

Reverse engineering the Commodore 128

Johan Grip, VCF West 2022

**Or: How to find all the rabbit
holes and jump into them**

Who am I?

- Computer and electronics nerd
- Self taught
- Working in enterprise IT since forever

<https://c128.se>

<https://github.com/jgrip/>

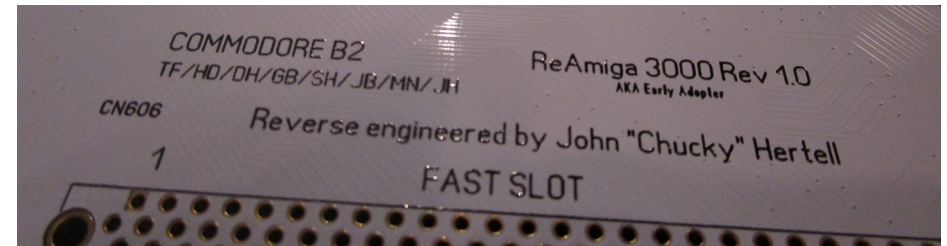
Background

- I still have my first computer
- It was broken when I unpacked it
- The repair snowballed a bit...

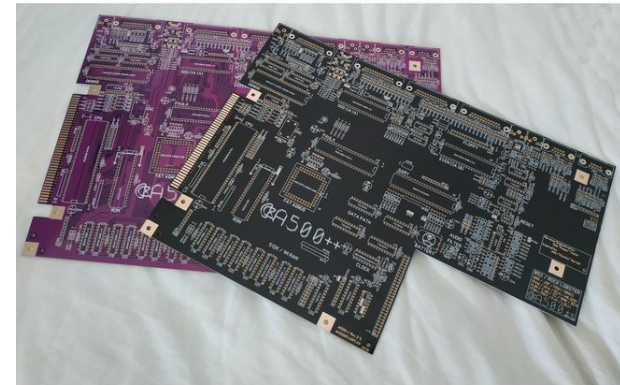


Inspirations

- John „Chucky“ Hertell



- Rob Taylor

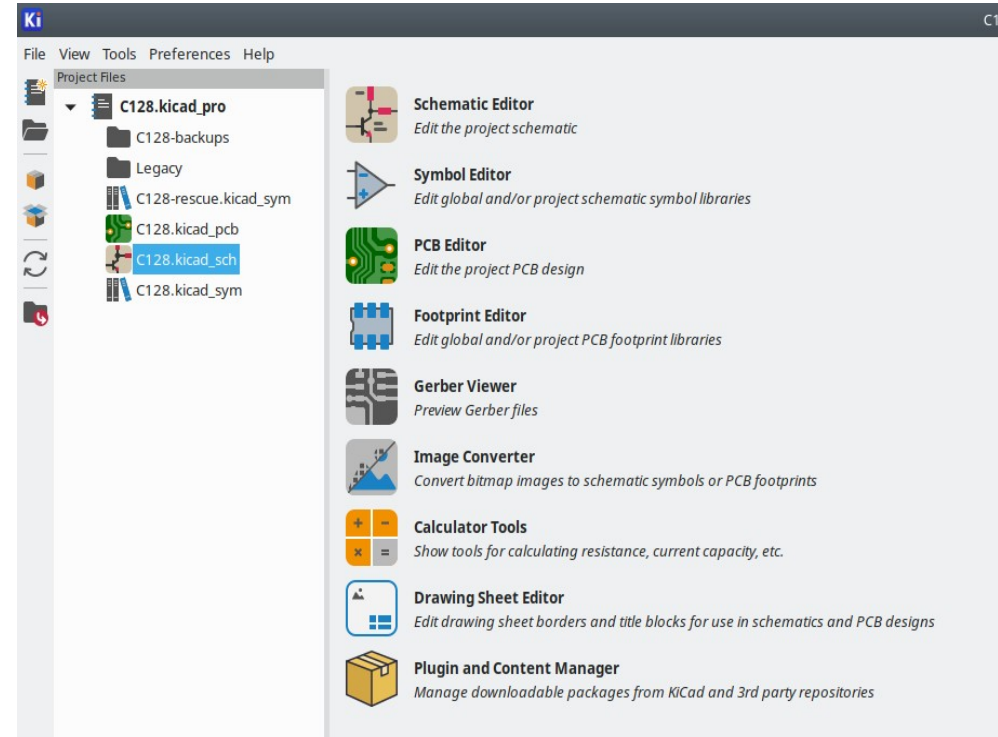


Goals

- Platform preservation
- Integrate factory fixes
- Small quality of life improvements

