Flash dump(l)ing 101

(You can thank my boyfriend for this joke)

$USER

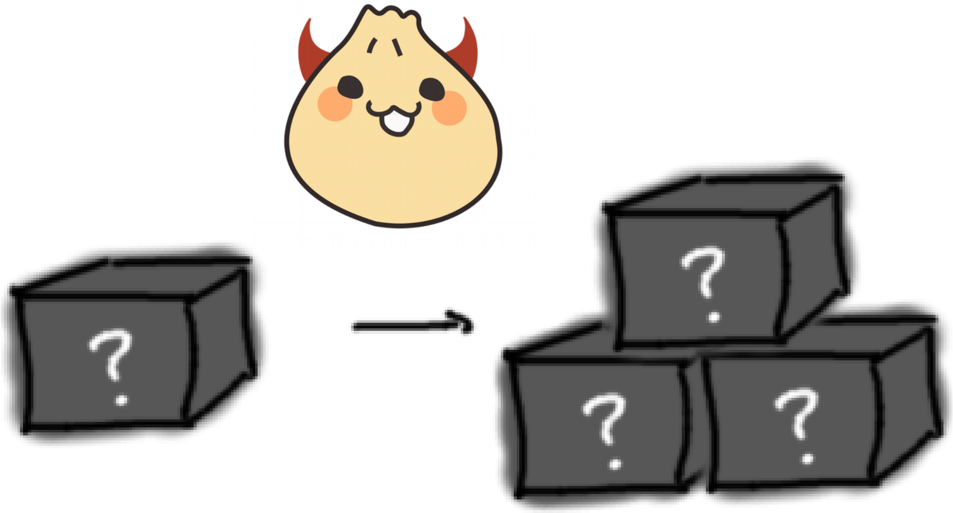
- **Security researcher at Quarkslab (Paris)**
  SECURING EVERY BIT OF YOUR DATA
- **Love**
  - (de)soldering stuff
  - hardware attacks

- **R&D project with:**
  - Philippe Teuwen (@doegox)
  - Guillaume Heilles (@PapaZours)

The magic box

- Box provides a service
- Users pay for that service

→ What if the box can be duplicated ?

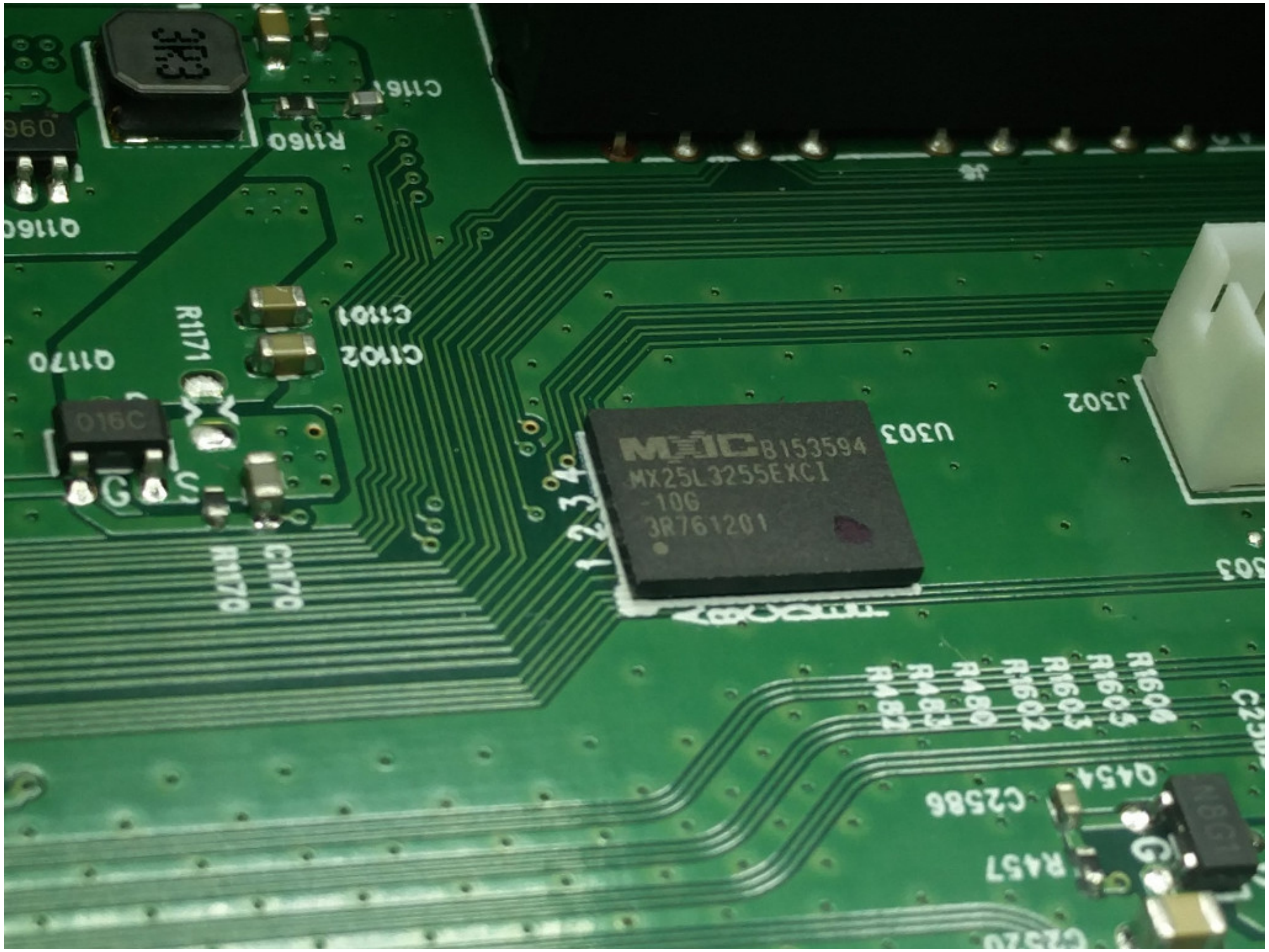


Opening up the black box

- **The easy part**
  - No proprietary screws
  - No fuse
  - No sensor

- **No picture of the black box or its PCB**
- **Here is a cute dumpling instead**

Inside the black box



Battleplan to attack the magic box

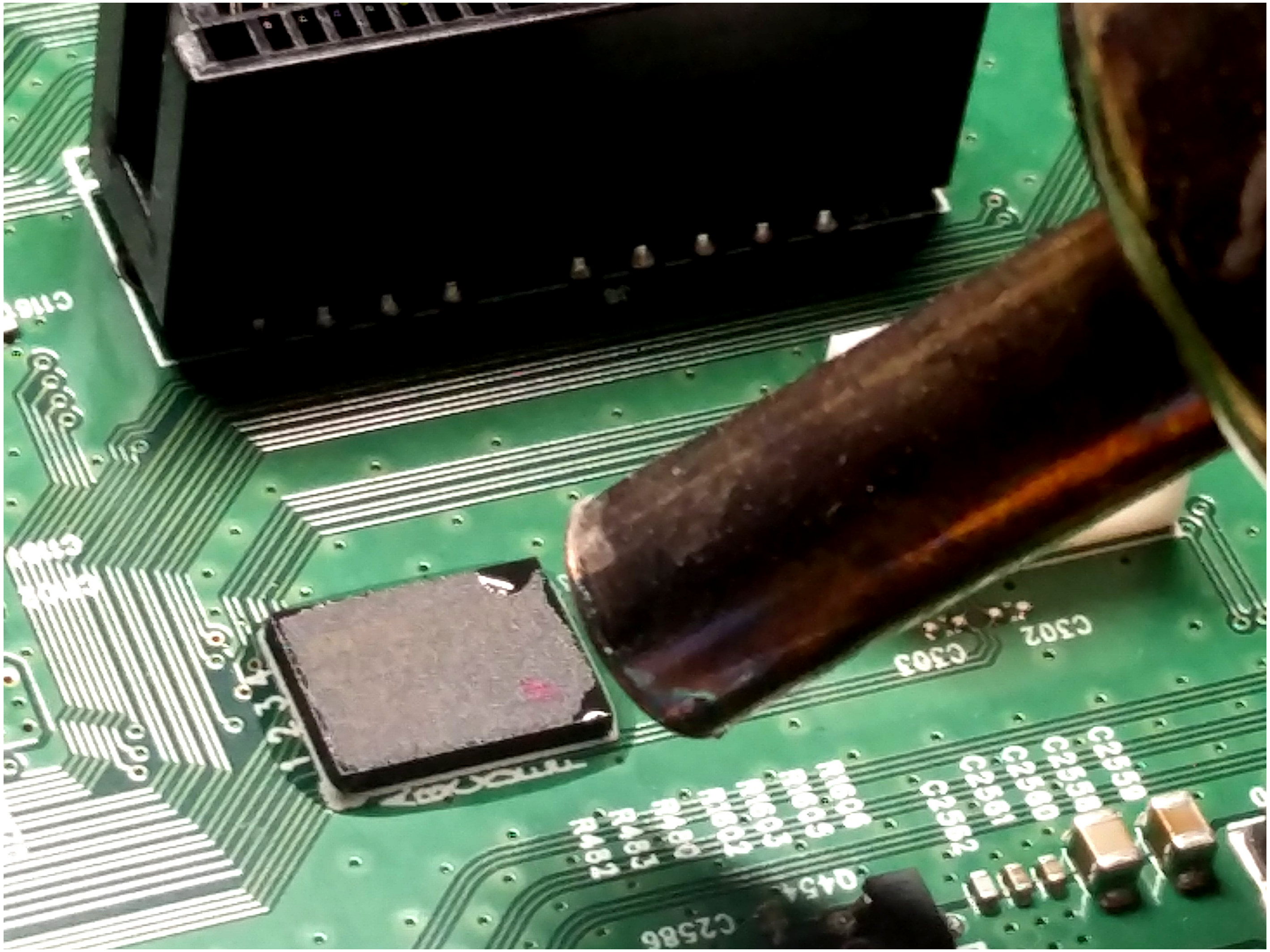
→ Target the flash chip which contains the firmware

1) Extract the flash chip from the board
2) Design a breakout PCB adapted to the chip
3) Craft the breakout PCB
4) Microsolder the chip to the breakout board
5) Make the chip talk! Dump it/reprogram it!

