ReA4091

… bringing Zorro III SCSI back to the future

Vintage Computer Festival East - 2022-04-22

Stefan Reinauer & Chris Hooper

THE TEAM

Two firmware engineers meet in a Silicon Valley garage and start building hardware together

Stefan Reinauer

Eng Manager, Google LLC

coresystems, coreboot, OpenBIOS, UAE

Chris Hooper

Founder, DSSD

MX29F1615 Prog, BFFS, RGB2HDMI

WHAT?

A brand new Zorro III SCSI Controller

- One of only two Zorro III SCSI controllers ever built
- Full-length Zorro-III DMA
- Fast SCSI-II (10MB/s)
- designed for the A4000, works in A3000
- Needs Buster 11 (minimum ;)
- NCR 53C710
- Autoboot ROM

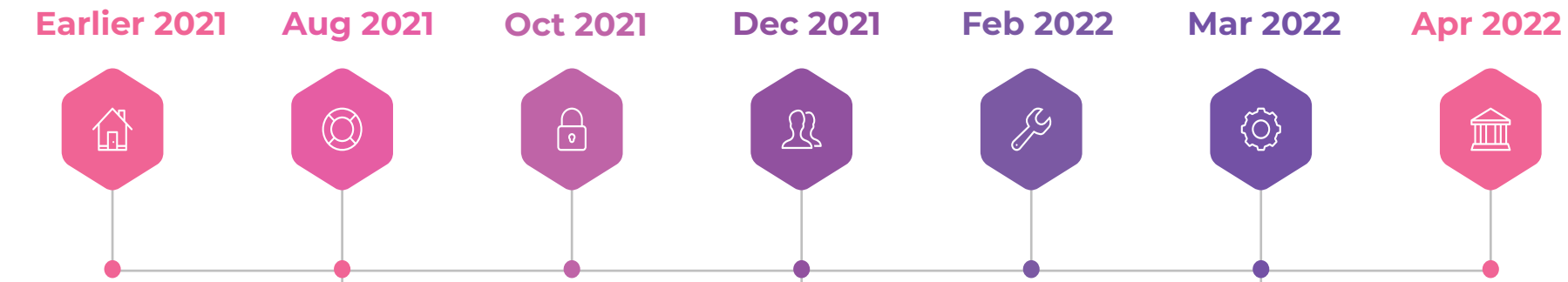
How it started

Because we can, and ...

- Stefan learned soldering in 2020
- Chris and Stefan met on Acill's discord and found out they live 7 minutes apart.
- Stefan got an A4091 on eBay
- Pandemic made the card sit in Germany until August 2021

How we got here

A short history of about everything that lead to this talk



Earlier 2021 — Ebay

Got a A4091 on Ebay

Aug 2021 — Pick-up

Mom, do you have another suitcase?

Oct 2021 — Measure

Hey Chris, let's build SCSI controllers!

Dec 2021 — First PCBs

We're done, right?

Feb 2022 — Debugging

It's working. No, now it's working. Or is it?

Mar 2022 — Collateral

There's more to the story

Apr 2022 — Mass Production

When this batch is done I need a break!

But Why? It's 2022!

Because we can, and ...

- Classical Amiga hardware prices skyrocketed
- Inspired by folks like Paul Rezendes and John Hertell, and others!
- Dave Haynie Files!
- Create an accessible but compatible storage solution
- Open Source helps future generations learn about technology
- A tribute to the shoulders of the giants on which we stand today