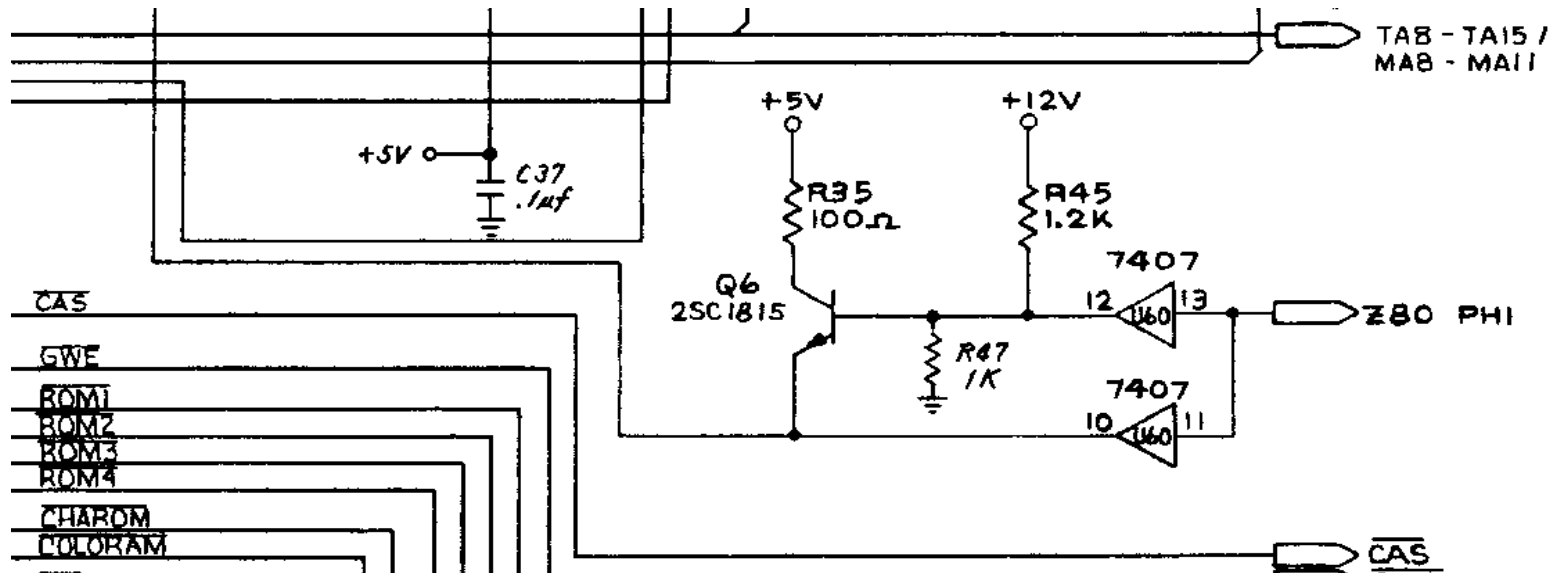
Software

- Sprint Layout
- Open source preferred
- KiCad is getting real good



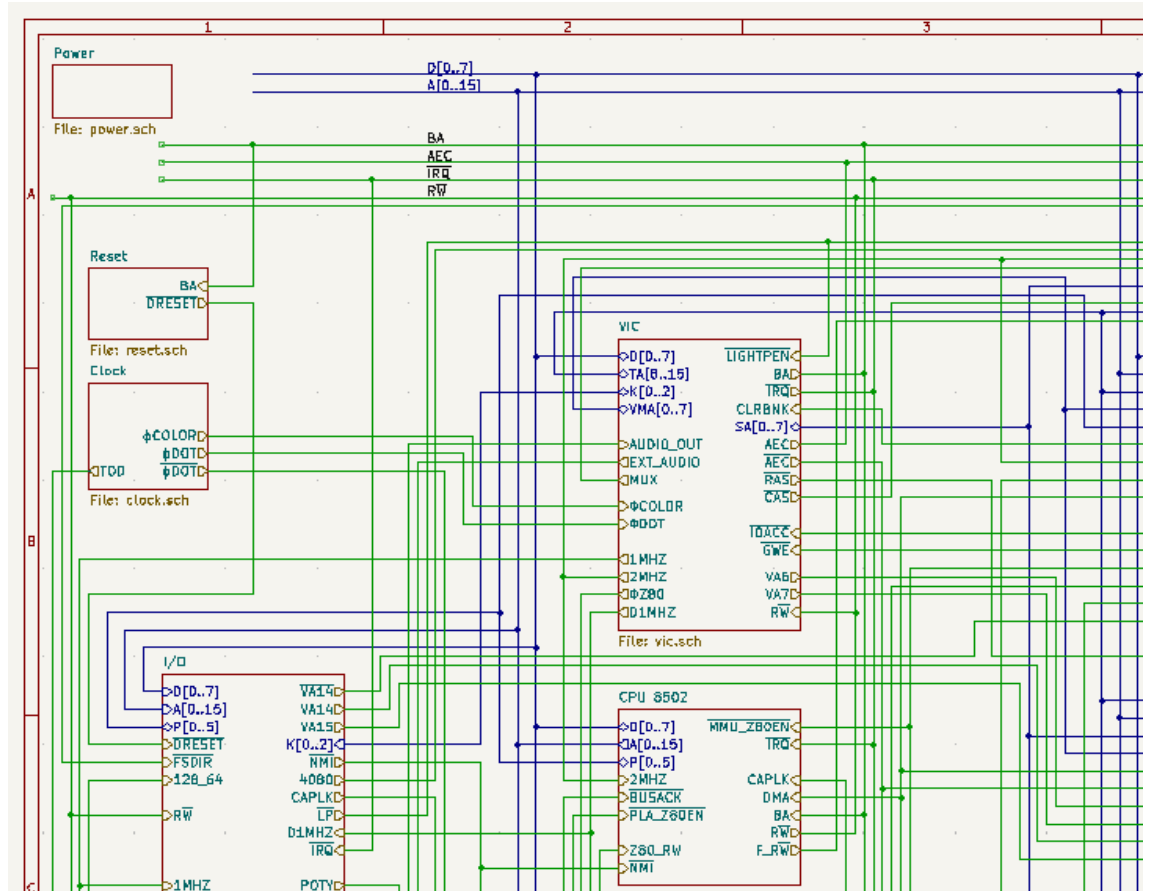
Schematic capture

- C= schematic very accurate
- Did not attempt to preserve layout in KiCad



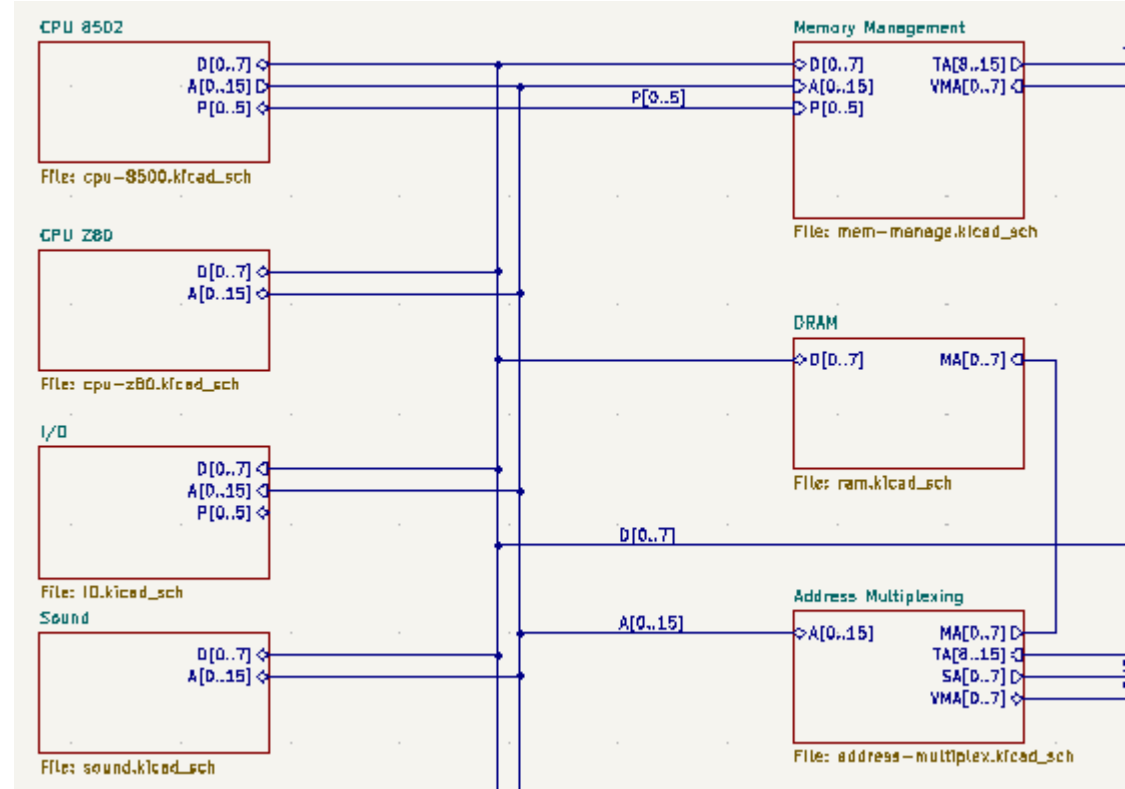
Schematic capture

- First attempt



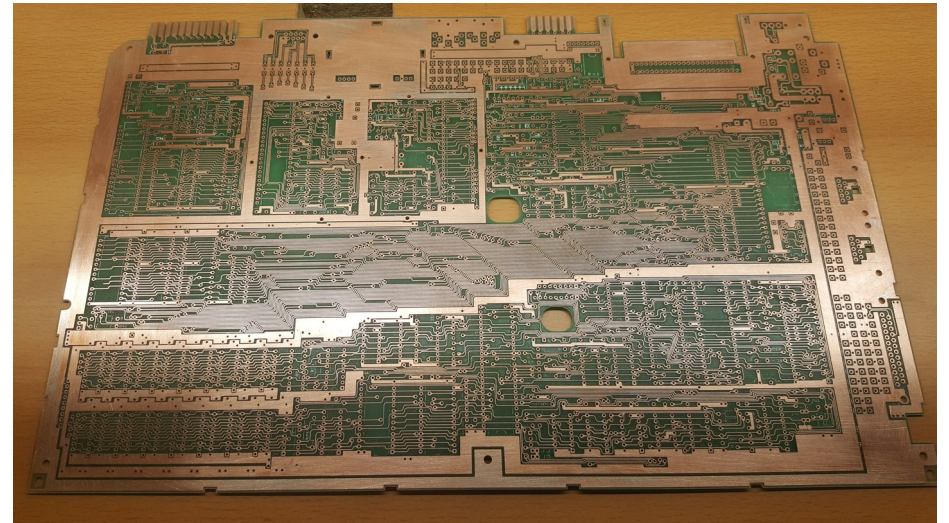
Schematic capture

- Better now



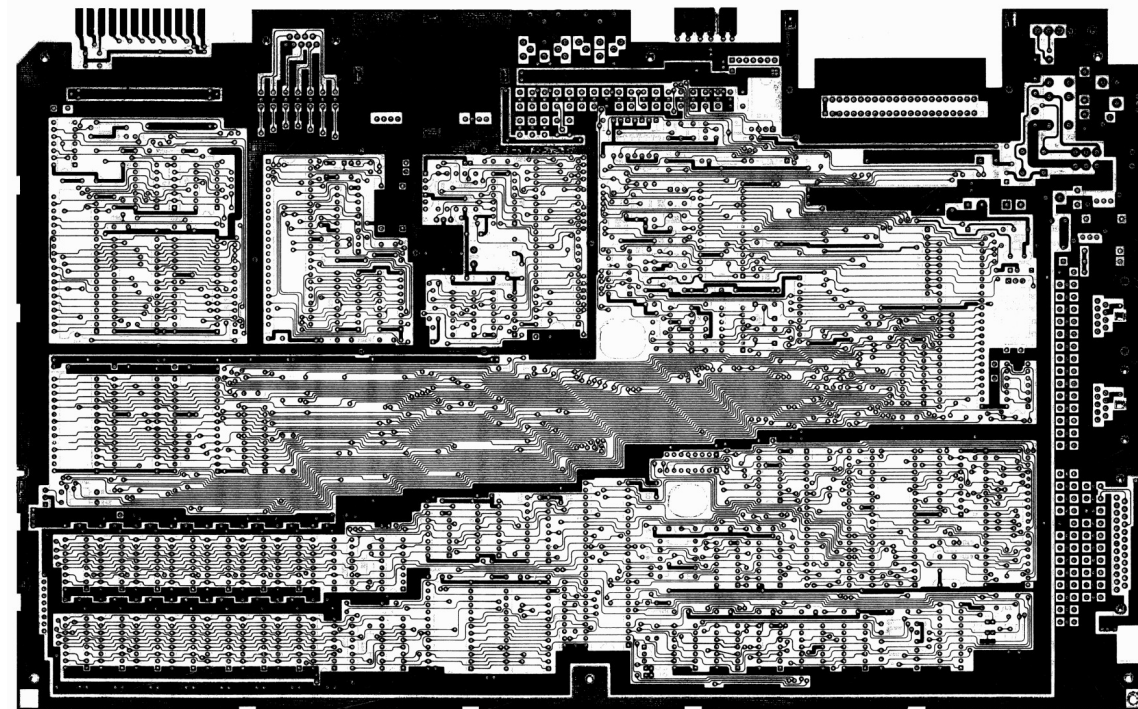
Prepare PCB

- Desolder all the things
- Sanded down solder mask
- Flatbed scanner



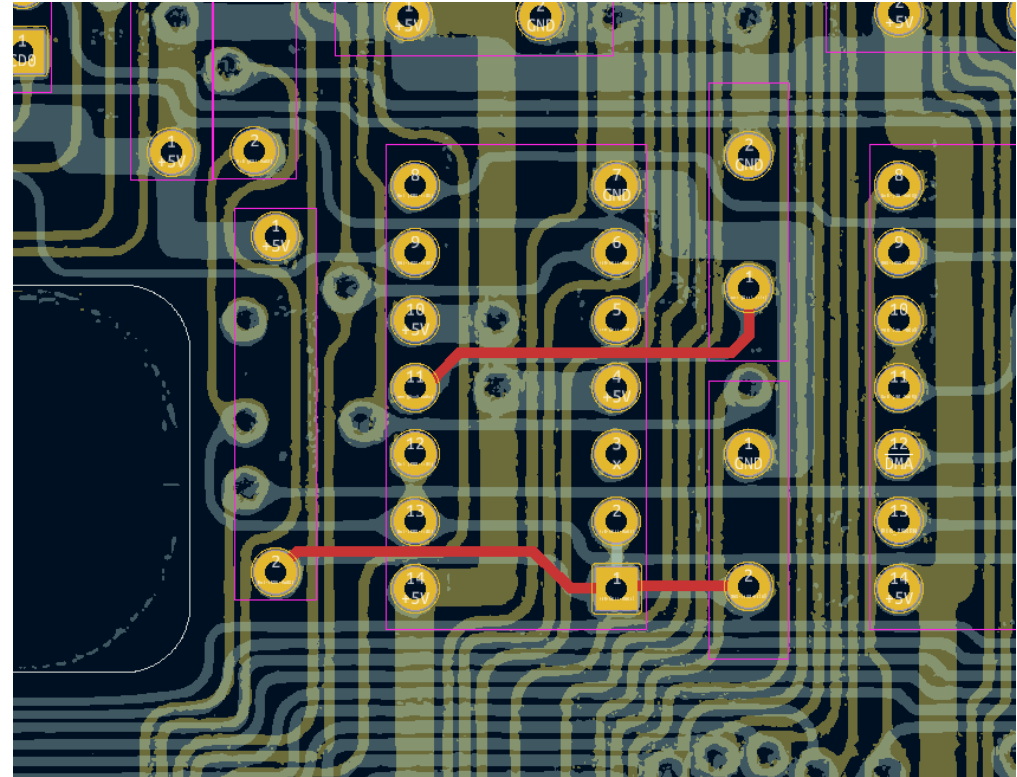