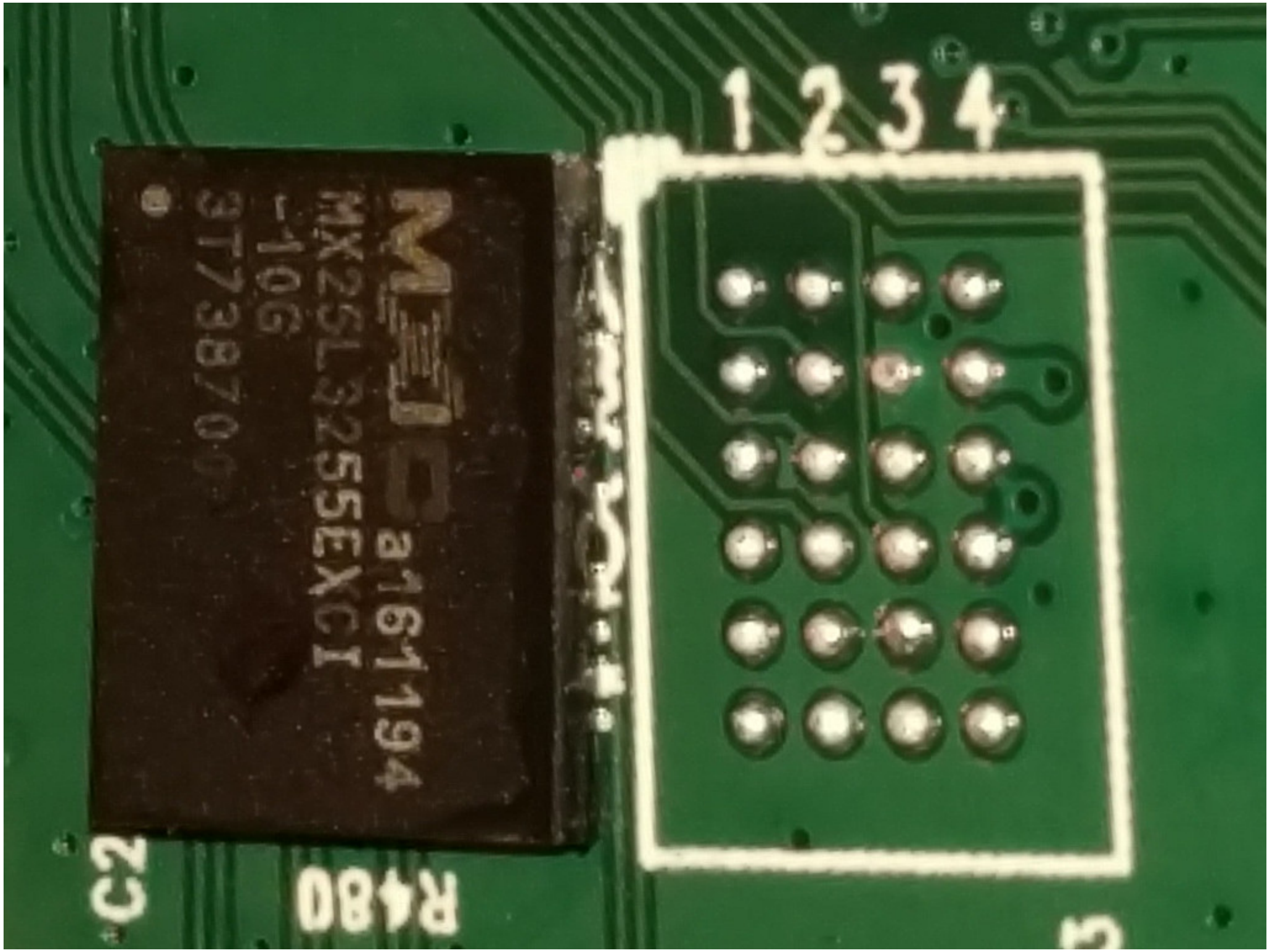
Step 1: Extracting the flash chip

http://www.aoyue.eu/aoyue-int860-smd-rework-station-hot-air-soldering-station.html

Step 1: Extracting the flash chip



Desoldered Flash



Step 2: Design a breakout board

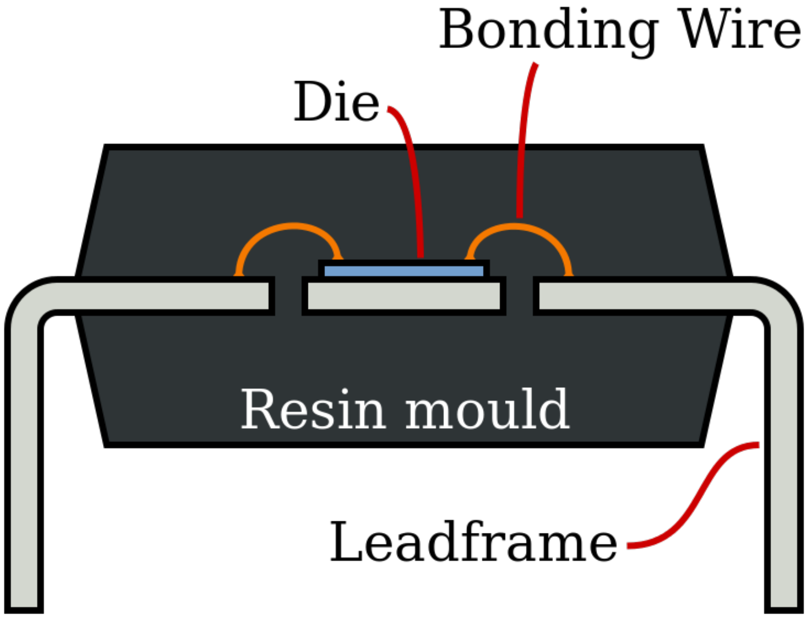
- **Breakout board gives an easy access to each pin of the chip**
- **Translate one type of chip package to another**

→ Need more information on the chip

- What is the source chip package ?
- What is the target chip package ?
- What are the useful pins of the chip ?

Chip packages?

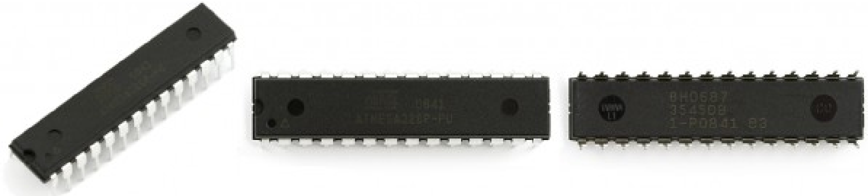
Chip packages



https://en.wikipedia.org/wiki/File:DIP_Cross-section.svg

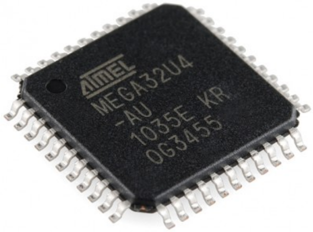
Chip packages

- Dual In-Line Package (DIP)

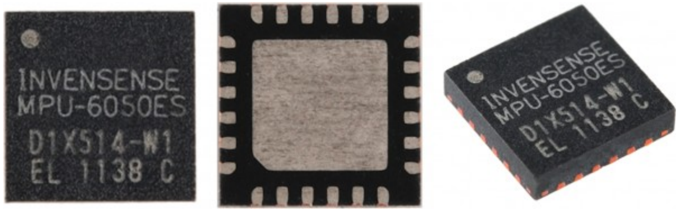


- Small Outline Package (SOP)

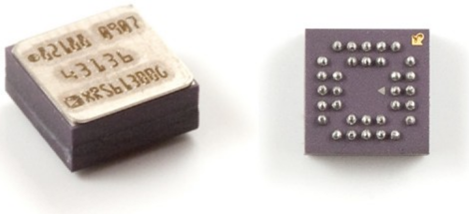
- Quad Flat Package (QFP)



- Leadless Chip Carrier (LCC)



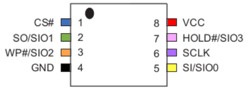
- Ball Grid Array (BGA)



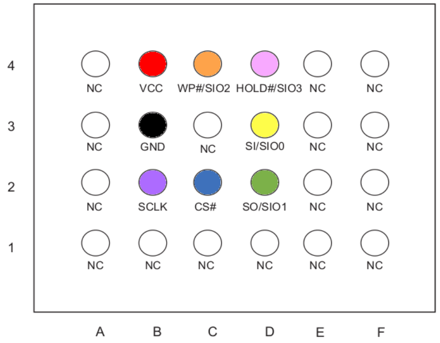
Pins of the breakout board

3. PIN CONFIGURATION

8-PIN SOP (200mil)

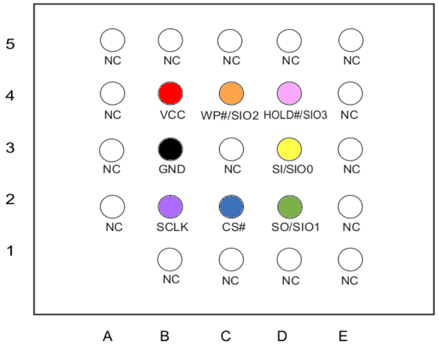


24-Ball TFBGA (6x8 mm, 4x6 Ball Array)