End-to-End

Brackets

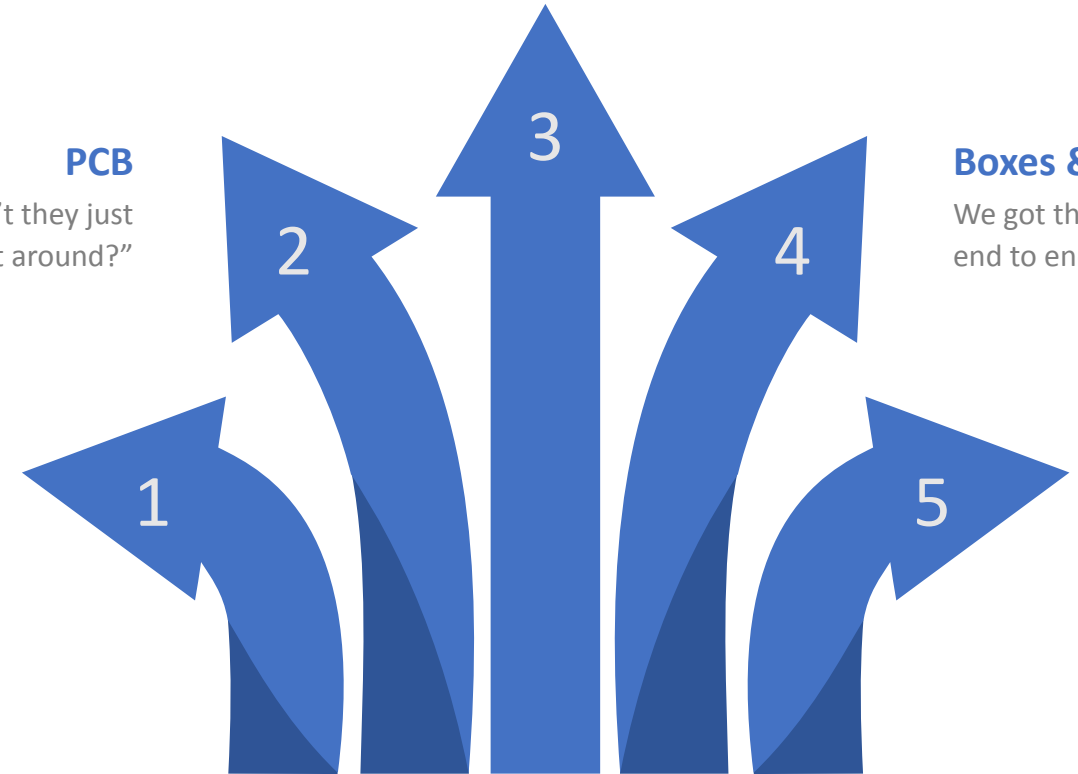
A transatlantic cooperation

PCB

… or “why didn’t they just turn this part around?”