Prepare for KiCad

- Turn monochrome
- Align rotation
- Convert to component
- Add to PCB and align

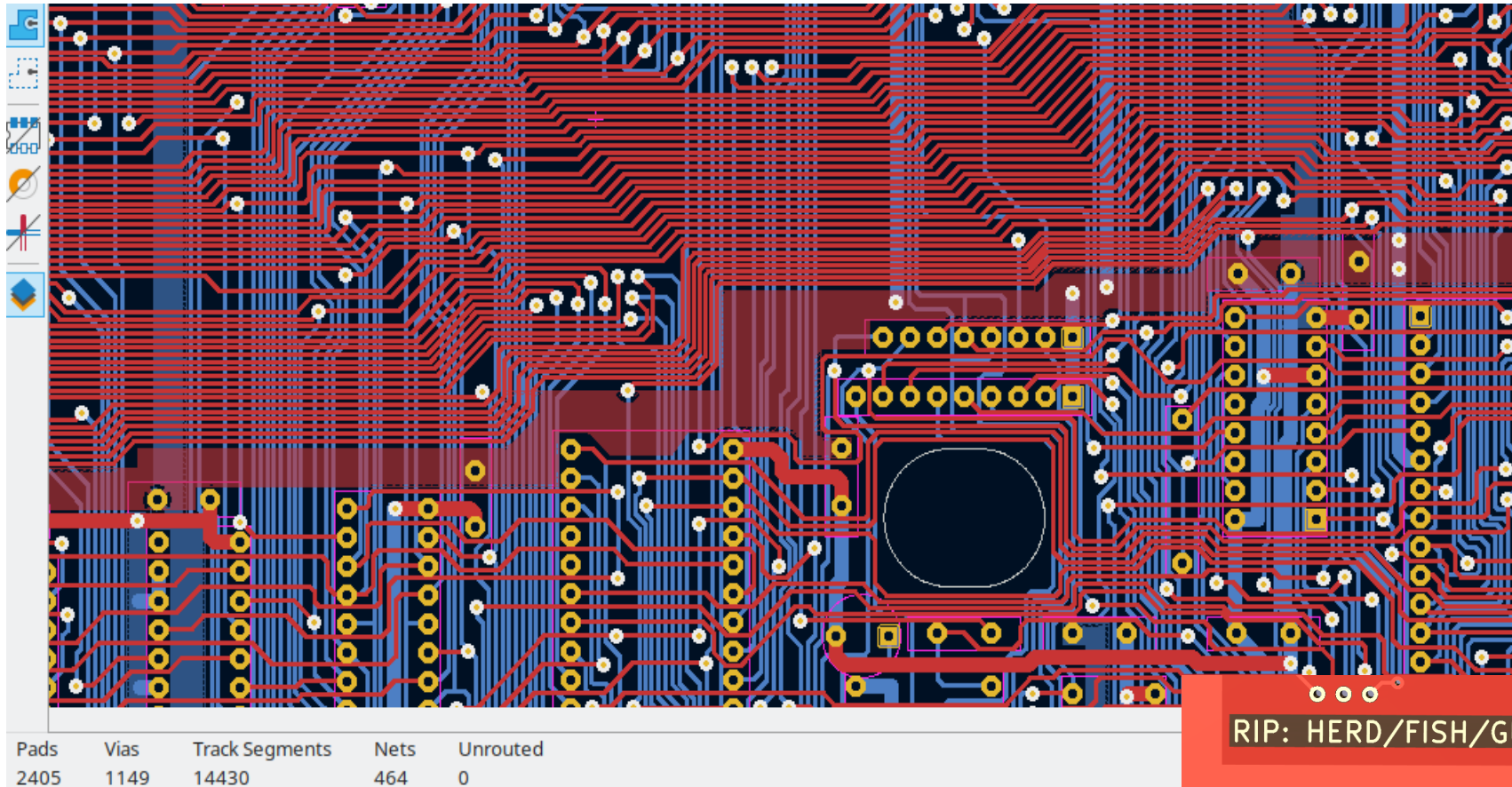


KiCad PCB

- Import scan as component
- Place components
- Draw traces
- Bring patience

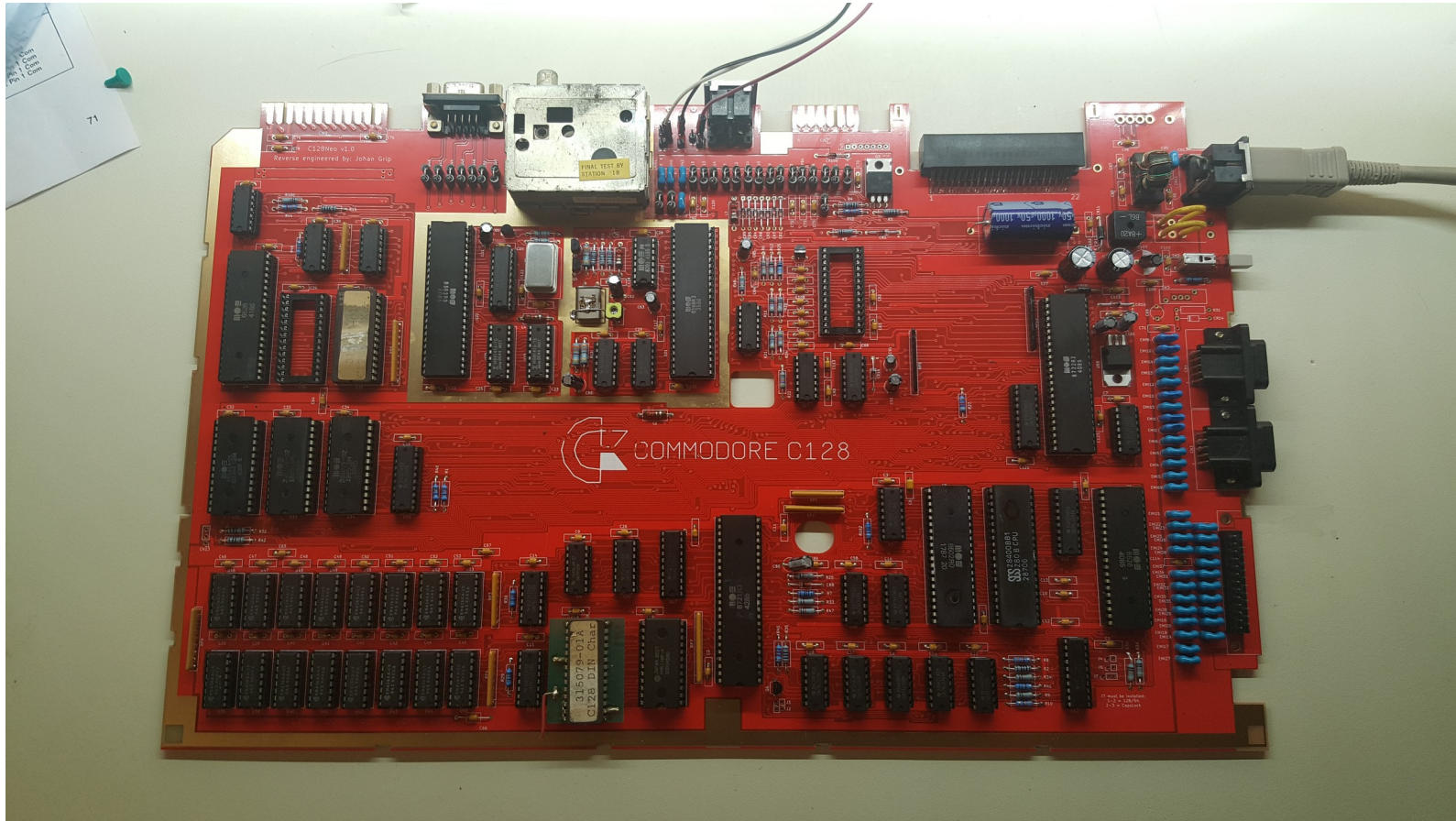


Lots of patience...

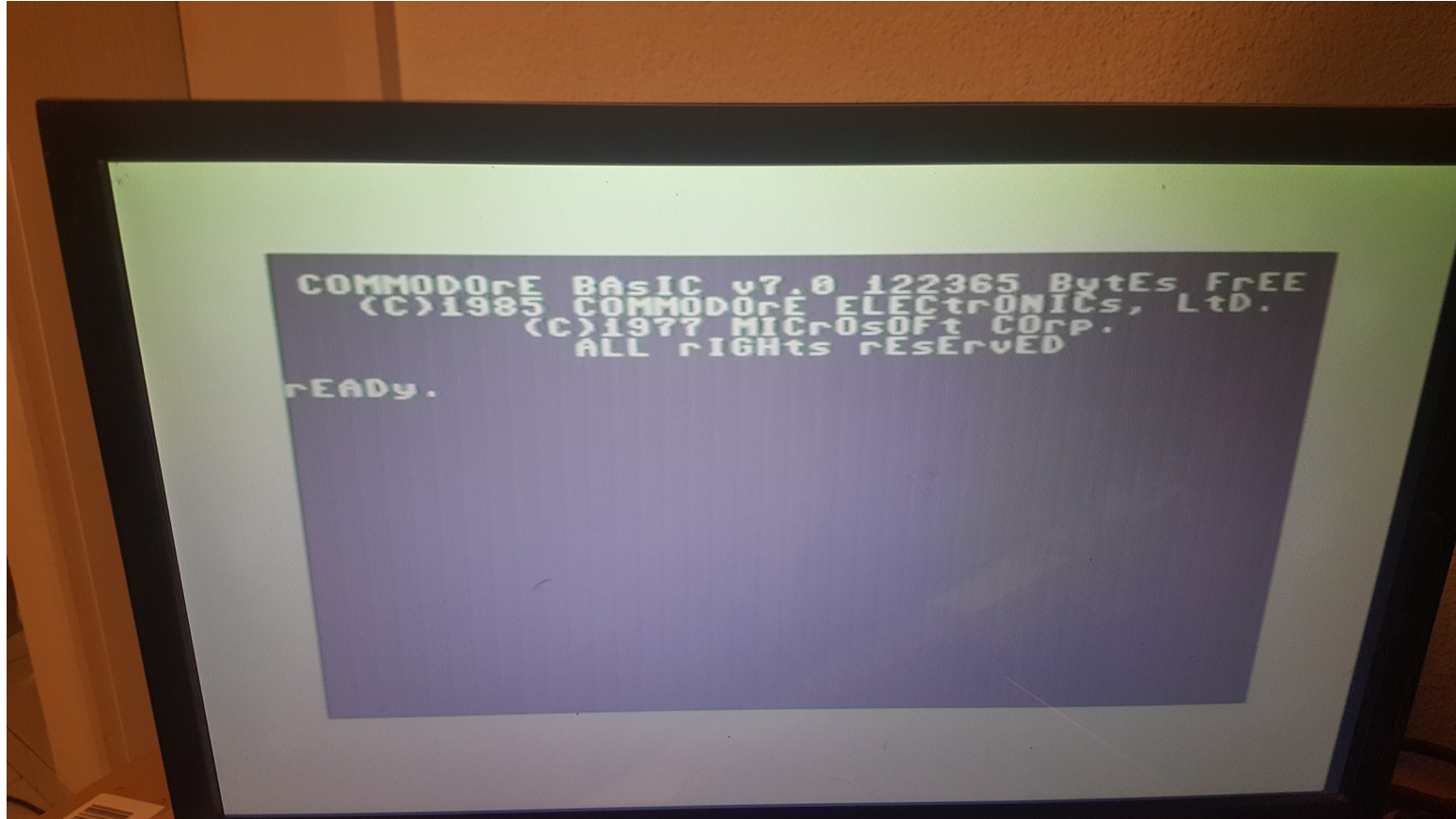


RIP: HERD/FISH/GUAY/PAR

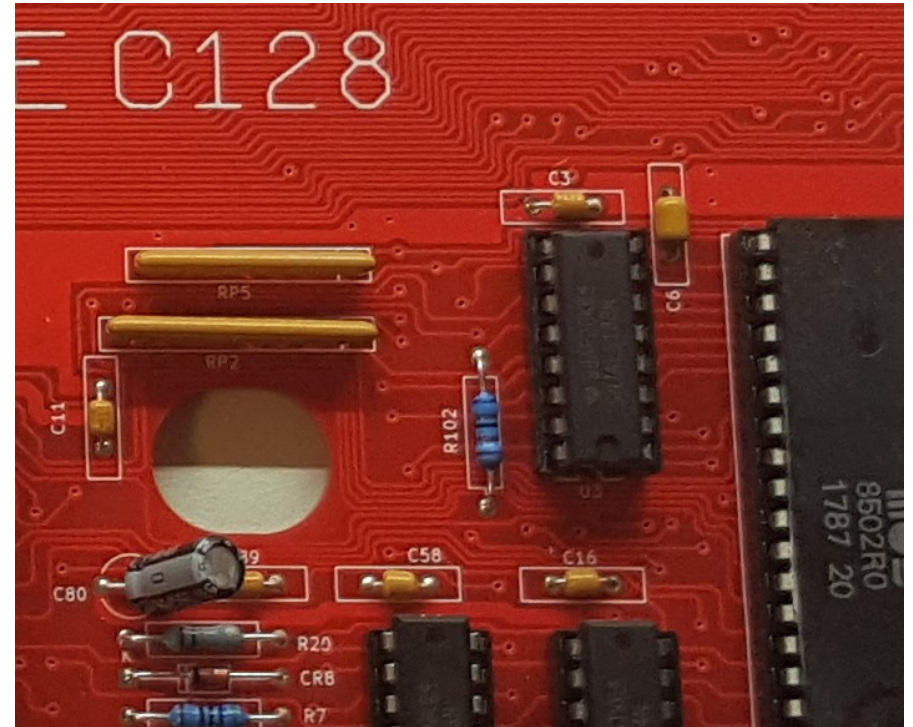
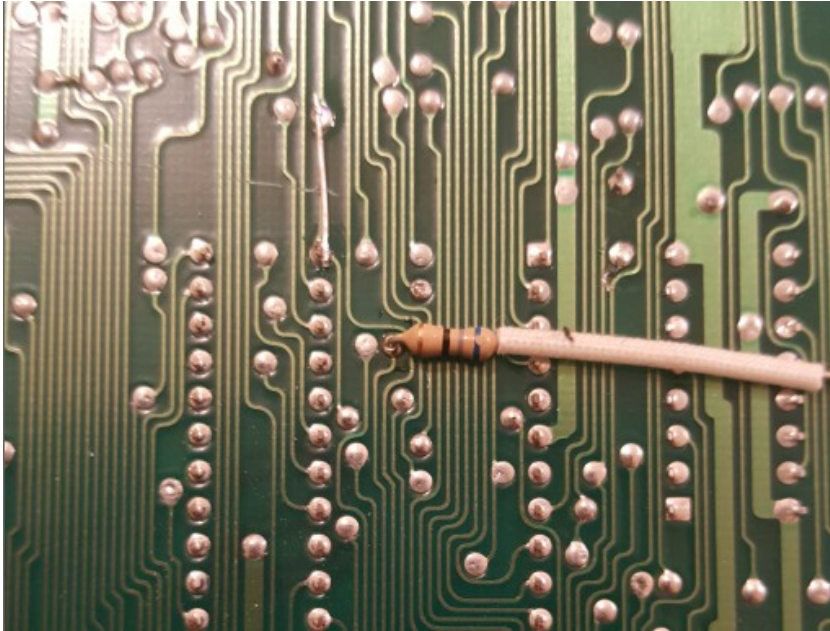
First prototype board



Worked on first try...



Fix: R102

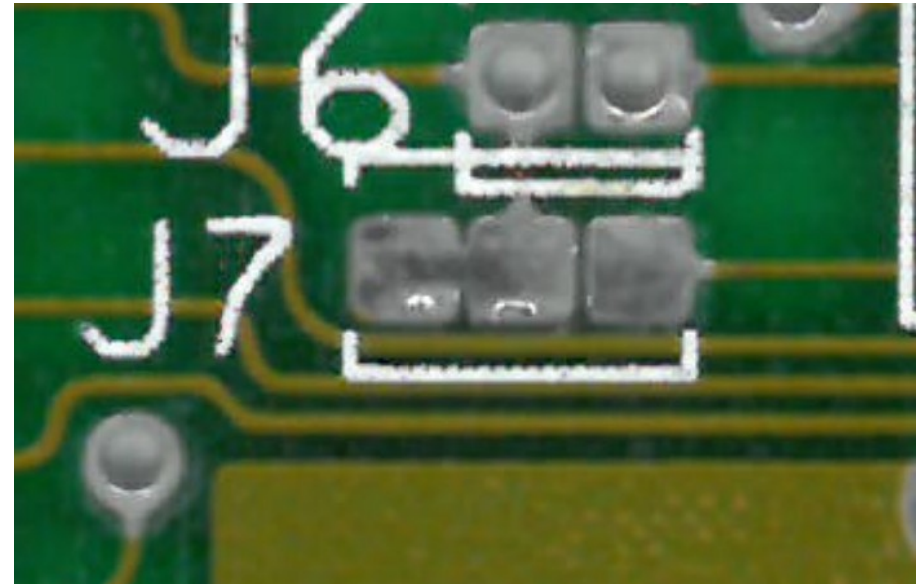
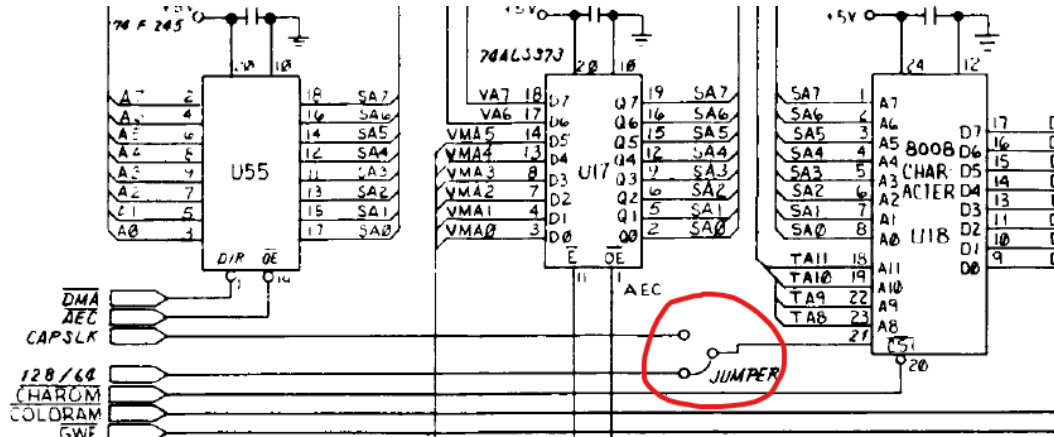