	A	B	C	D	E	F
4	NC	VCC	WP#/SIO2	HOLD#/SIO3	NC	NC
3	NC	GND	NC	SI/SIO0	NC	NC
2	NC	SCLK	CS#	SO/SIO1	NC	NC
1	NC	NC	NC	NC	NC	NC

24-Ball TFBGA (6x8 mm, 5x5 Ball Array)



	A	B	C	D	E
5	NC	NC	NC	NC	NC
4	NC	VCC	WP#/SIO2	HOLD#/SIO3	NC
3	NC	GND	NC	SI/SIO0	NC
2	NC	SCLK	CS#	SO/SIO1	NC
1		NC	NC	NC	NC

4. PIN DESCRIPTION

SYMBOL	DESCRIPTION
CS#	Chip Select
SI/SIO0	Serial Data Input (for 1xI/O)/ Serial Data Input & Output (for 2xI/O or 4xI/O mode)
SO/SIO1	Serial Data Output (for 1xI/O)/Serial Data Input & Output (for 2xI/O or 4xI/O mode)
SCLK	Clock Input
WP#/SIO2	Write protection: connect to GND or Serial Data Input & Output (for 4xI/O mode)
HOLD#/ SIO3	To pause the device without deselecting the device or Serial data Input/Output for 4 x I/O mode
VCC	+ 3.0V Power Supply
GND	Ground
NC	No Connection

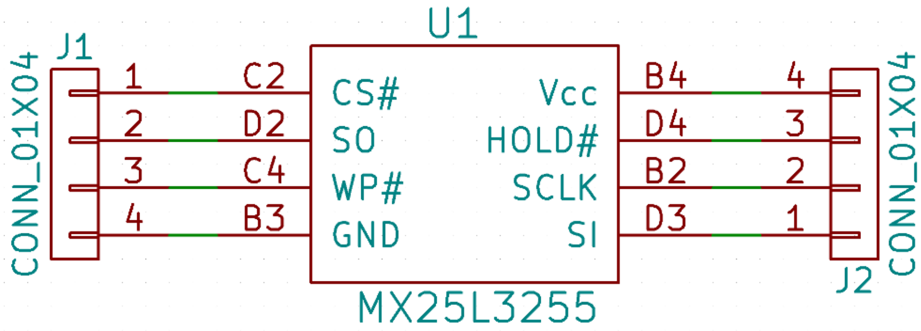
Note:
1. The HOLD# pin is internal pull high.

- Translate BGA to DIP8
- Expose only the 8 pins used

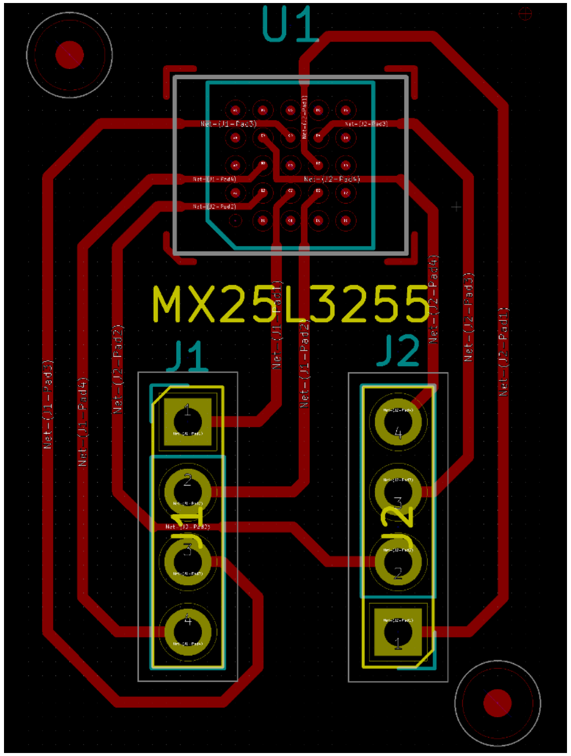
Actual PCB Design

- **PCB design with KiCad**

  1) create an electronic schematic

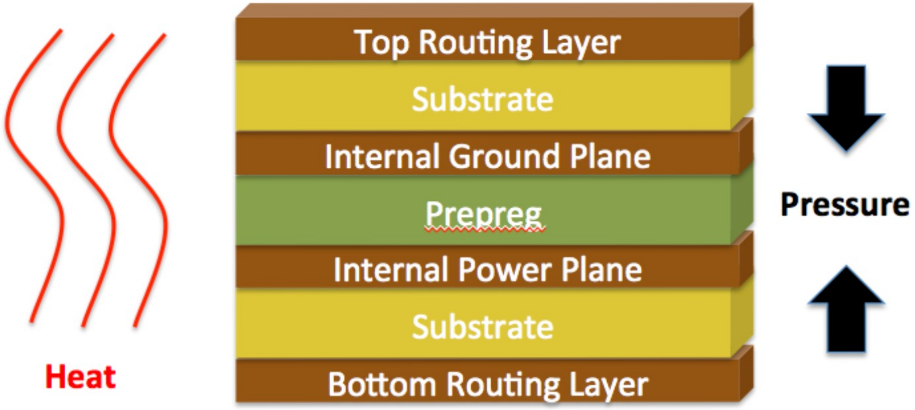


  2) Create the footprint of the flash chip

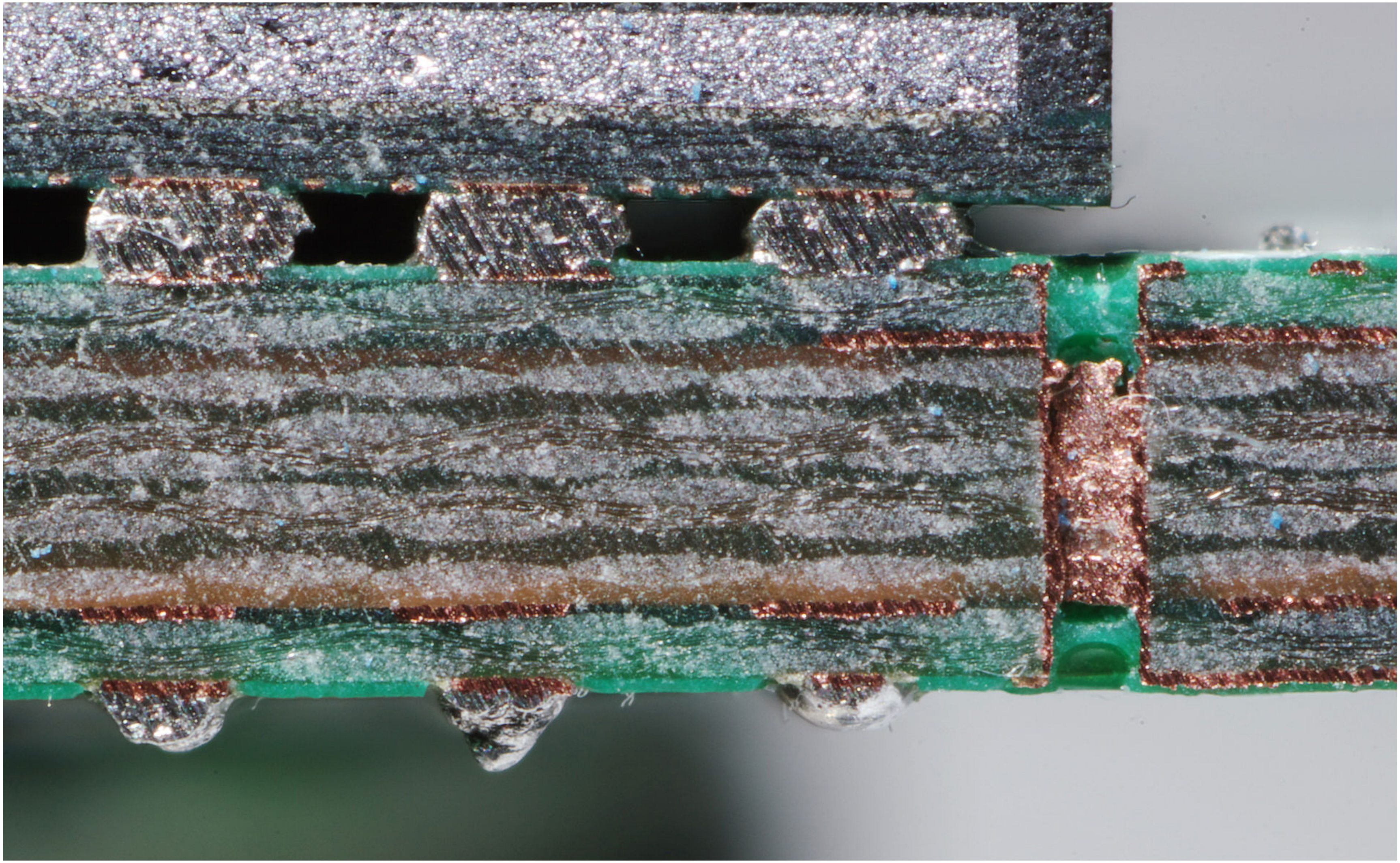


Step 3 : Craft a breakout PCB

- **PCB 101**
  - It’s a sandwich
  - Substrate, non-conductive layer, FR4 (epoxy + fiberglass)
  - Conductive layer: copper
  - Soldermask on top



PCB sandwich

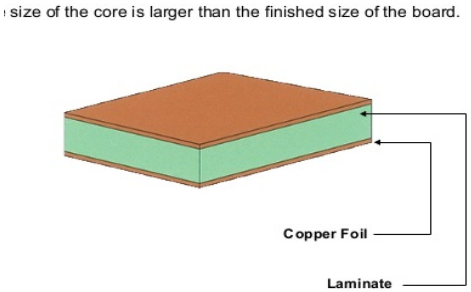


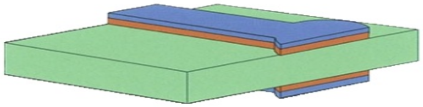
PCB fabrication

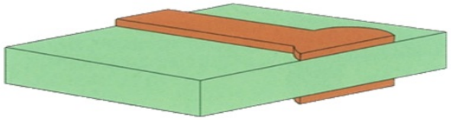
- **We tried 2 different techniques:**
  - Etching which uses chemical component
  - Milling which uses mechanical drilling bit

