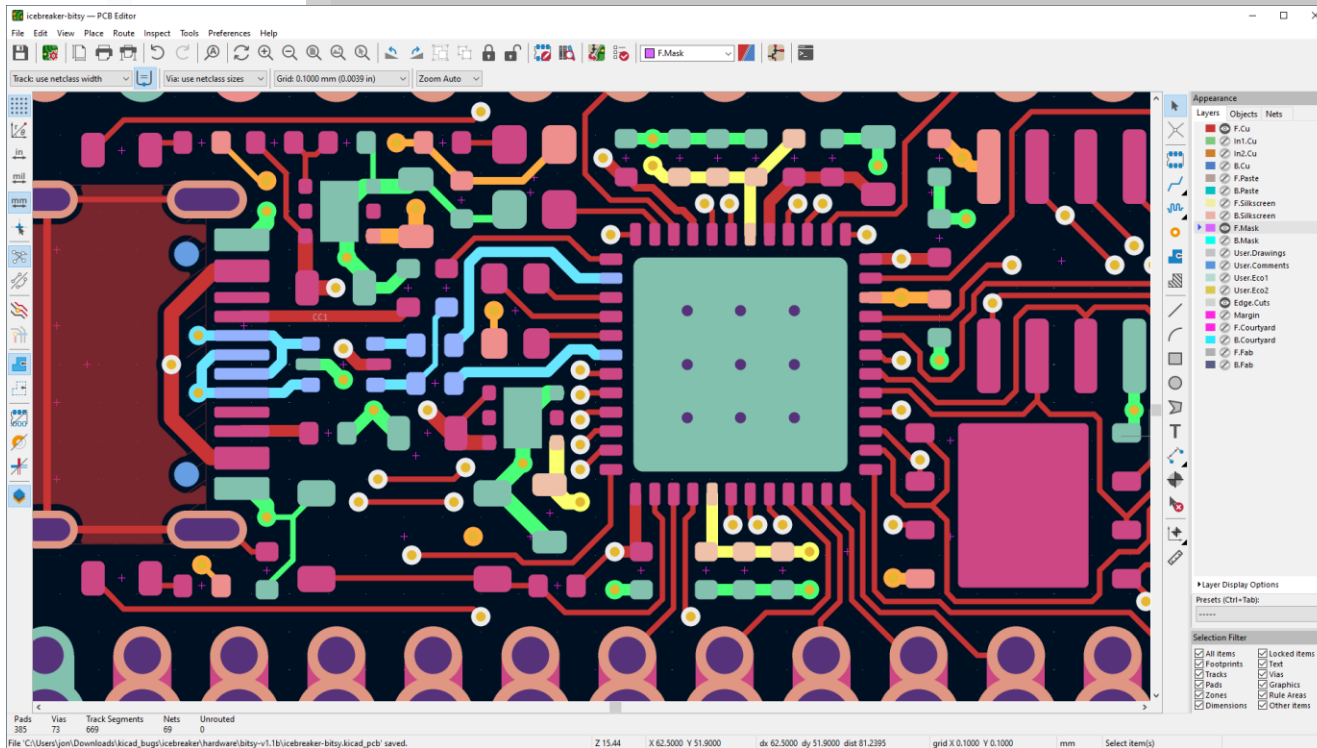
Layers: 1 Layer 2 Layers 4 Layers 6 Layers 8 Layers 10 Layers 12 Layers 14 Layers

Material: FR-4 Aluminum Rogers HDI (Buried/blind vias) Copper Base
*Material model can be remarked below. HDI is available for 4-layer or more.

FR4-TG: TG 130-140 TG 150-160 TG 170-180 S1000H TG150 S1000-2M TG170
*The base material of 2-layer PCBs(>=3m2 area order) is automatically upgraded to S1000H TG150 for FREE with more stable and higher quality.

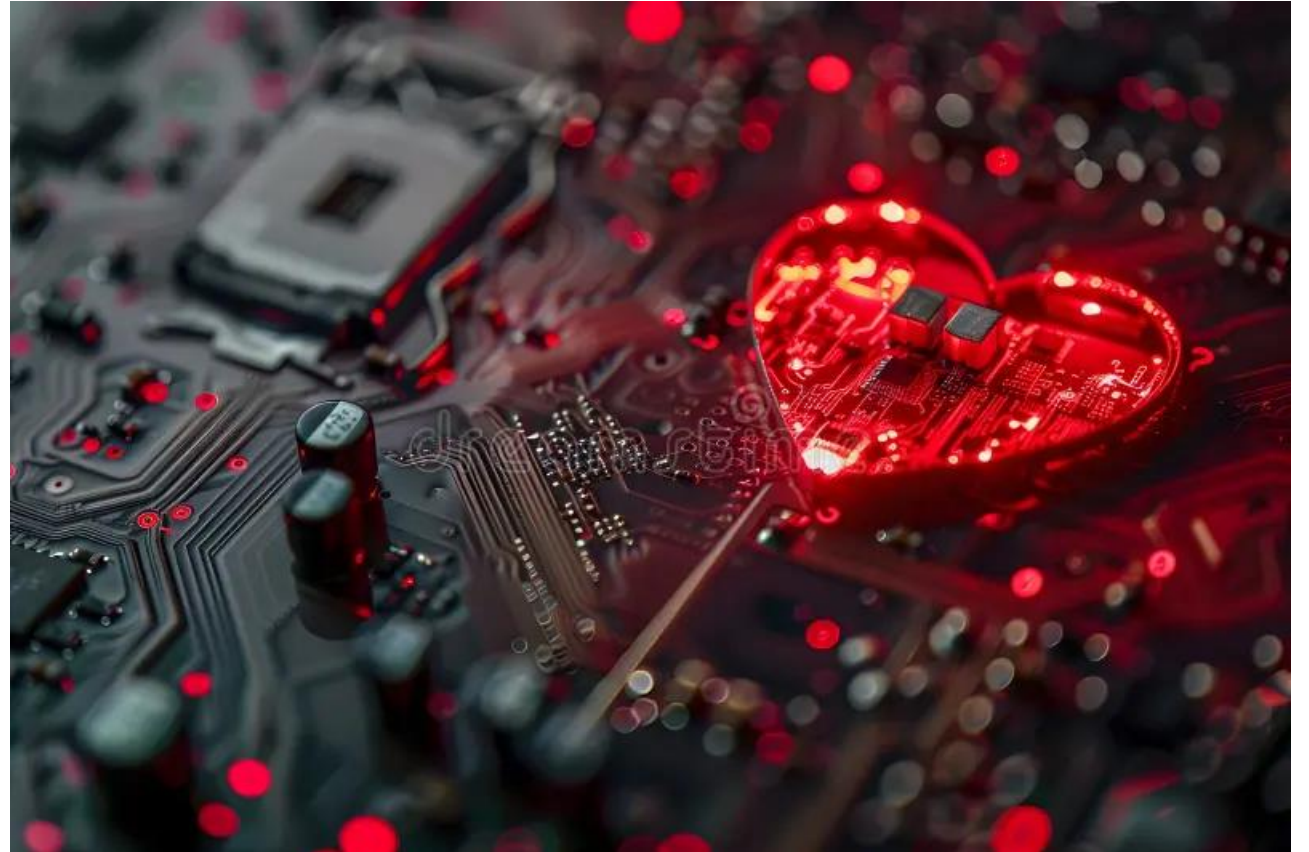
Thickness: 0.2 0.3 0.4 0.6 0.8 1.0 1.2 1.6 2.0 2.4 2.6 2.8 3.0 3.2
 * Unit: mm 

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>
-