Fix: J6

- Used to select size of Kernal ROM
- Should be A15
- Was connected to A14

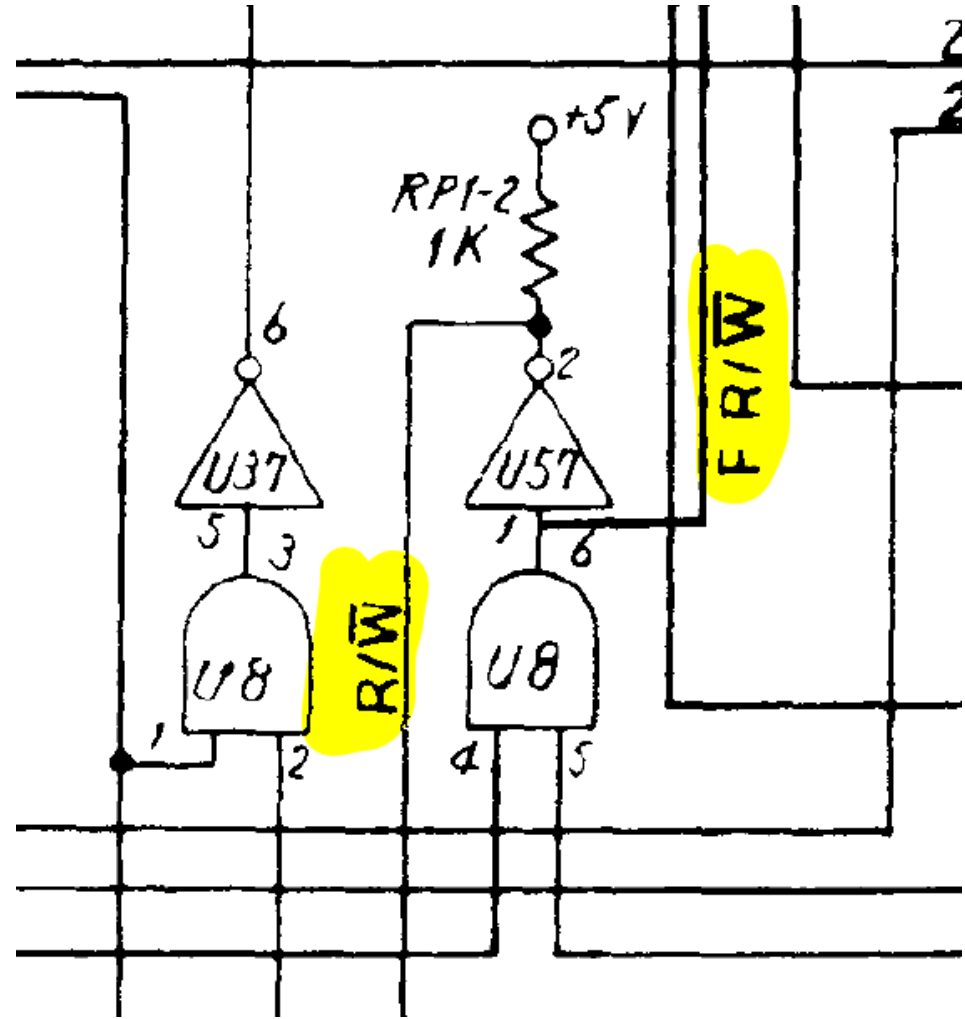
Fix: J7

- Use to select source of font selection
- Not functional
- Bodge wire on international