PCB fabrication by etching

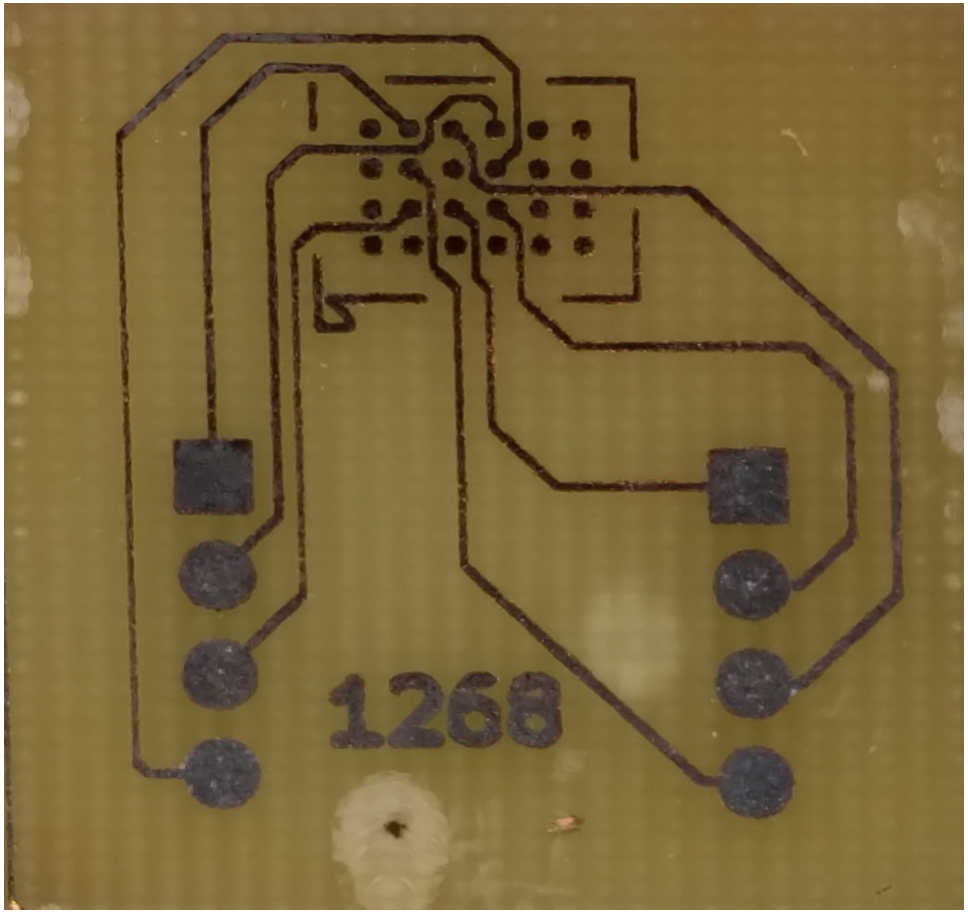
- Transfer ink to the substrate
- Exposed copper is eaten away by chemicals
- Ink is removed

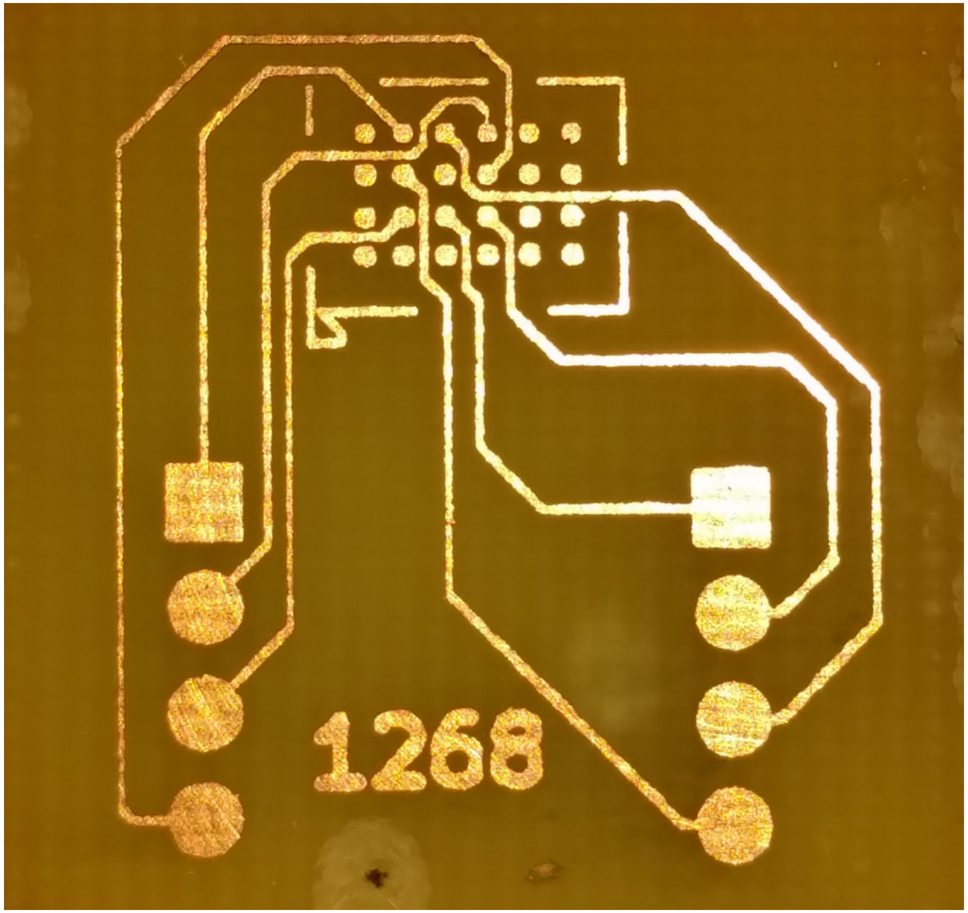

size of the core is larger than the finished size of the board.
Copper Foil
Laminate