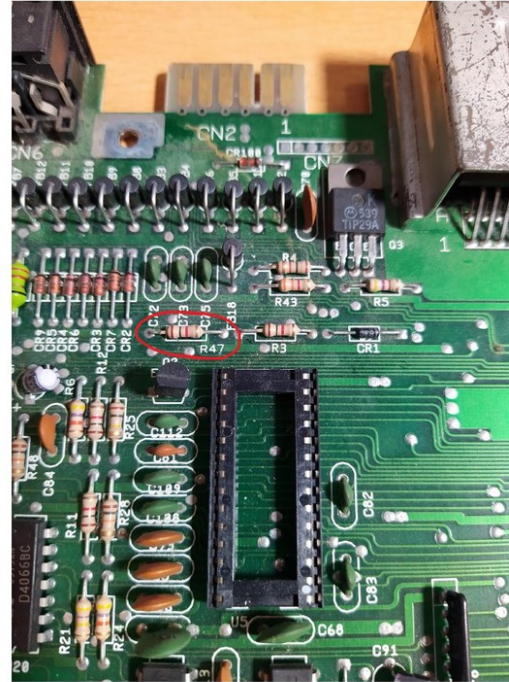
VDC R/W

- Buffer gate on R/W
- VDC first
- Introduced on rev.7

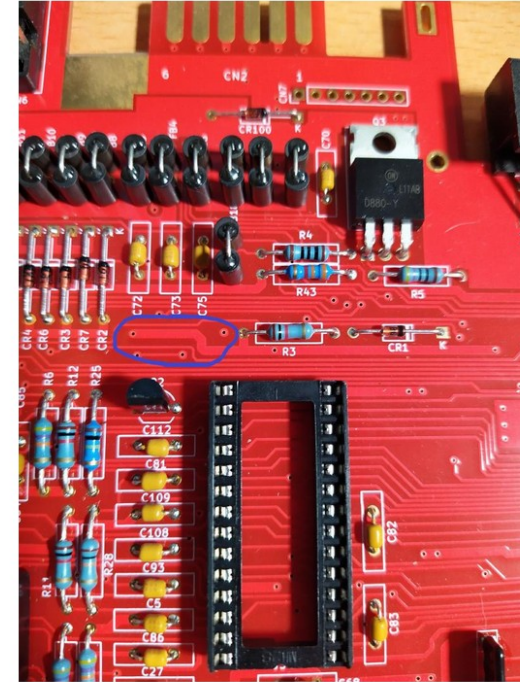


One bug

- Missing pullup
- Dotclock on expansion



R47 Commodore



R47 Neo

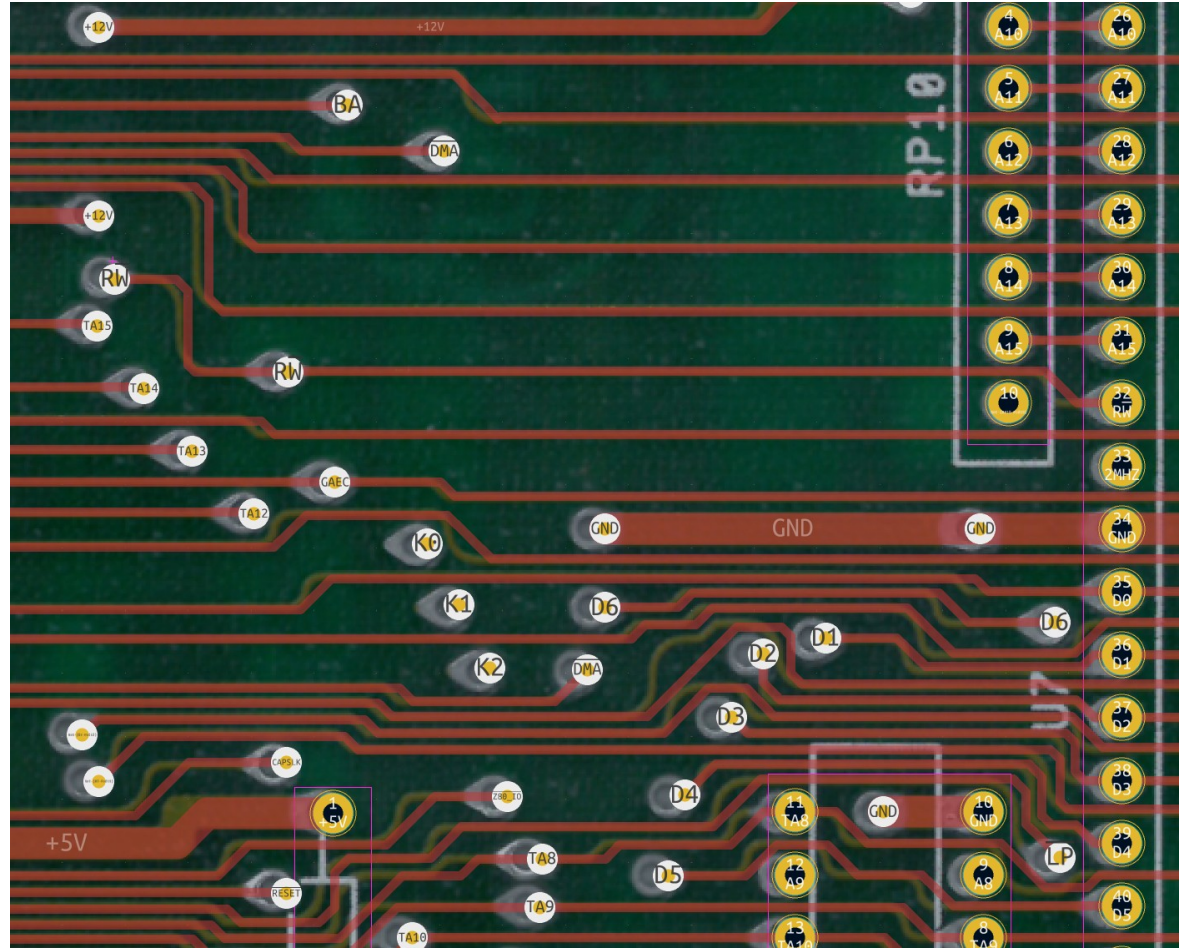
Rev.4 soon

- Lots of quality of life
- Pin headers
- RF modulator
- Minimal jailbars



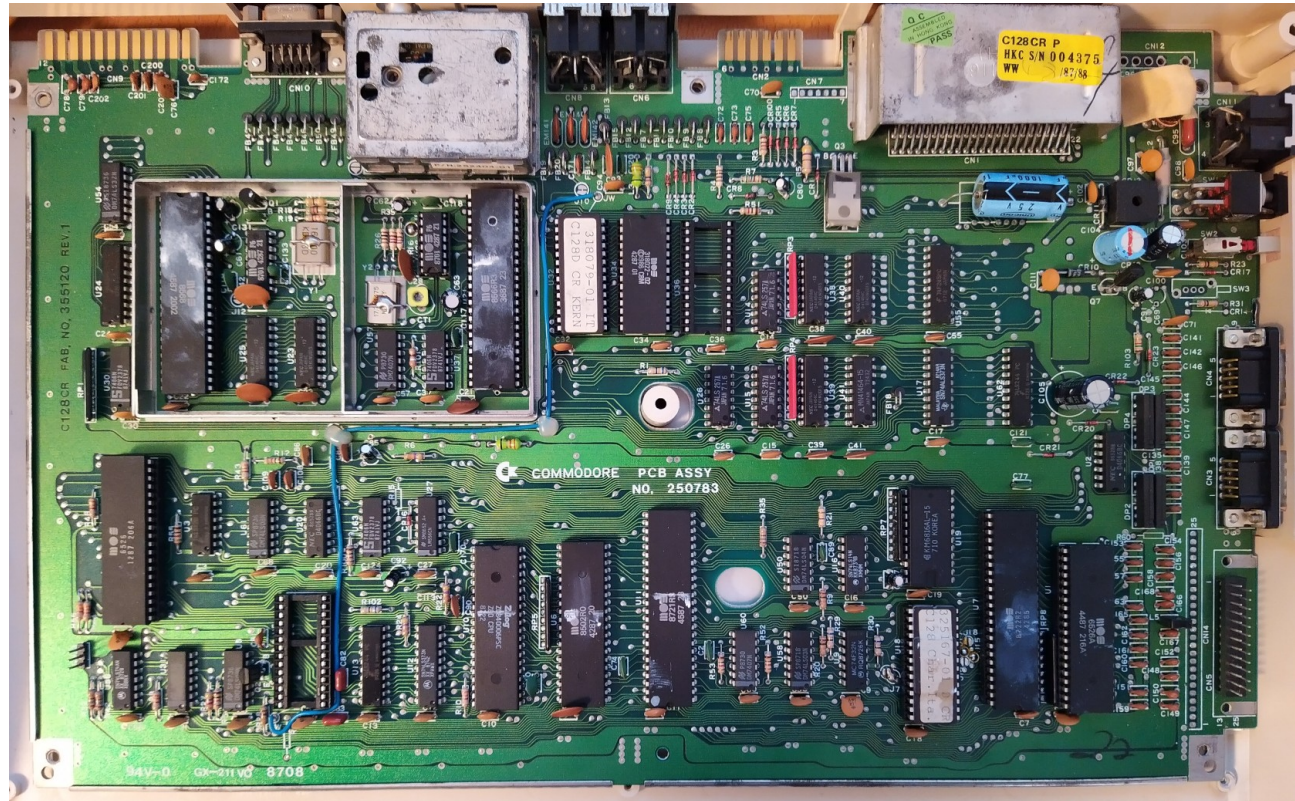
KiCad 7

- Early next year
- Bitmap backgrounds
- In nightlies now



Other PCB work

- C128CR board
- On github



Interesting curiosities

- C128D CES prototype



- Drean 128



Keyboard

- Mechanical kbd PCB
- Alps/MX hybrid
- Key latches
- On github

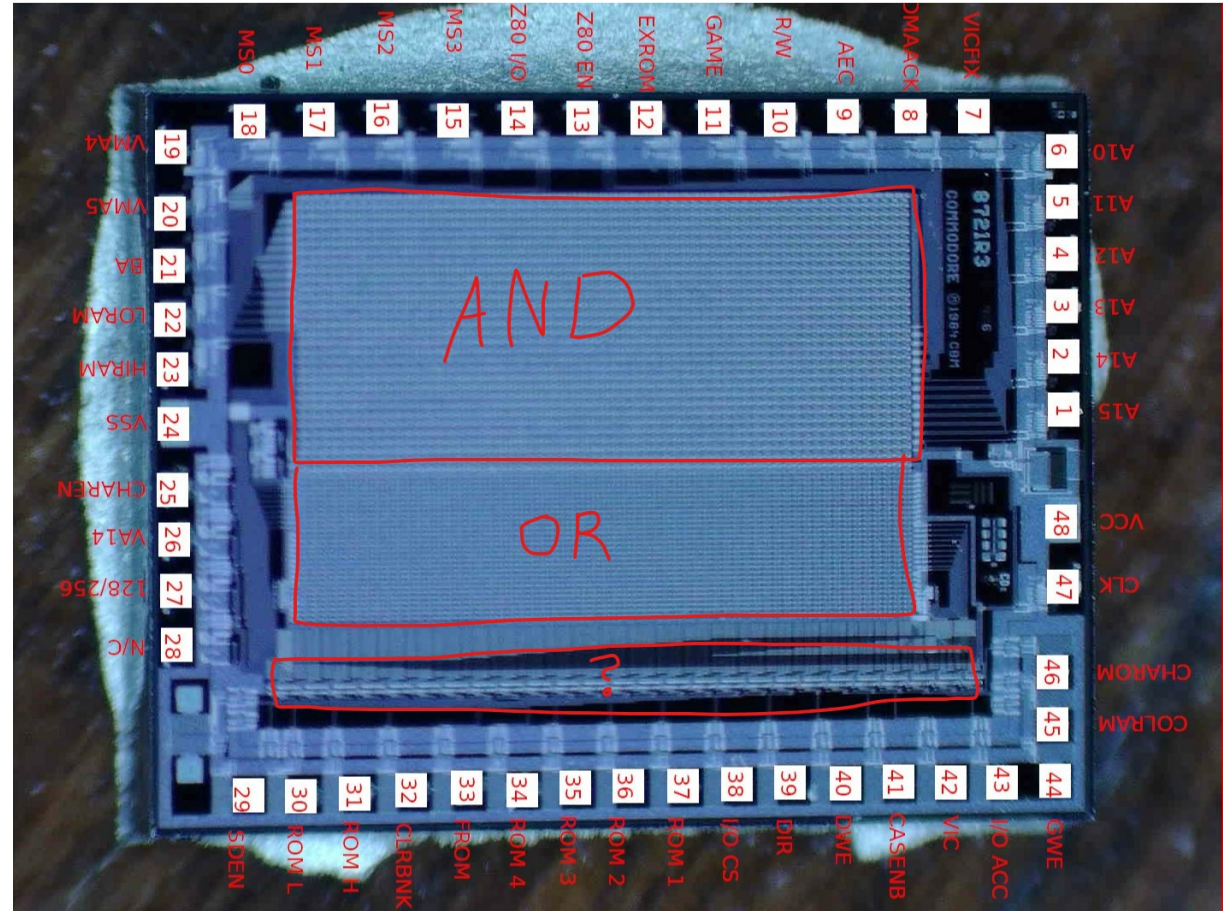
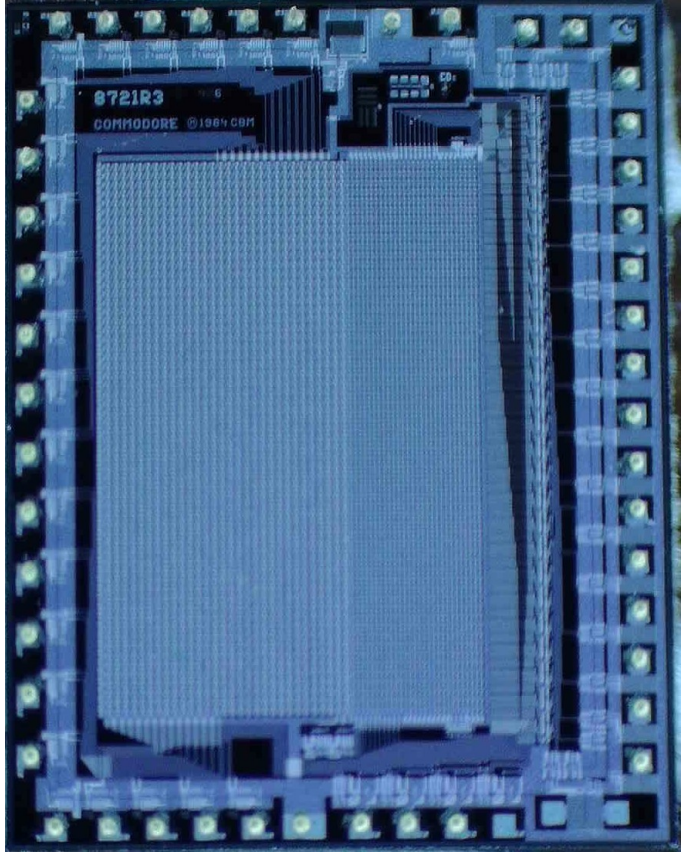


So, I bought a microscope

- AmScope SM-4T for working on surface mount
- Got curious about ICs
- Nasty Chemicals
- Chips a la Antoine

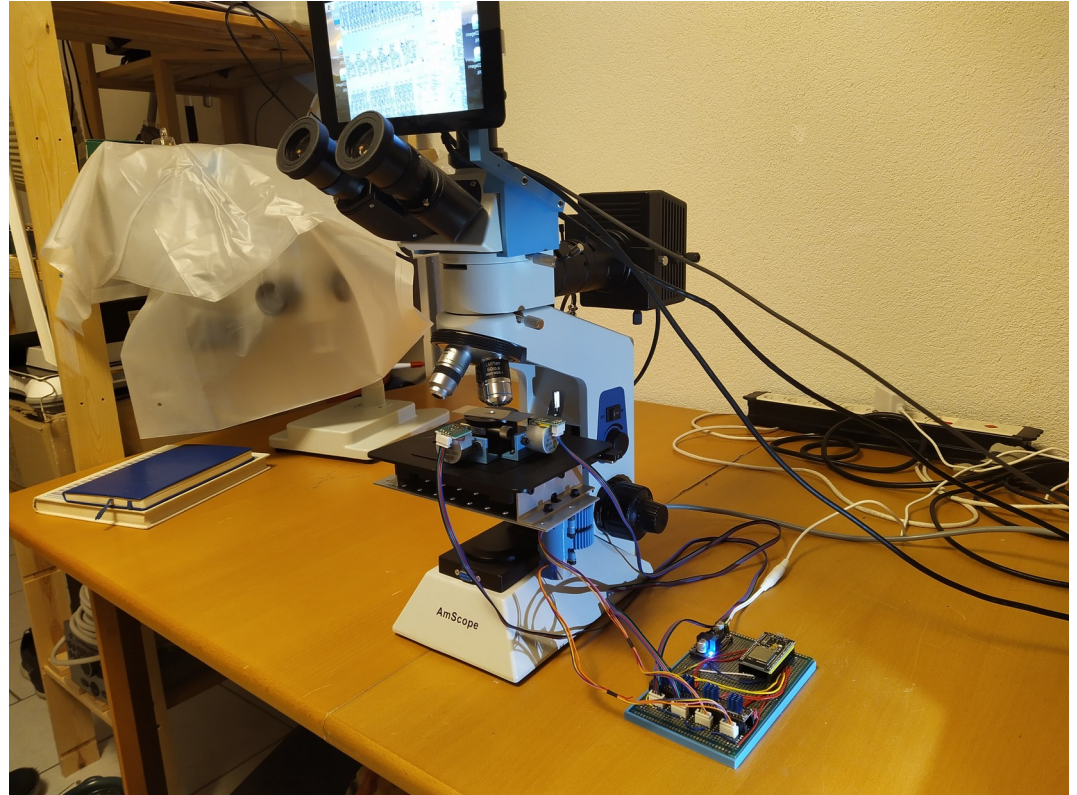


First die shot

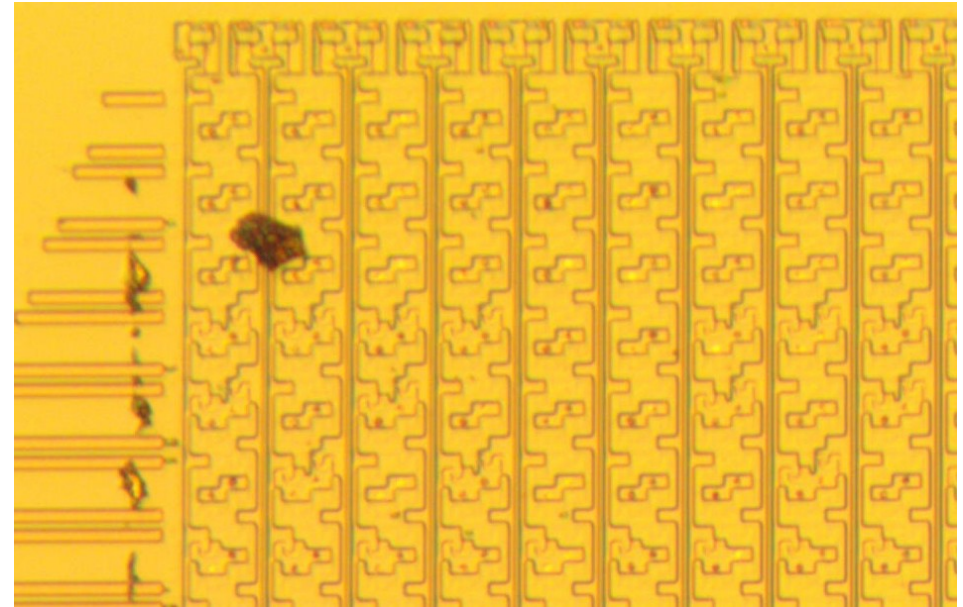
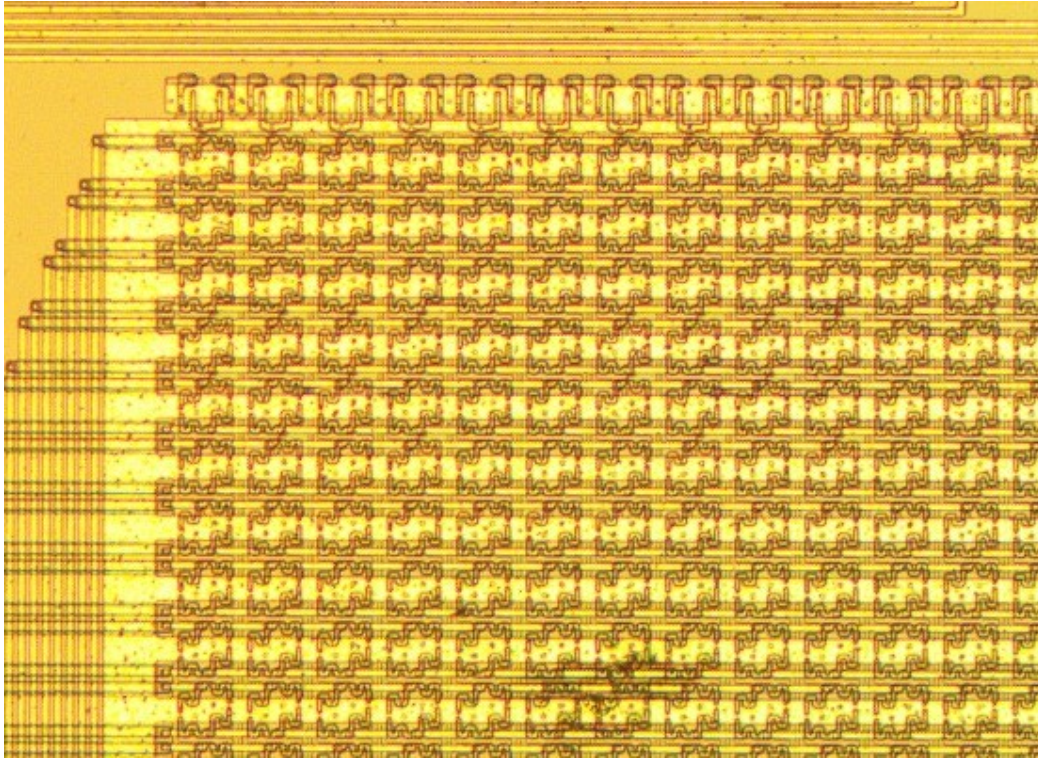


So, I bought a microscope

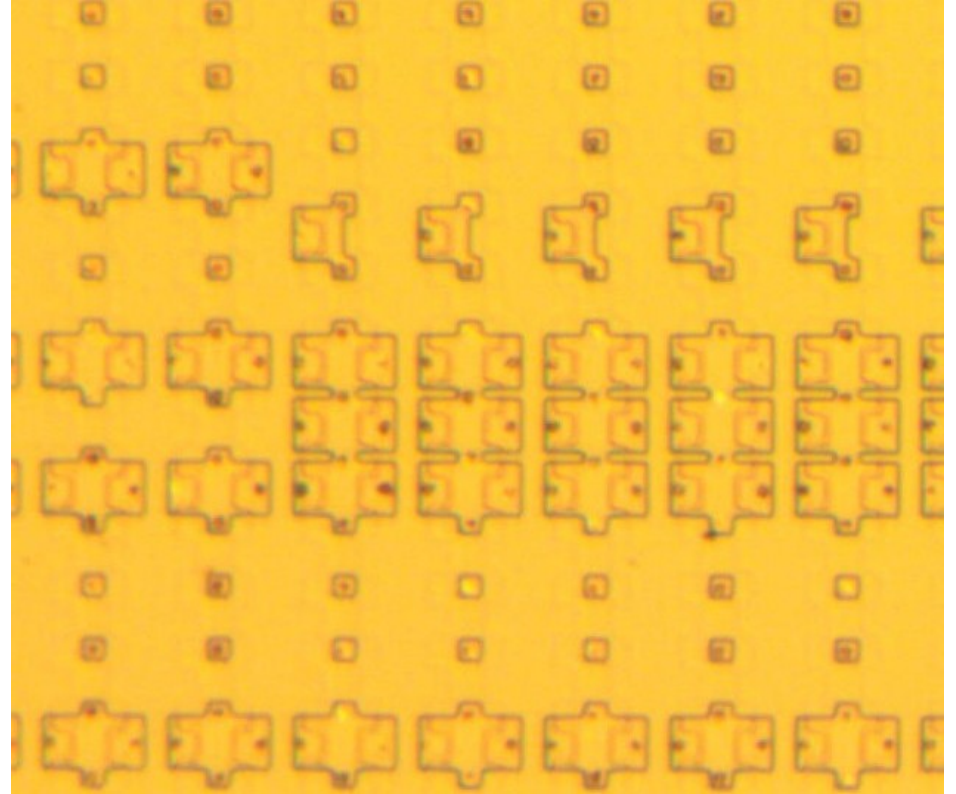
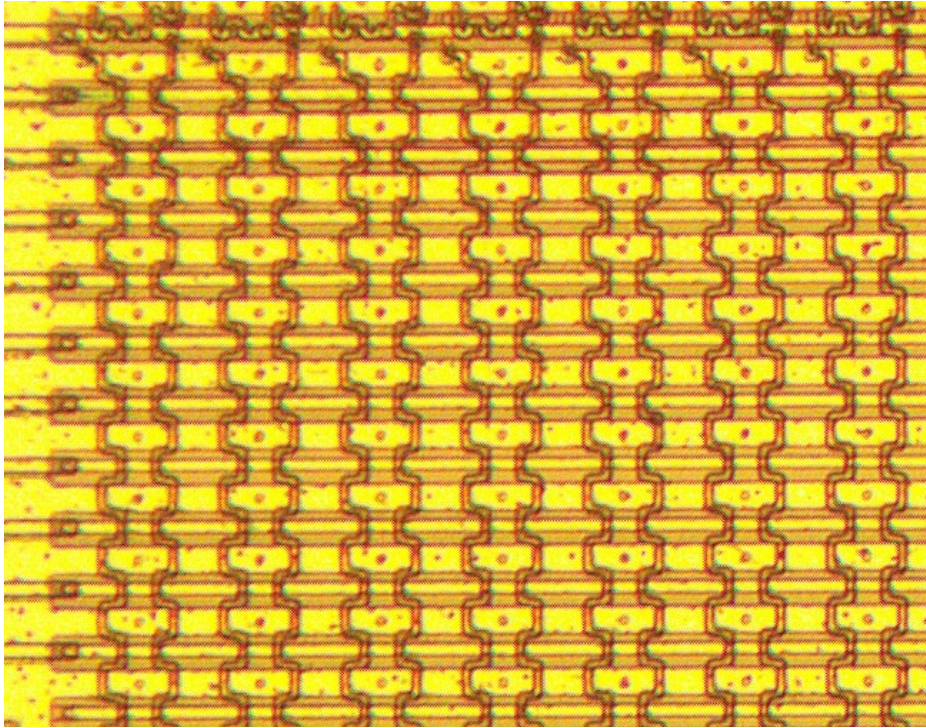
- AmScope ME580-T
- Home brew motorization
- RPi HQ Camera