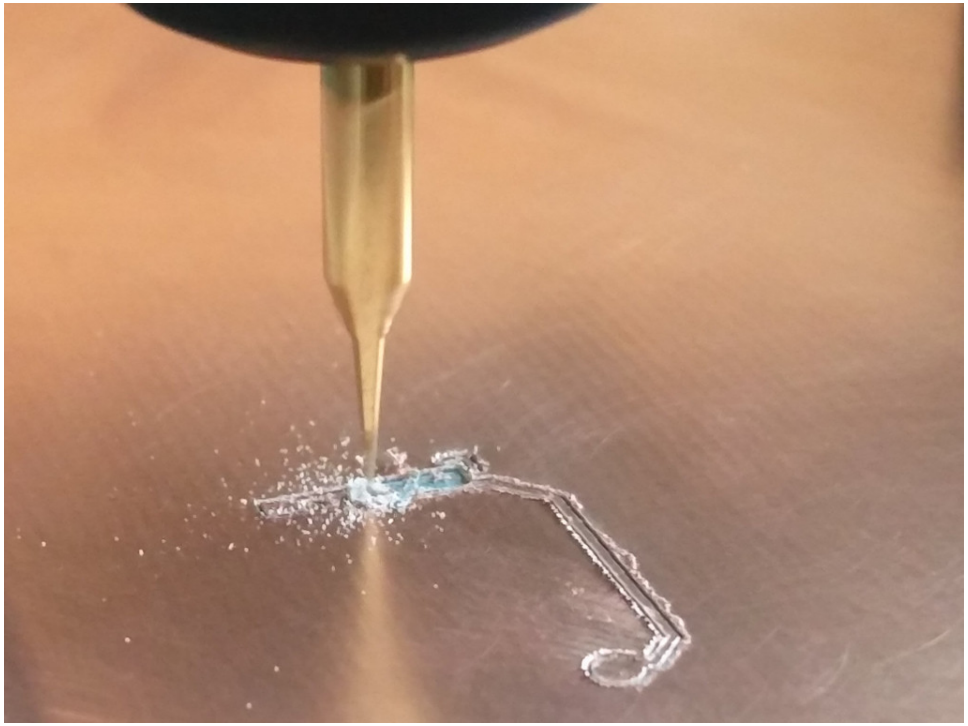
Pics of etching



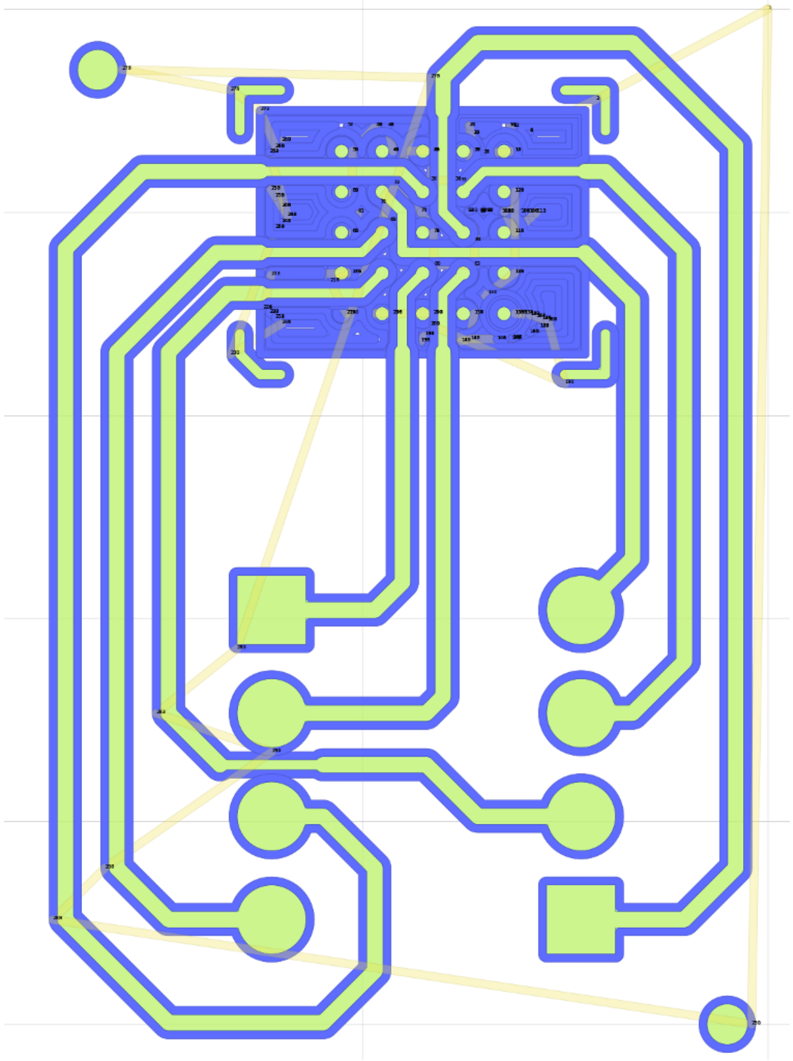


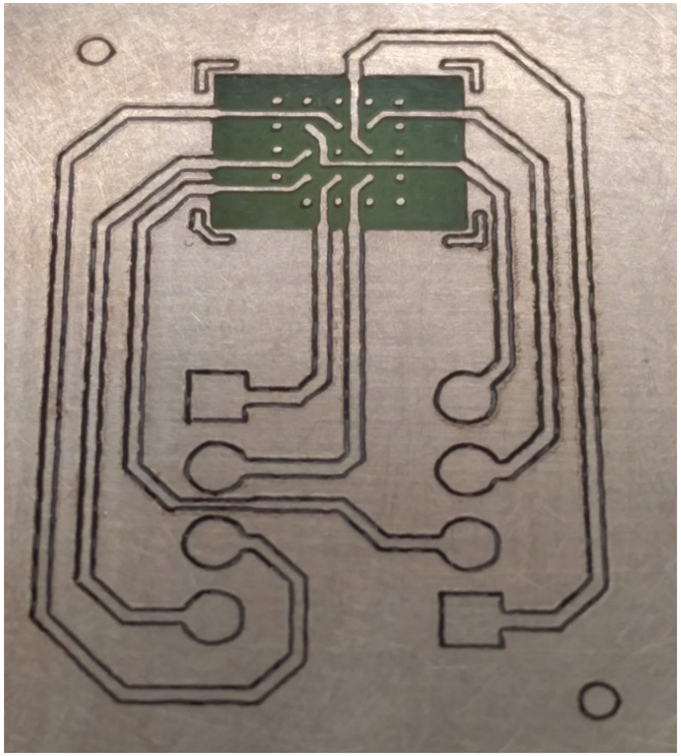
PCB fabrication by milling

- CNC (Computer Numerical Control) milling machine
- Rotating cutter shaves chips of material