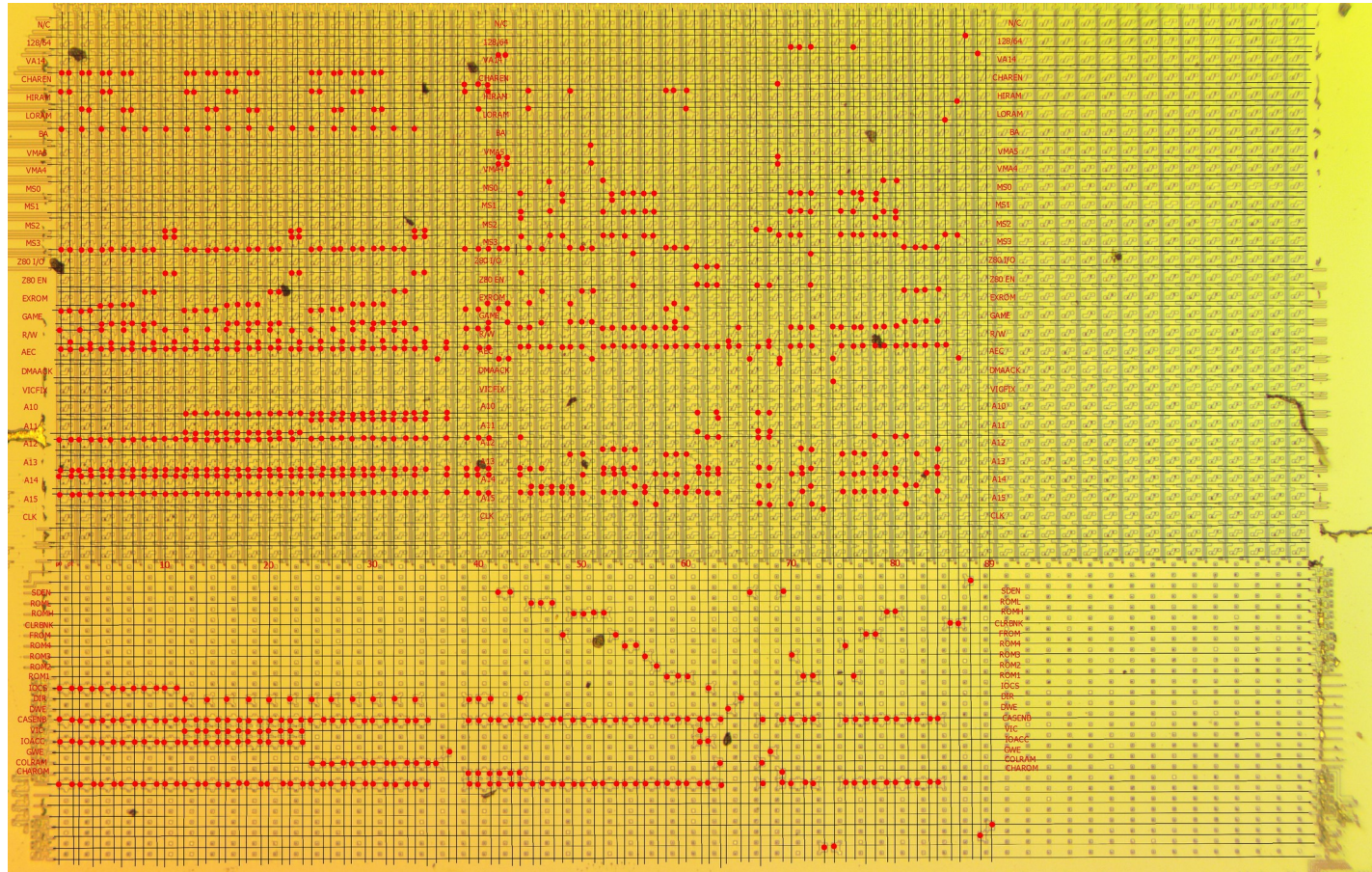
AND matrix



OR matrix

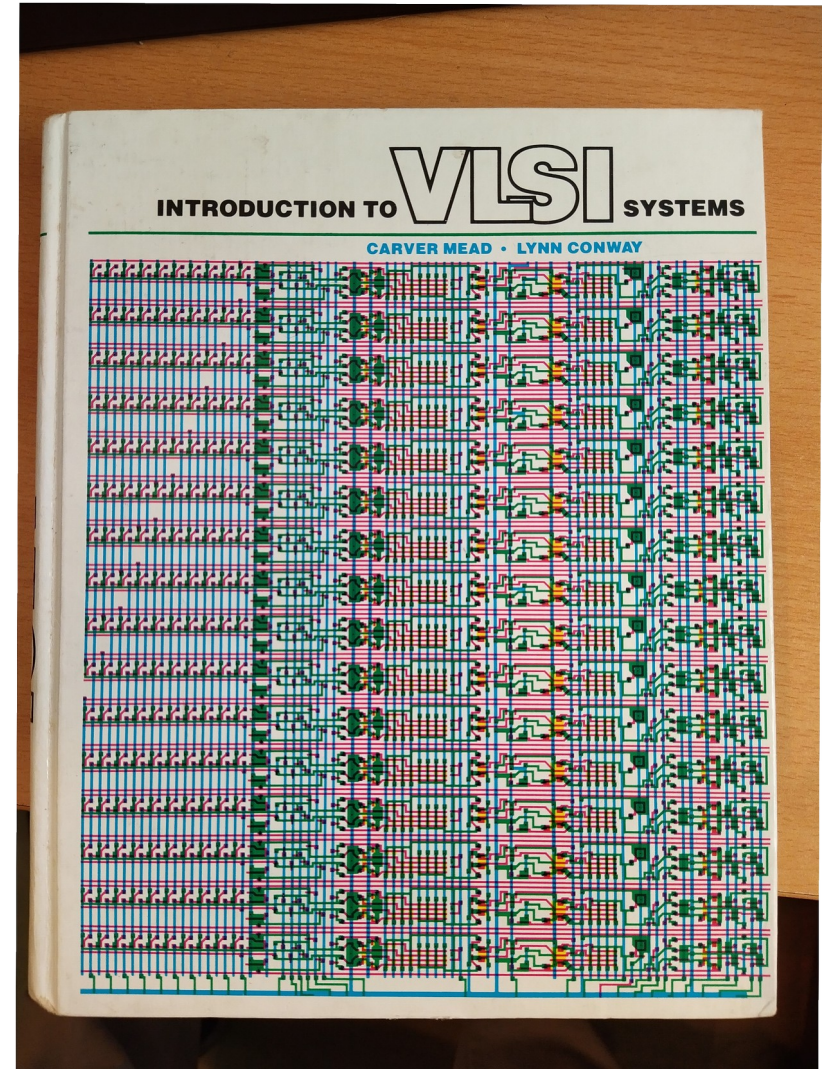


Full decode



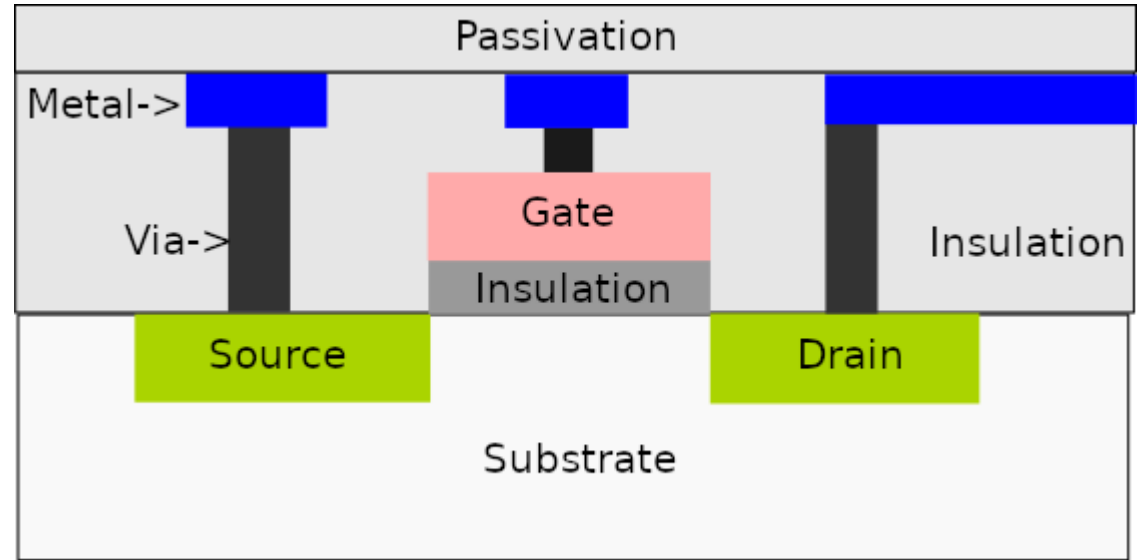
The book

- Conway and Mead
- NMOS

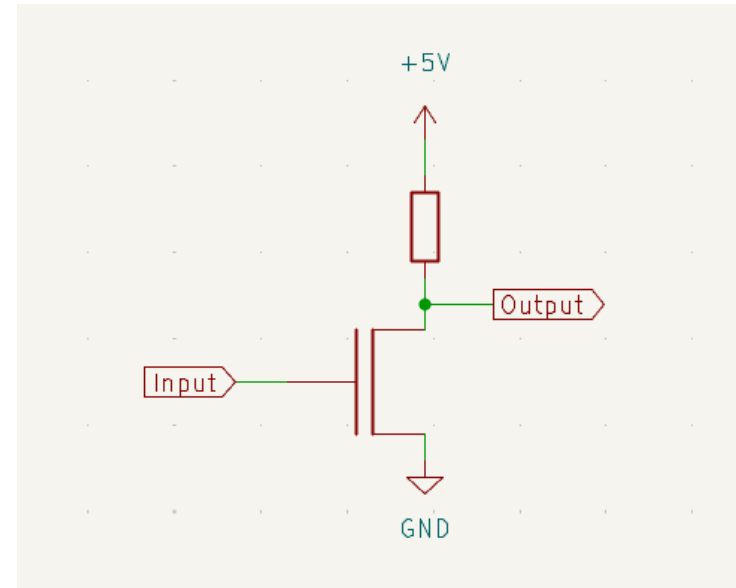
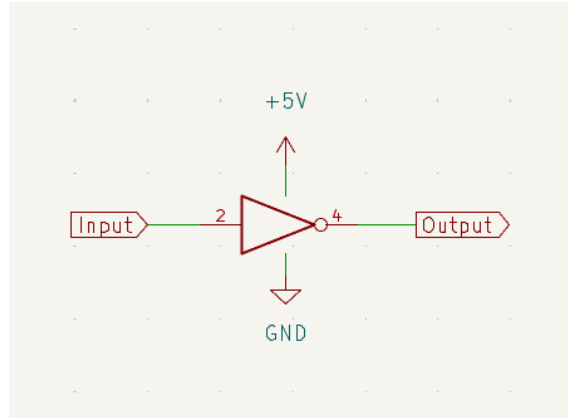


MOS/CSG NMOS

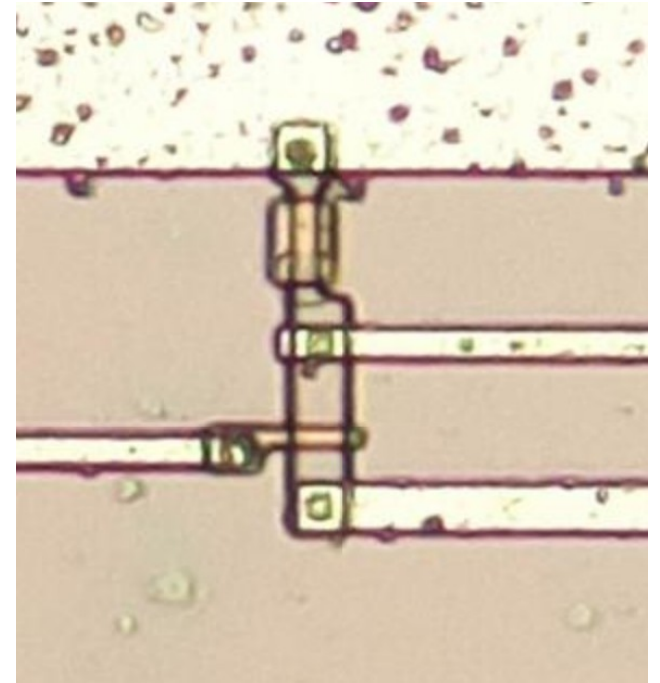
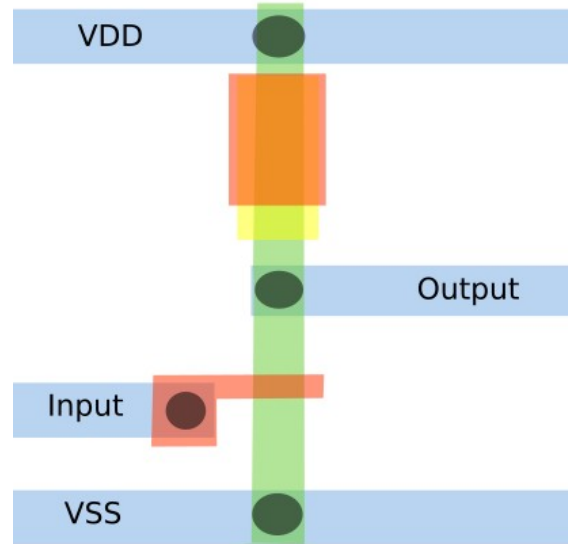
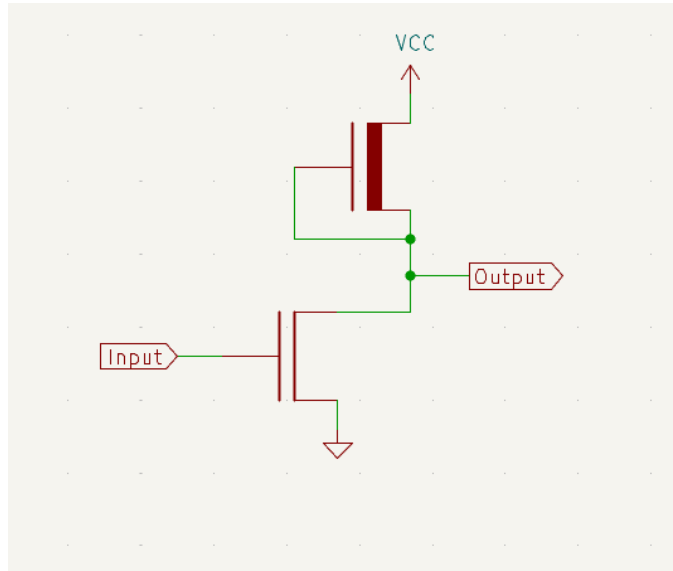
- Single metal layer
- Feature size
- NMOS/HMOS/HMOS-II



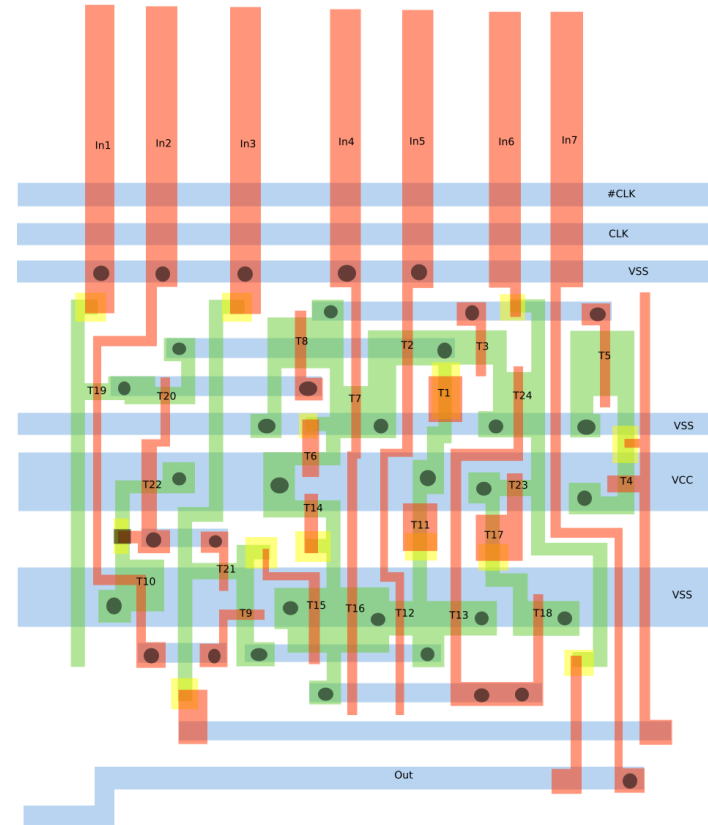
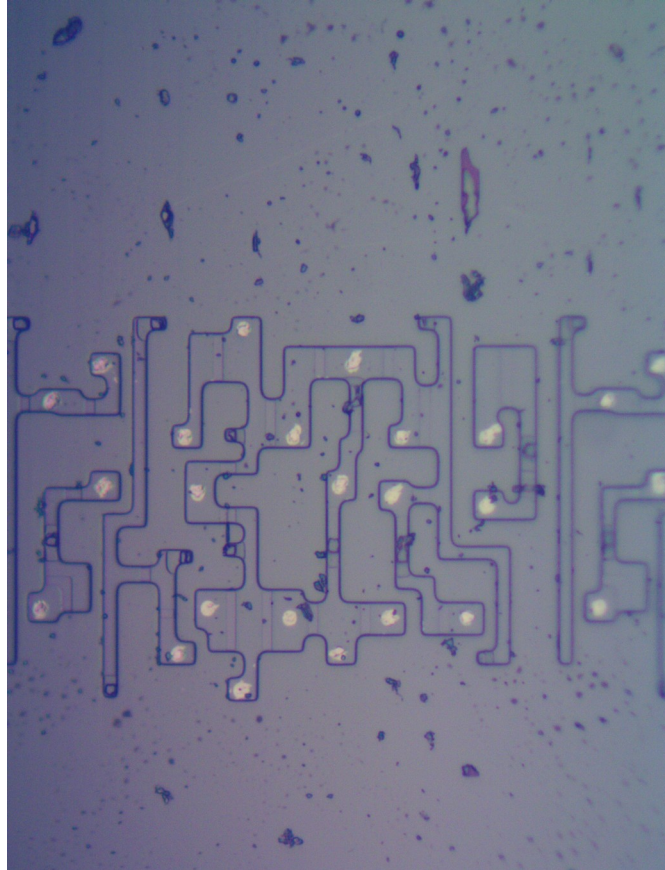
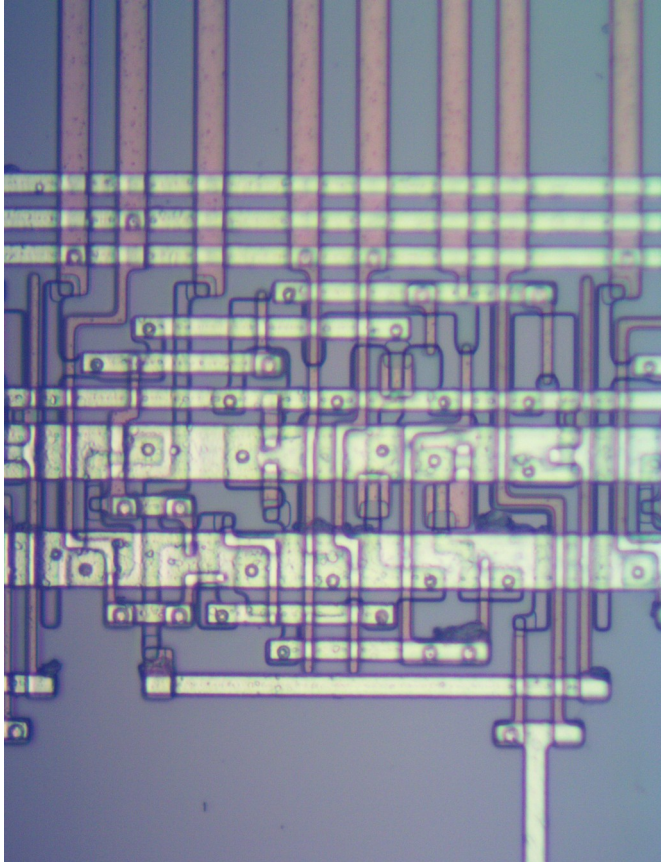
NMOS logic inverter



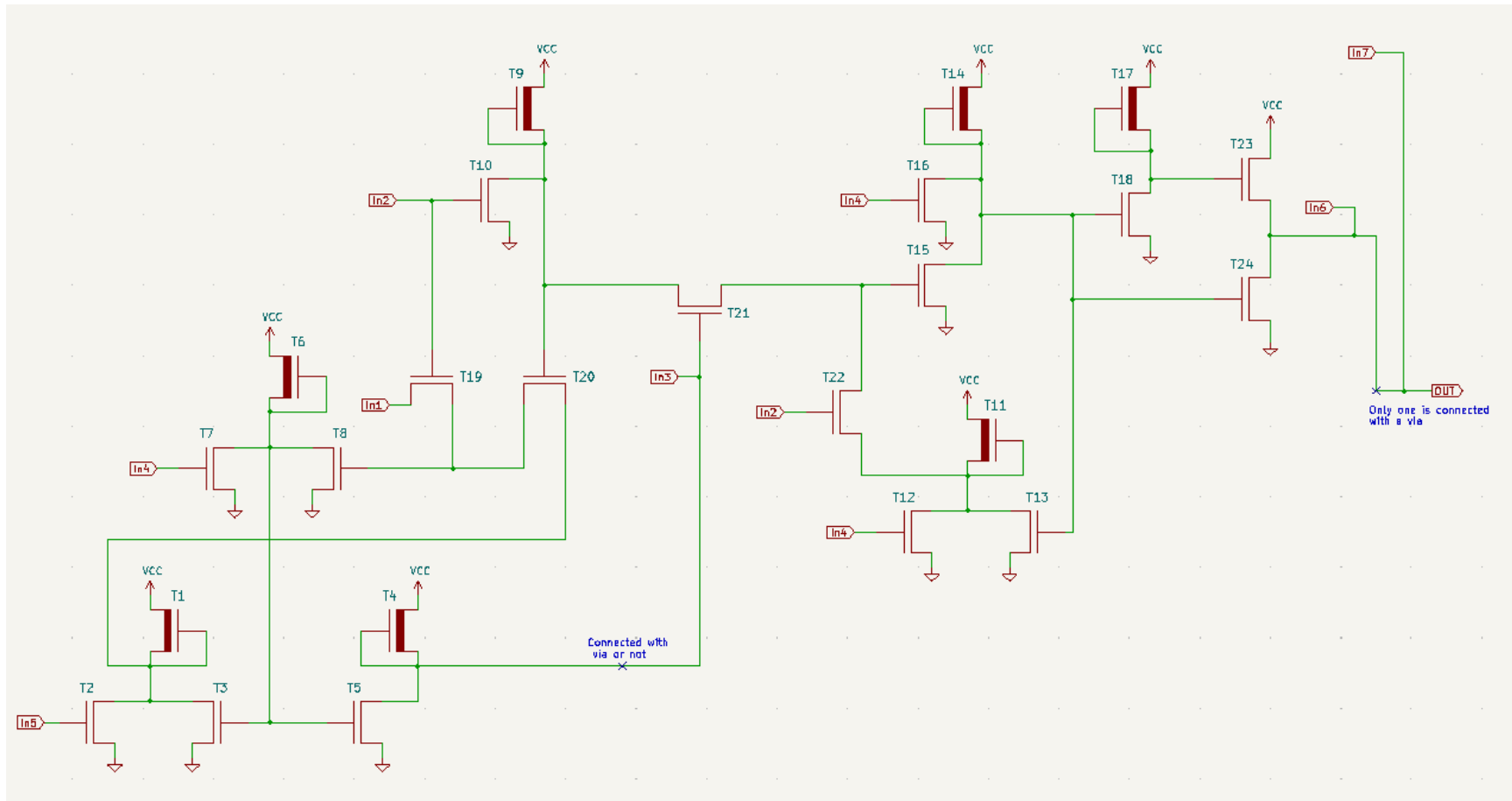
NMOS logic inverter



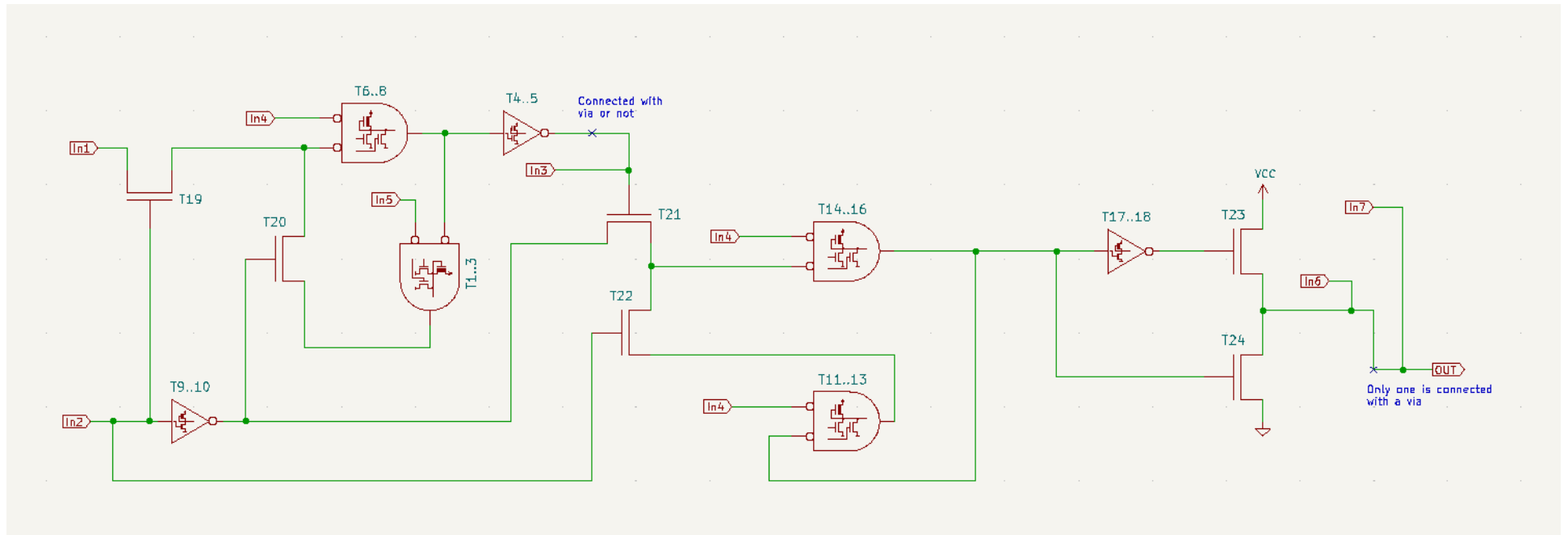
Outputs



Outputs



Outputs

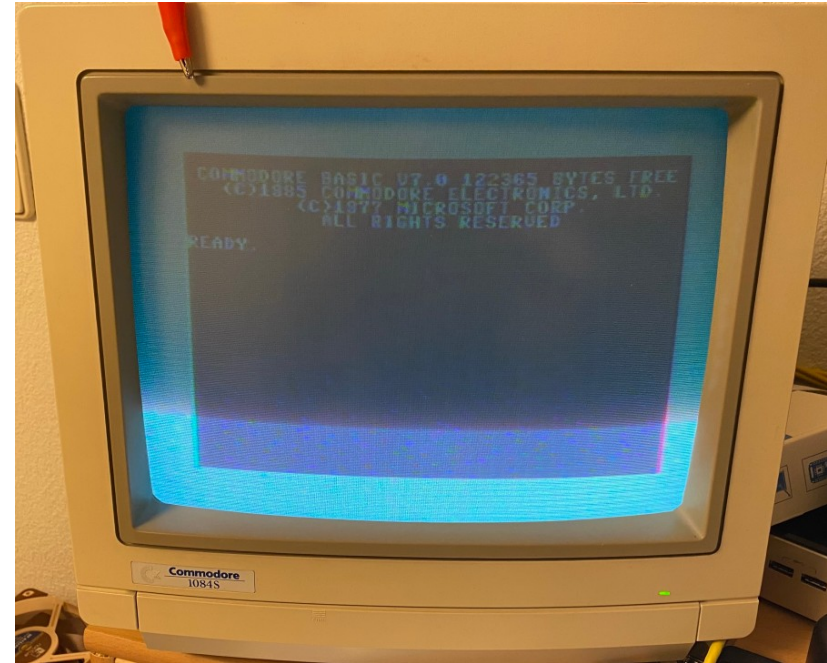
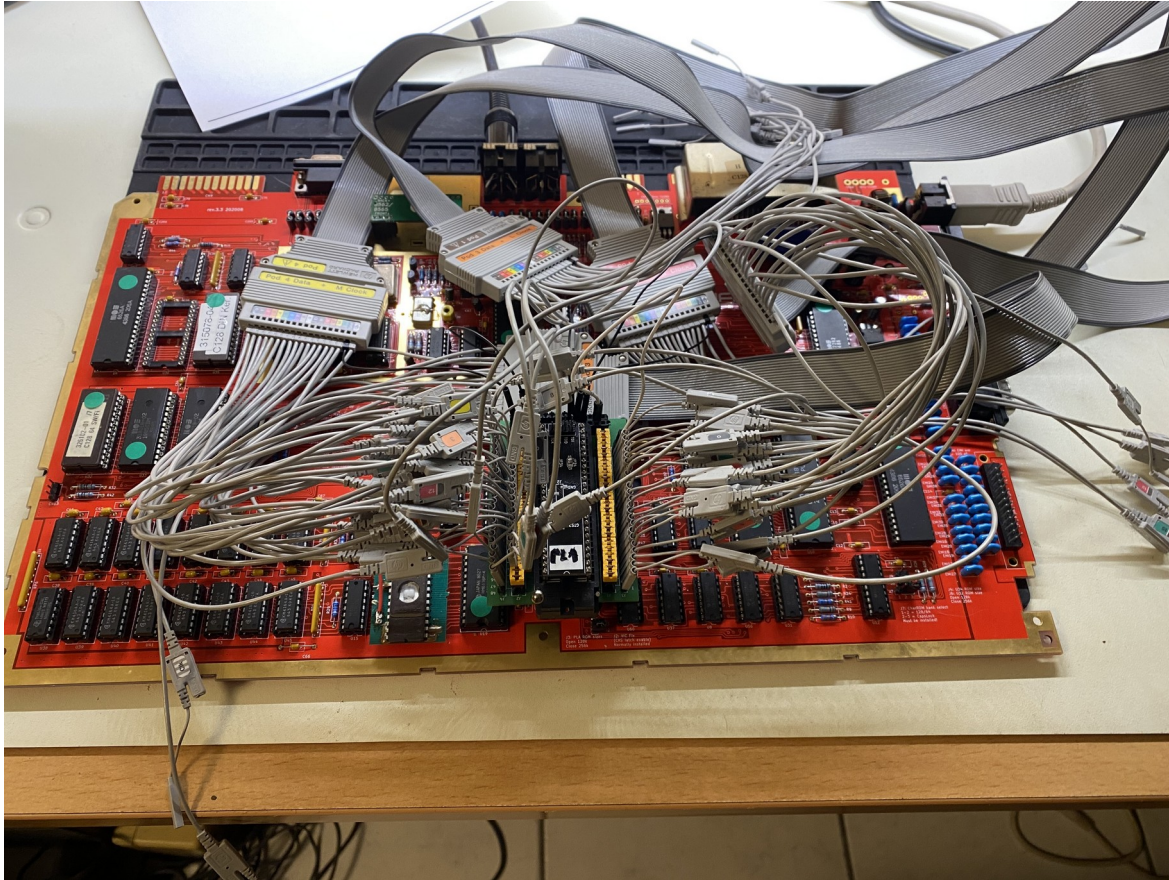


Verilog

```
254 assign p82 = !ms3 & exrom & !game & aec & a13 & a14;
255 assign p83 = !ms3 & exrom & !game & aec & a14;
256 assign p84 = !ms3 & exrom & !game & aec & !a12 & !a13 & a14 & a15;
257
258 assign p85 = !loram & ms3 & aec;
259 assign p86 = !hram & ms3 & !aec;
260
261 /* outputs */
262
263 assign sden = p42 || p43 || p66 || p69;
264 assign rom1 = p45 || p46 || p47;
265 assign romh = p49 || p50 || p51 || p52 || p79 || p80;
266 assign clrbnk = p85 || p86;
267 assign from = p48 || p53 || p77 || p78;
268 assign rom4 = p54 || p55 || p75;
269 assign rom3 = p56 || p70;
270 assign rom2 = p57;
271 assign rom1 = p58 || p59 || p60 || p71 || p72 || p73;
```

<https://github.com/jgrip/c128-verilog>

Some debugging later



So, I bought a microscope

- Olympus BH2 w/ UMA
- Home built motirization
- DSLR camera



Future plans

- Finish re-implementing the MMU
- Reverse engineer the VDC
- Built a complete C128 with only new parts

Questions?