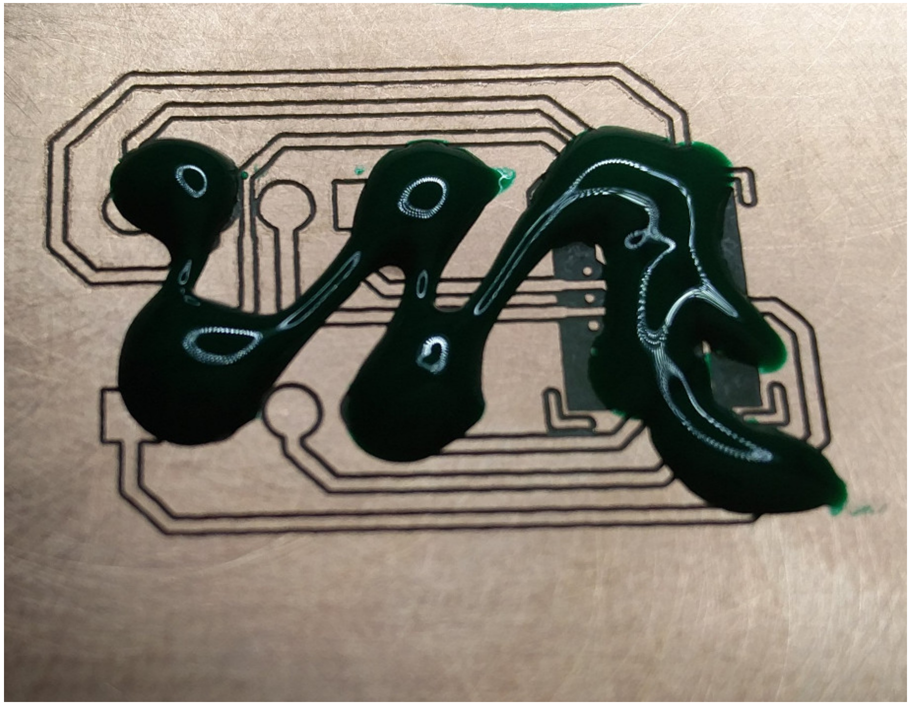
PCB fabrication by milling

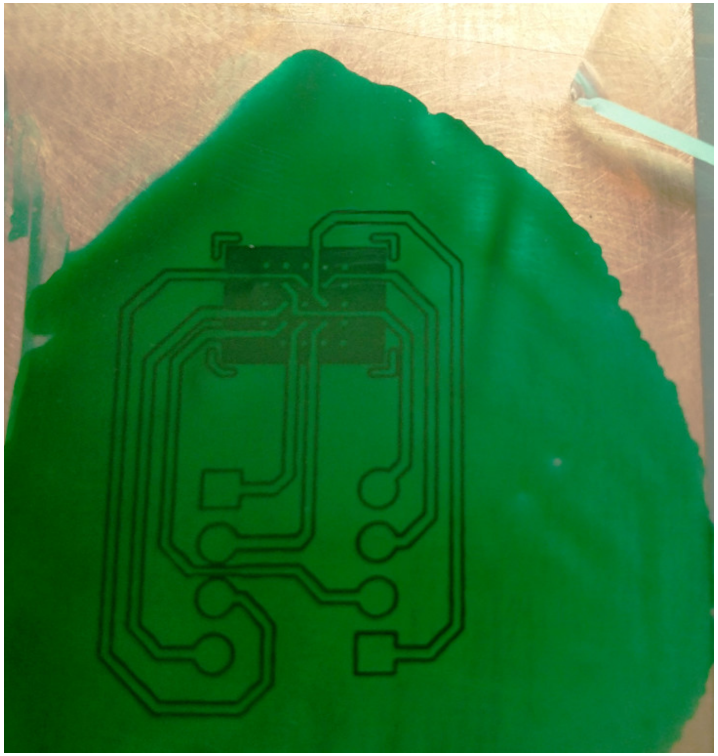




Add the soldermask

- Protect the copper from oxydation

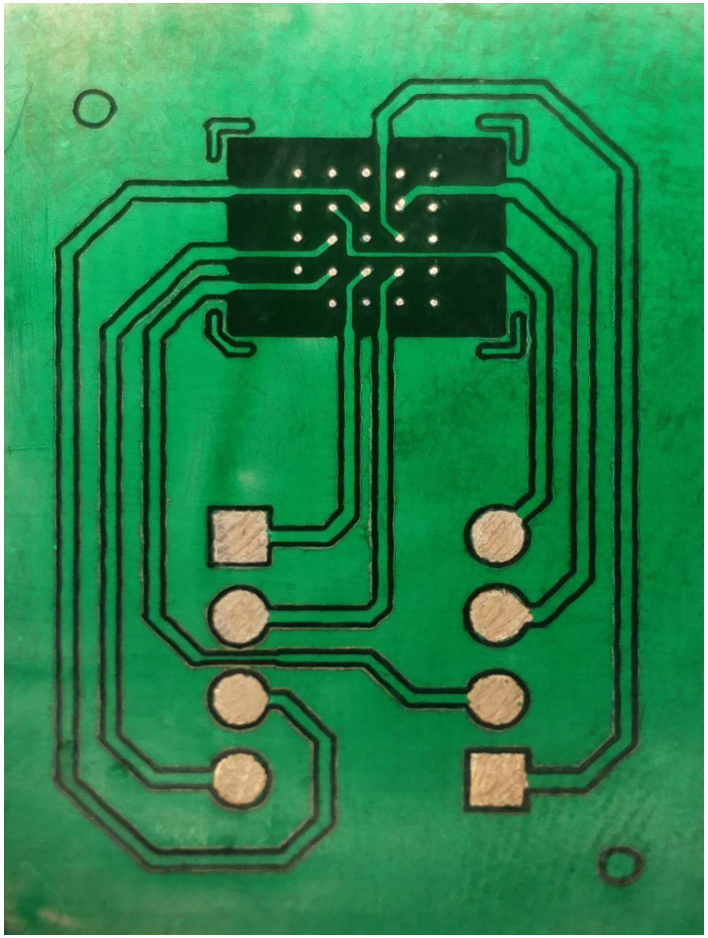




- Lost access to copper pads :(

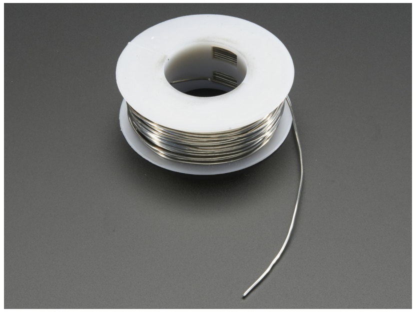
Fix the soldermask

- **Scratch the soldermask to (re)gain access to the pads**



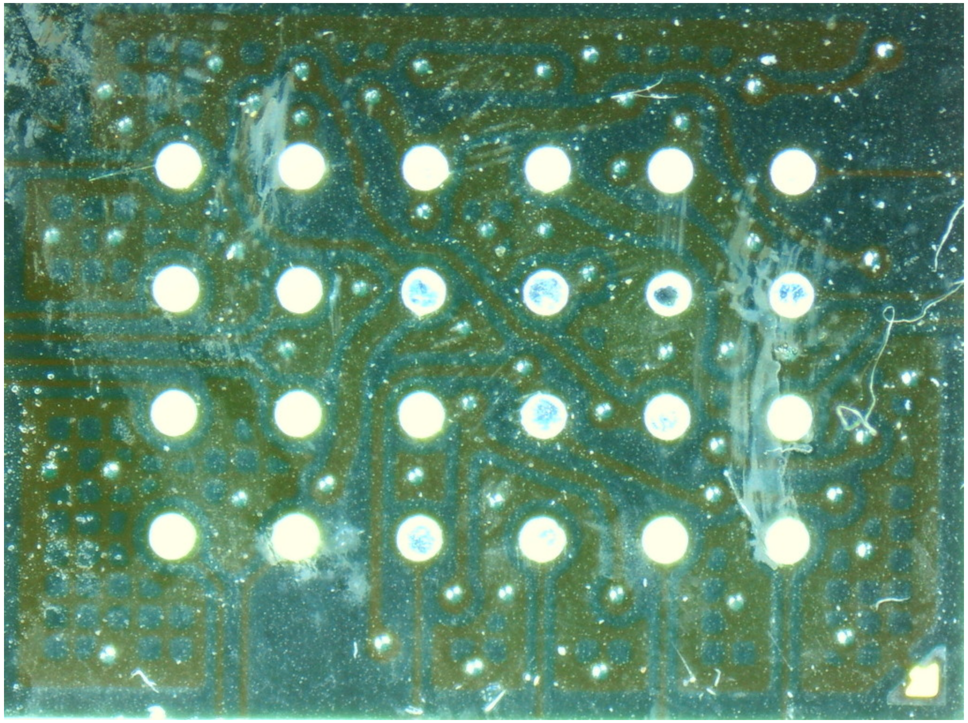
Step 4: Solder the chip to the breakout board

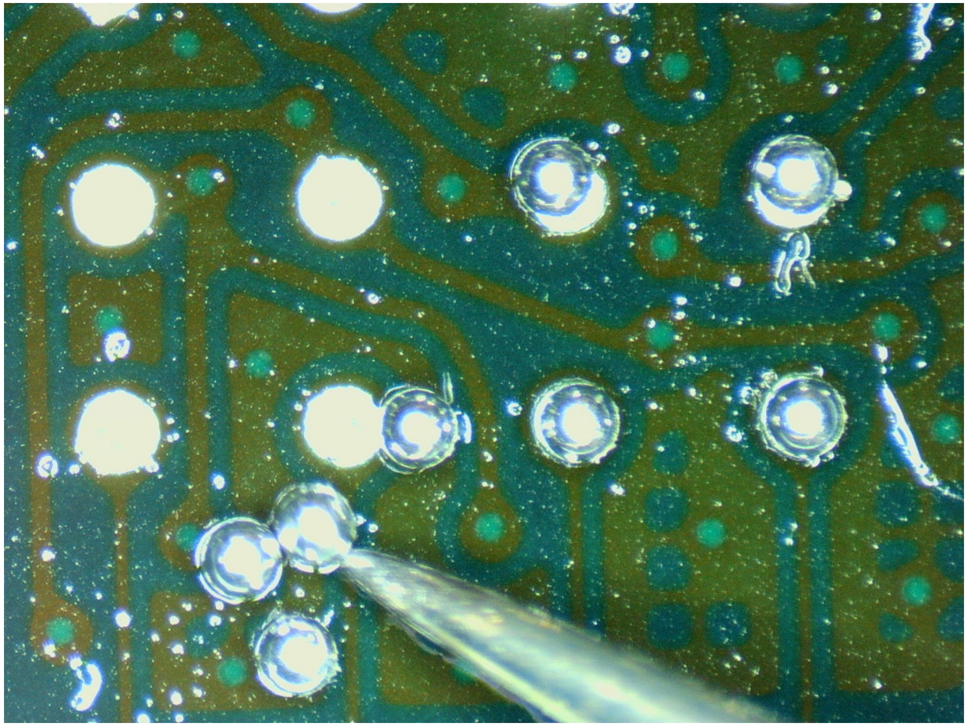
- BGA soldering
- Usage of microscope recommended
- Solder spool vs solder balls



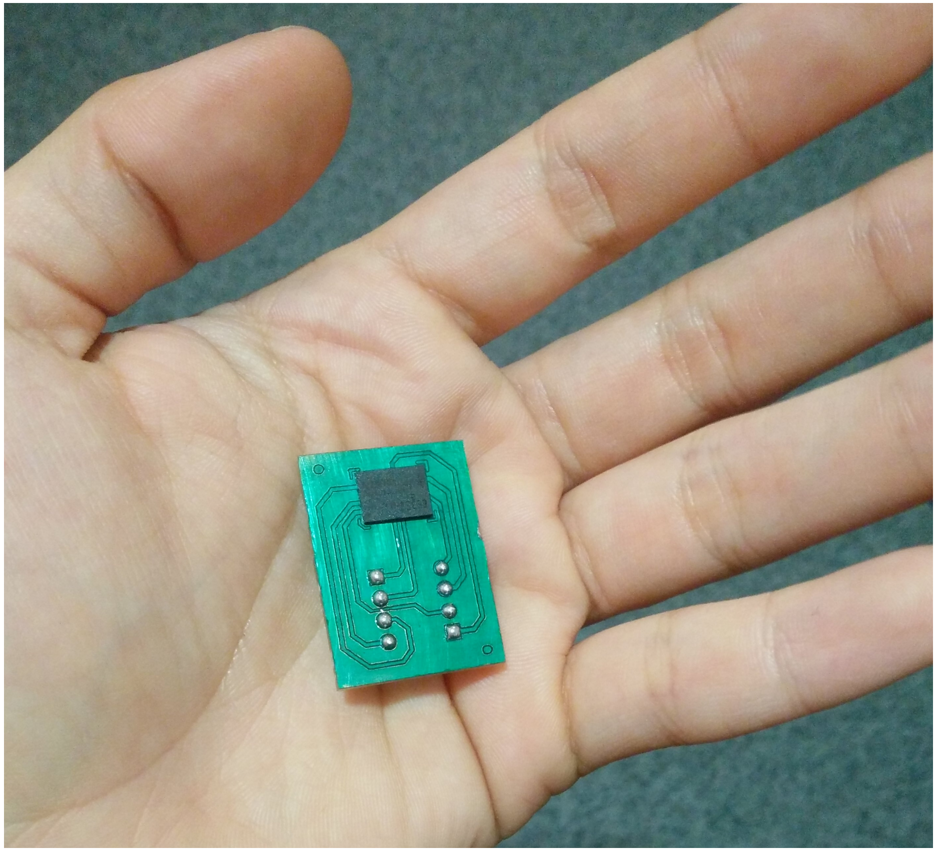
- A solder ball must be placed in each slot of the BGA
- Requires lots of patience and steady hands :D

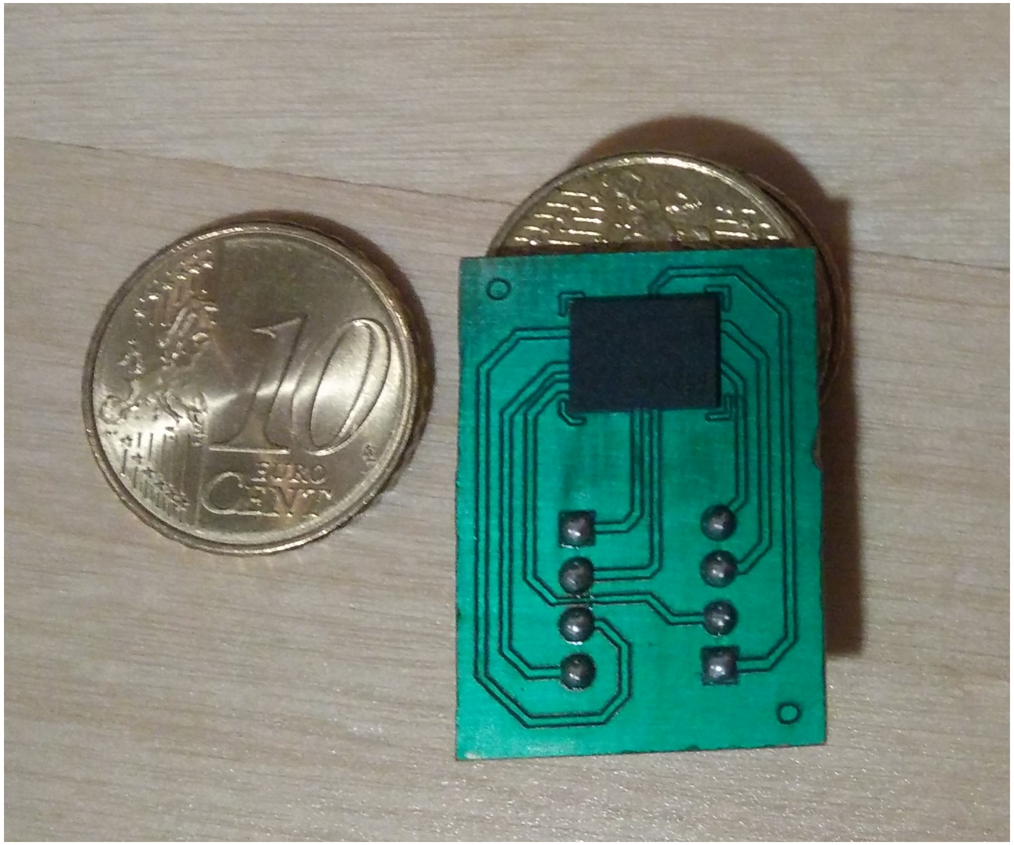
Pics of BGA reballing



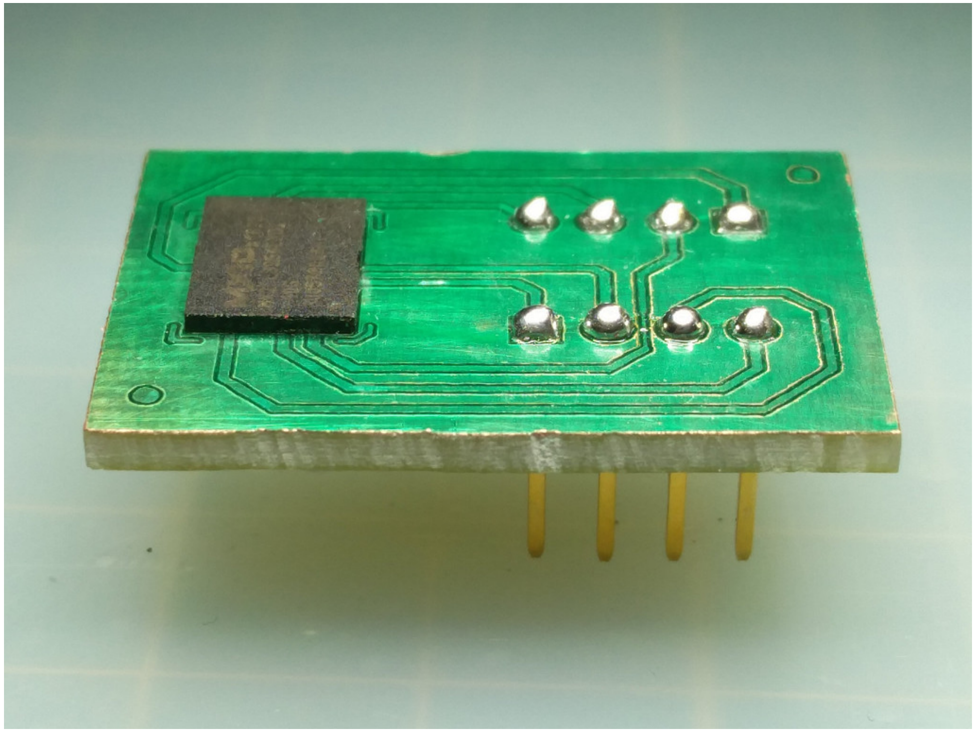


Finished breakout board

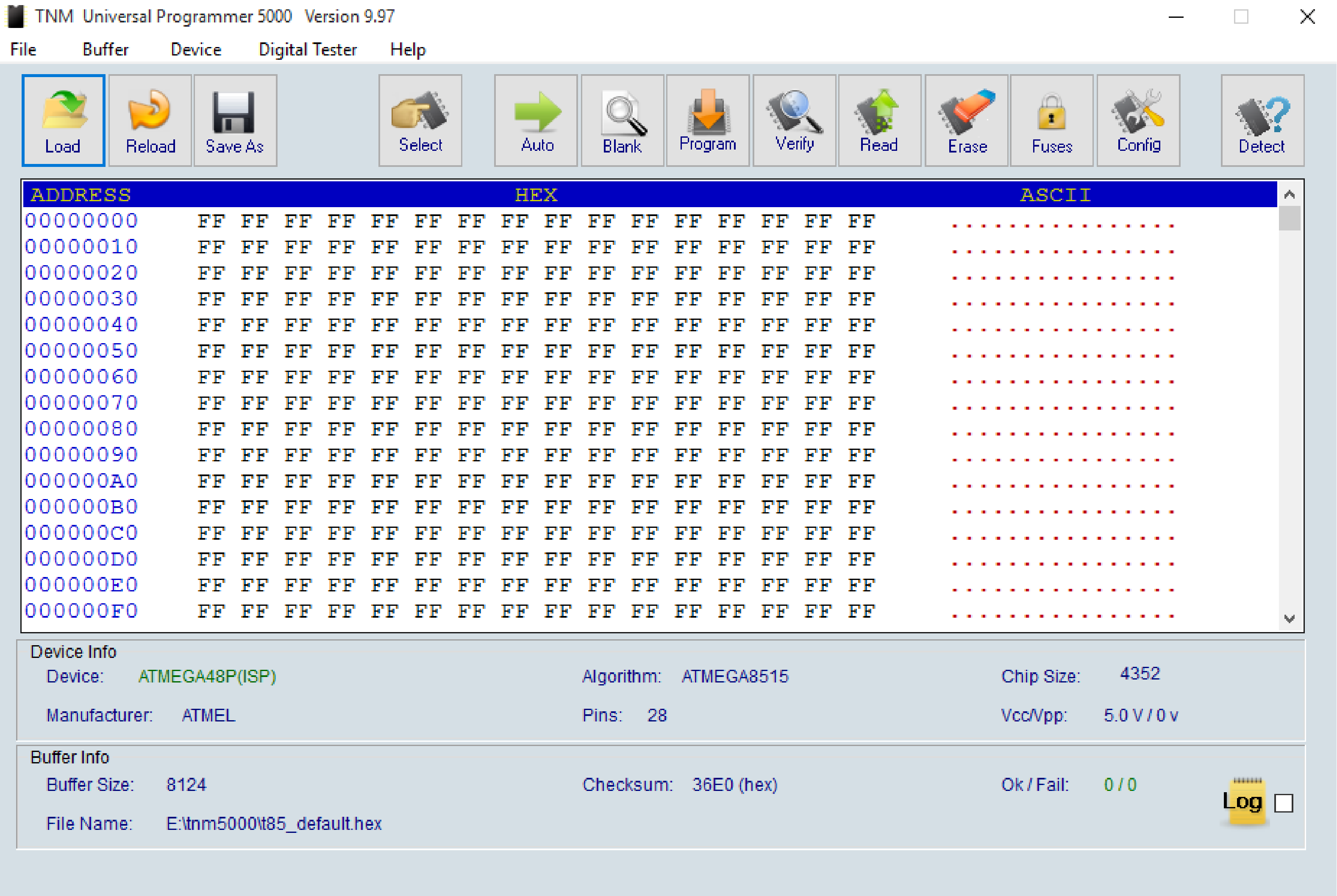




Step 5: Dump the flash



Dump the flash



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Device Info

Device: ATMEGA48P(ISP) Algorithm: ATMEGA8515 Chip Size: 4352

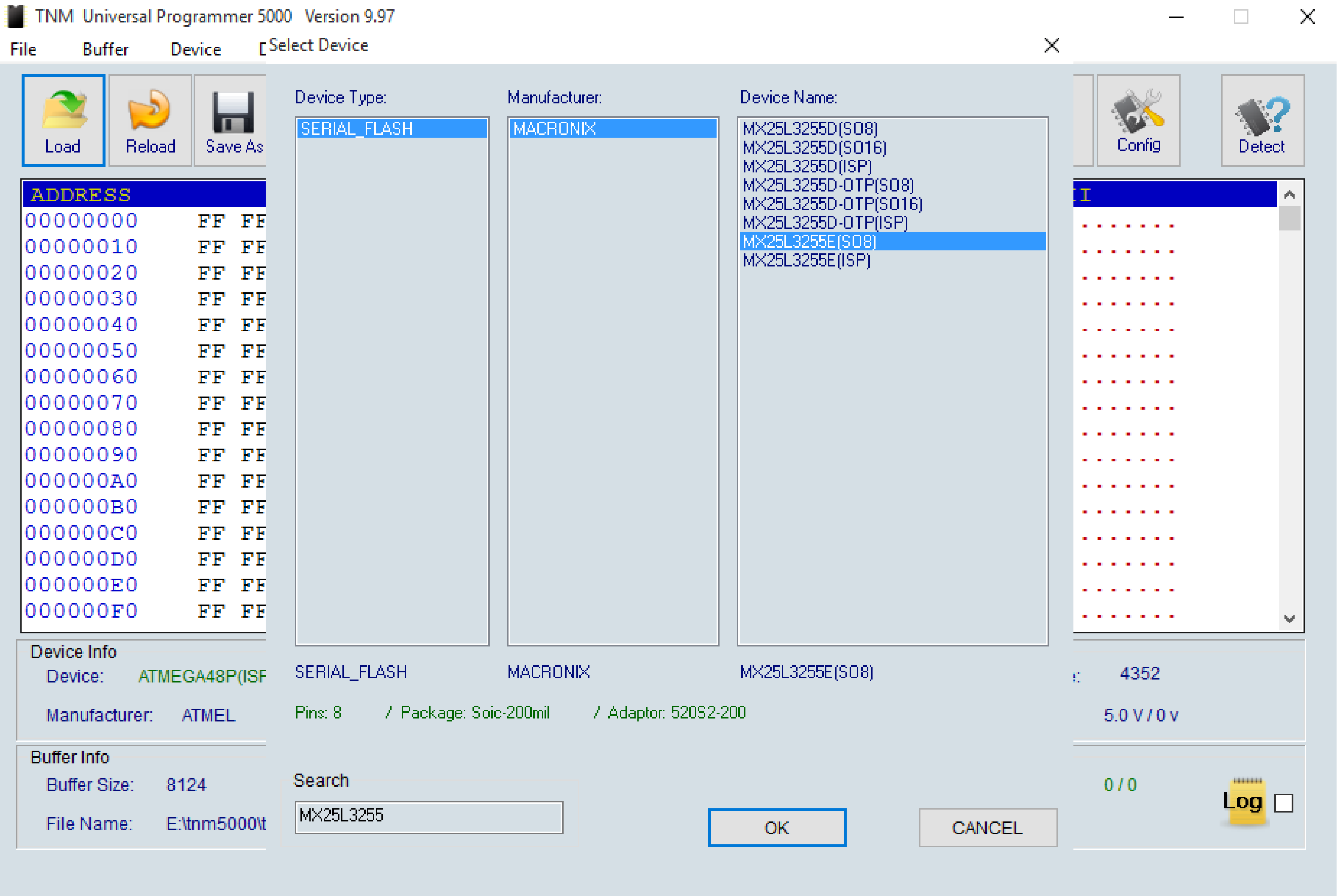
Manufacturer: ATMEL Pins: 28 Vcc/Vpp: 5.0 V / 0 v

Buffer Info

Buffer Size: 8124 Checksum: 36E0 (hex) Ok / Fail: 0 / 0 □

File Name: E:\tnm5000\t85_default.hex

Dump the flash



TNM Universal Programmer 5000 Version 9.97

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000000C0    FF  FF
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000000E0    FF  FF
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```

Device Type: SERIAL_FLASH

Manufacturer: MACRONIX

Device Name:
MX25L3255D(SO8)
MX25L3255D(SO16)
MX25L3255D(ISP)
MX25L3255D-OTP(SO8)
MX25L3255D-OTP(SO16)
MX25L3255D-OTP(ISP)
MX25L3255E(SO8)
MX25L3255E(ISP)

SERIAL_FLASH   MACRONIX   MX25L3255E(SO8)

Pins: 8 / Package: Soic-200mil / Adaptor: 520S2-200

Search: MX25L3255

Device Info
Device: ATMEGA48P(ISF
Manufacturer: ATMEL

4352
5.0 V / 0 v

Buffer Info
Buffer Size: 8124
File Name: E:\tnm5000\t

0 / 0

Conclusion: funky stats

- **PCB by CNC milling:**
  - ~12 drilling bits died
  - 4 PCBs made before calibration of the CNC was correct
  - 2 PCBs to test the soldermask
- **PCB by etching:**
  - 5 PCBs made before the ink transfer was correct
  - 3 PCBS for etching (worked on the first try)

Conclusion: Bill of materials

- **Bootstrap: ~1000€**
  - Hot air soldering station: ~100€
  - Flash programmer (TNM5000): ~300€
  - CNC machine: ~300€
  - Microscope: ~500€

- **Consumables: ~50€**
  - Soldering balls, soldering flux, desoldering braid ~10€
  - Chemicals (isopropanol, Ferric Chloride, ...) ~30€
  - Epoxy Fiber FR4 Copper Clad Plate ~10€

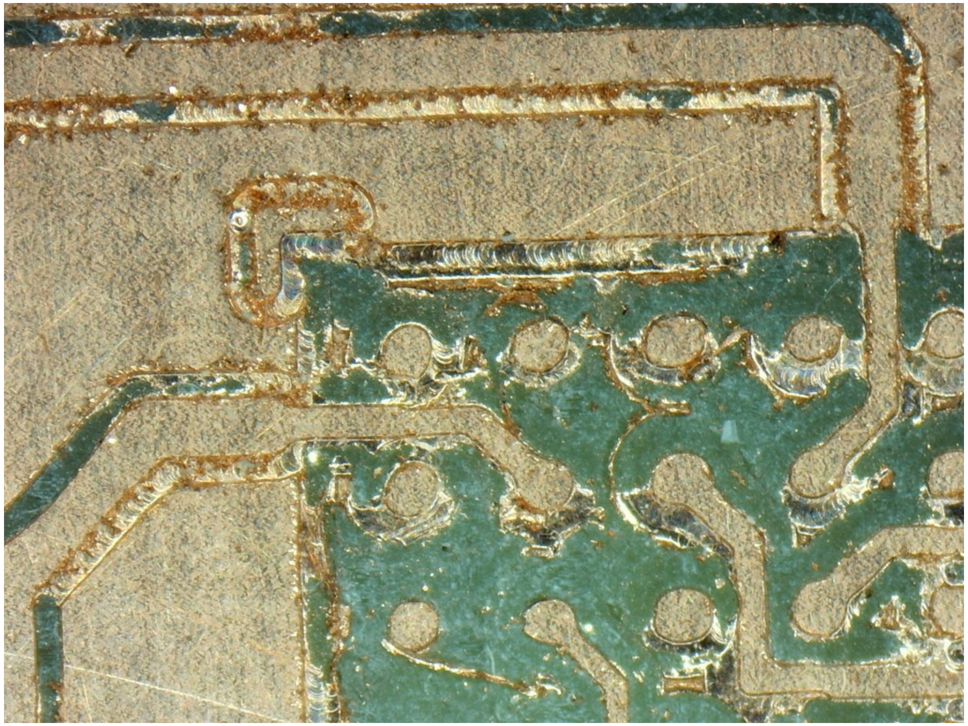
→ Crafting custom PCB is not that hard/expensive

Conclusion: and the magic box ?

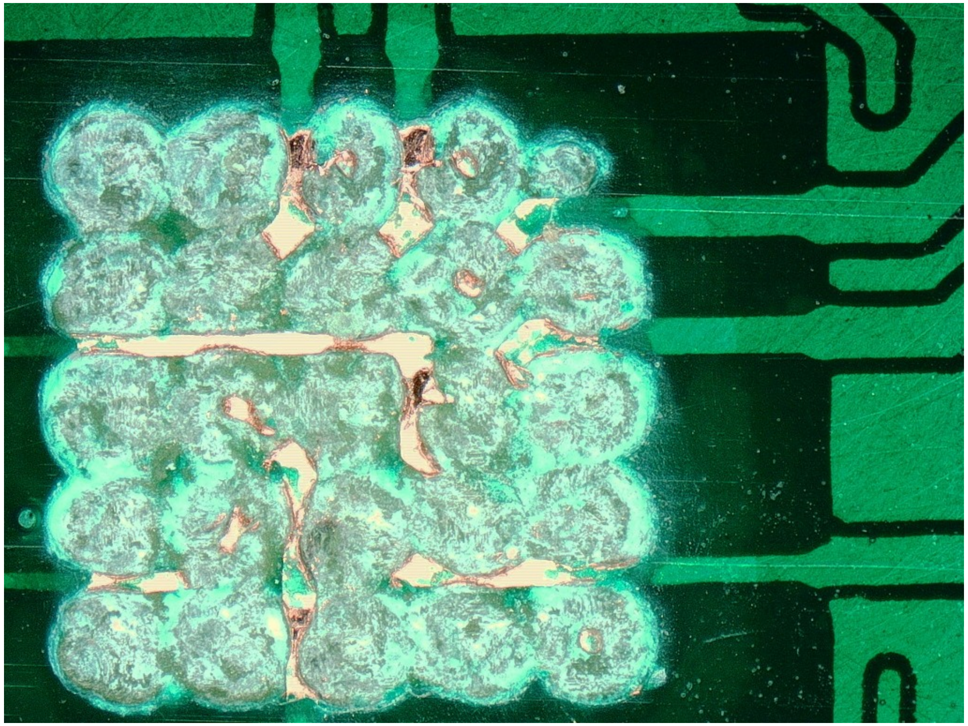
- **Attacks tested:**
  - Transplantation: success
  - Clone: success
  - Impersonating a competitor’s box: success

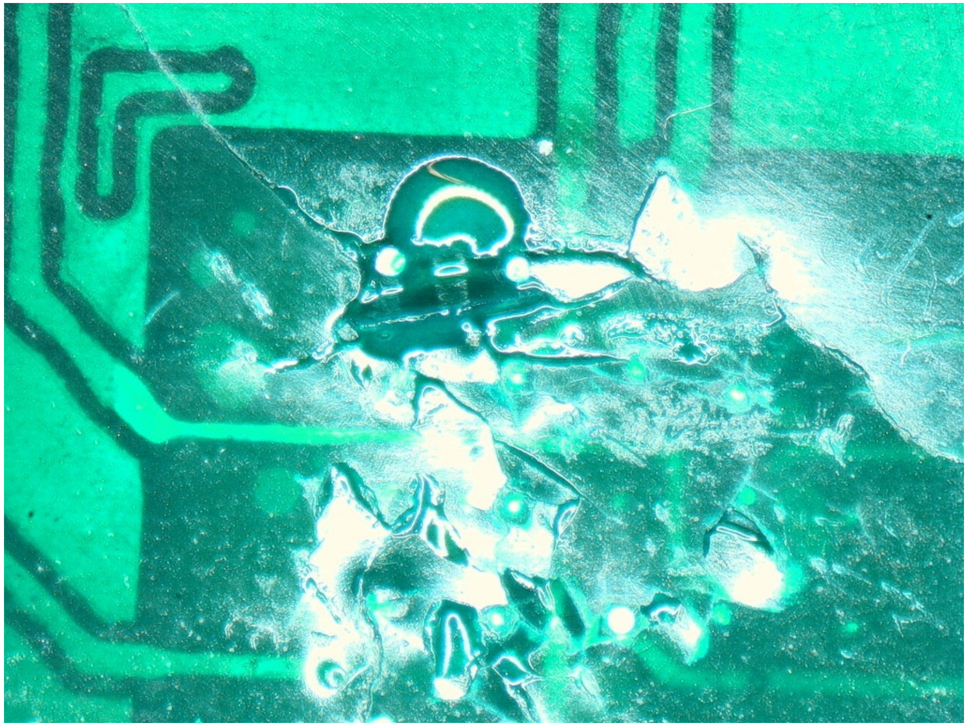
- ***The magic box is still commercially available… :)***

Bonus: the horror show



Bonus: the horror show (2)





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