Boxes & Manuals

We got this far, let’s do it end to end…



Schematics

Patience and a decent multimeter

Drivers

Patching binaries or standing on the shoulders of giants

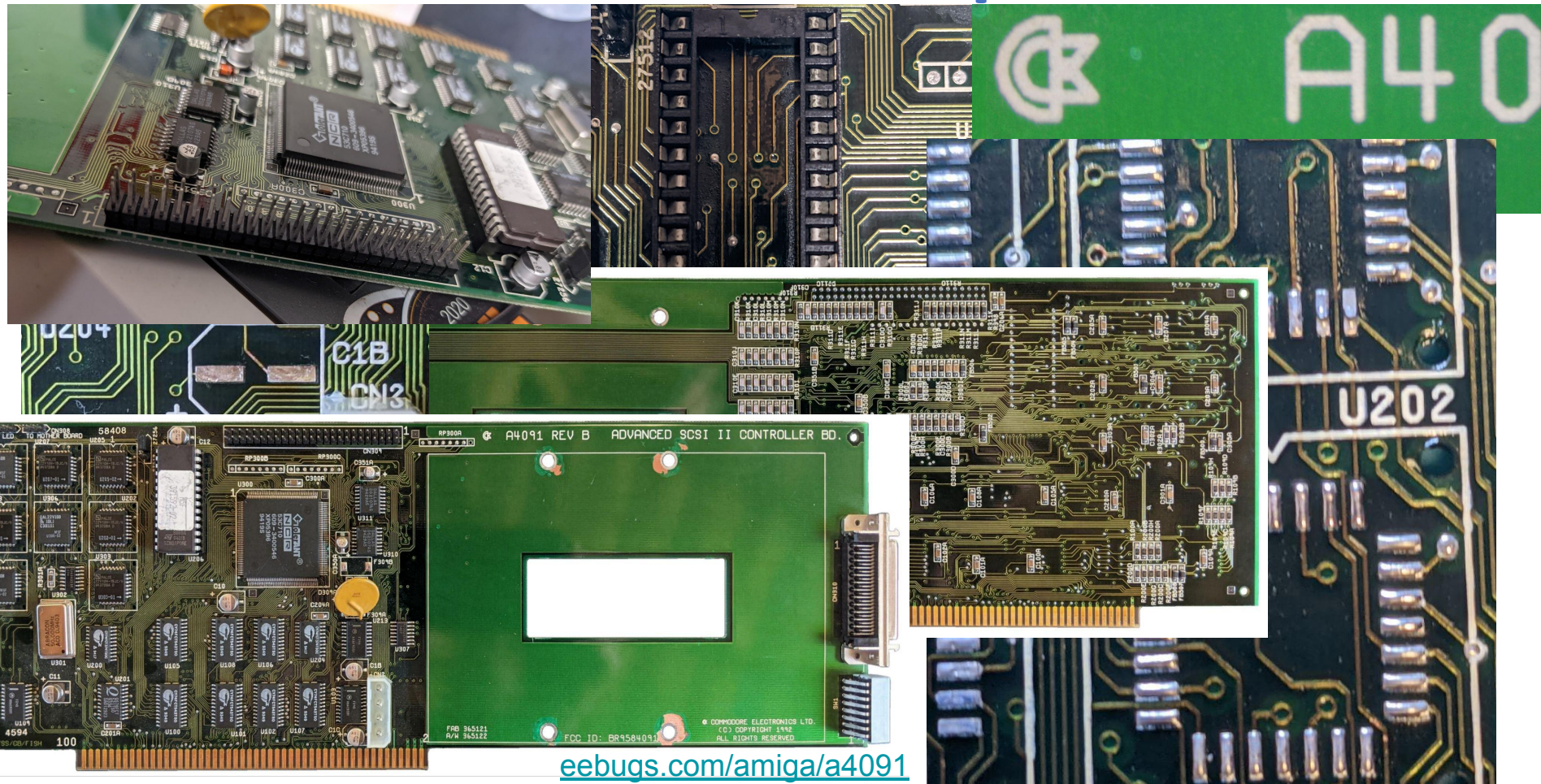
… Traveling to Germany

… Traveling to Germany

Retro stuff is cheaper in Germany, so I ordered a thing. And another. And…

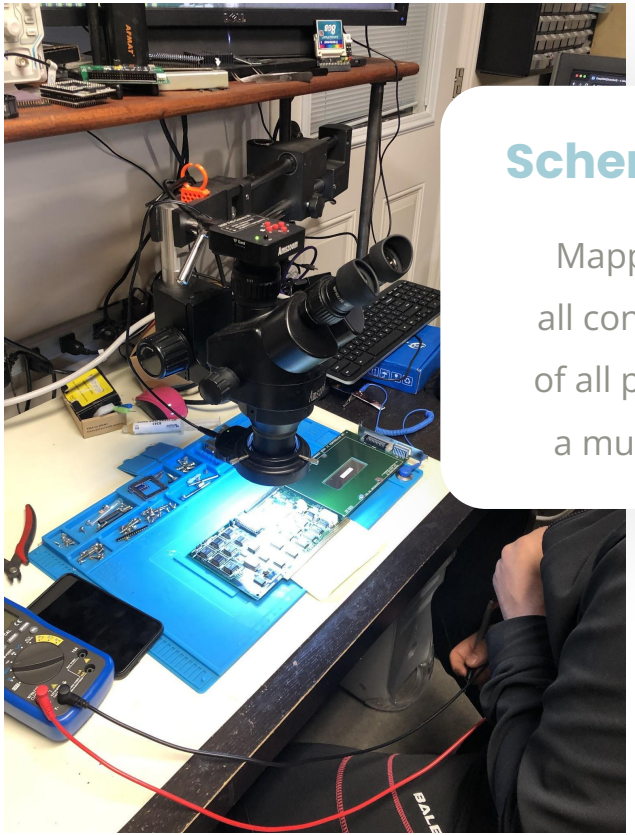
… two years later:

Let’s take some pics



eebugs.com/amiga/a4091

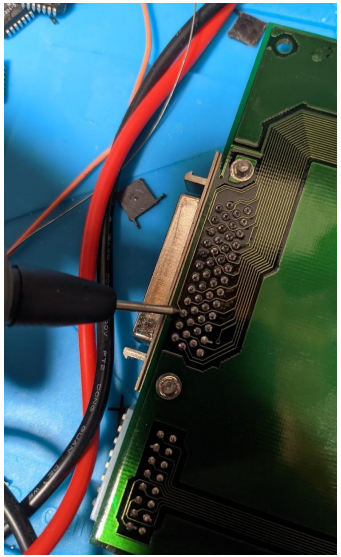
… and how it continued



Schematics

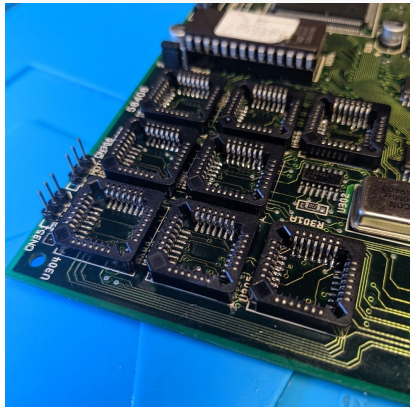
Mapping out
all connections
of all parts with
a multimeter

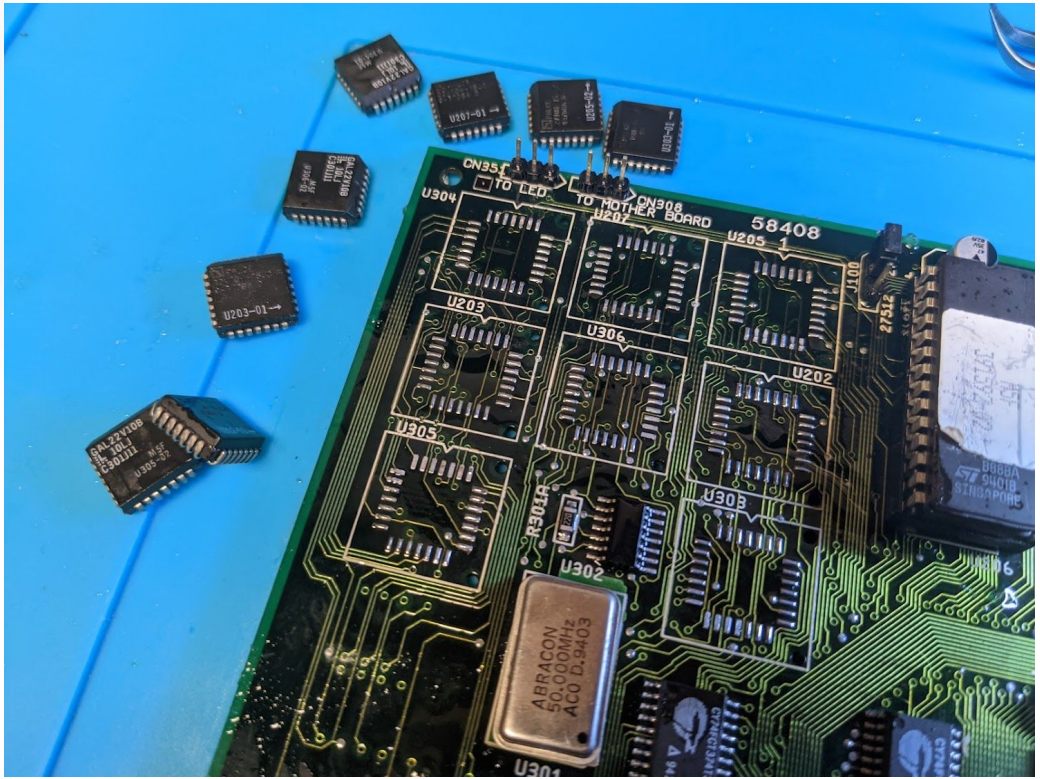
… and how it continued



Schematics

Some traces
were hidden
under the GALs

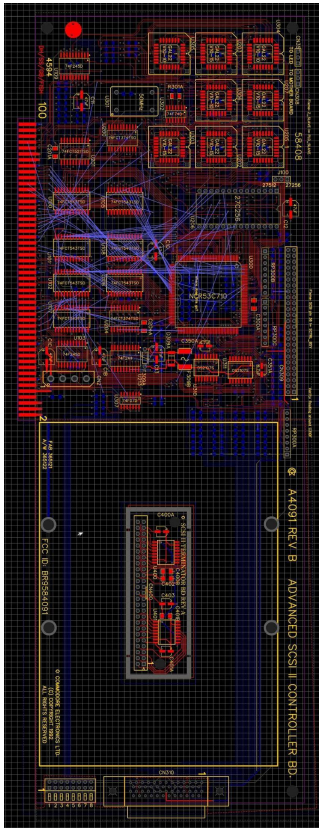




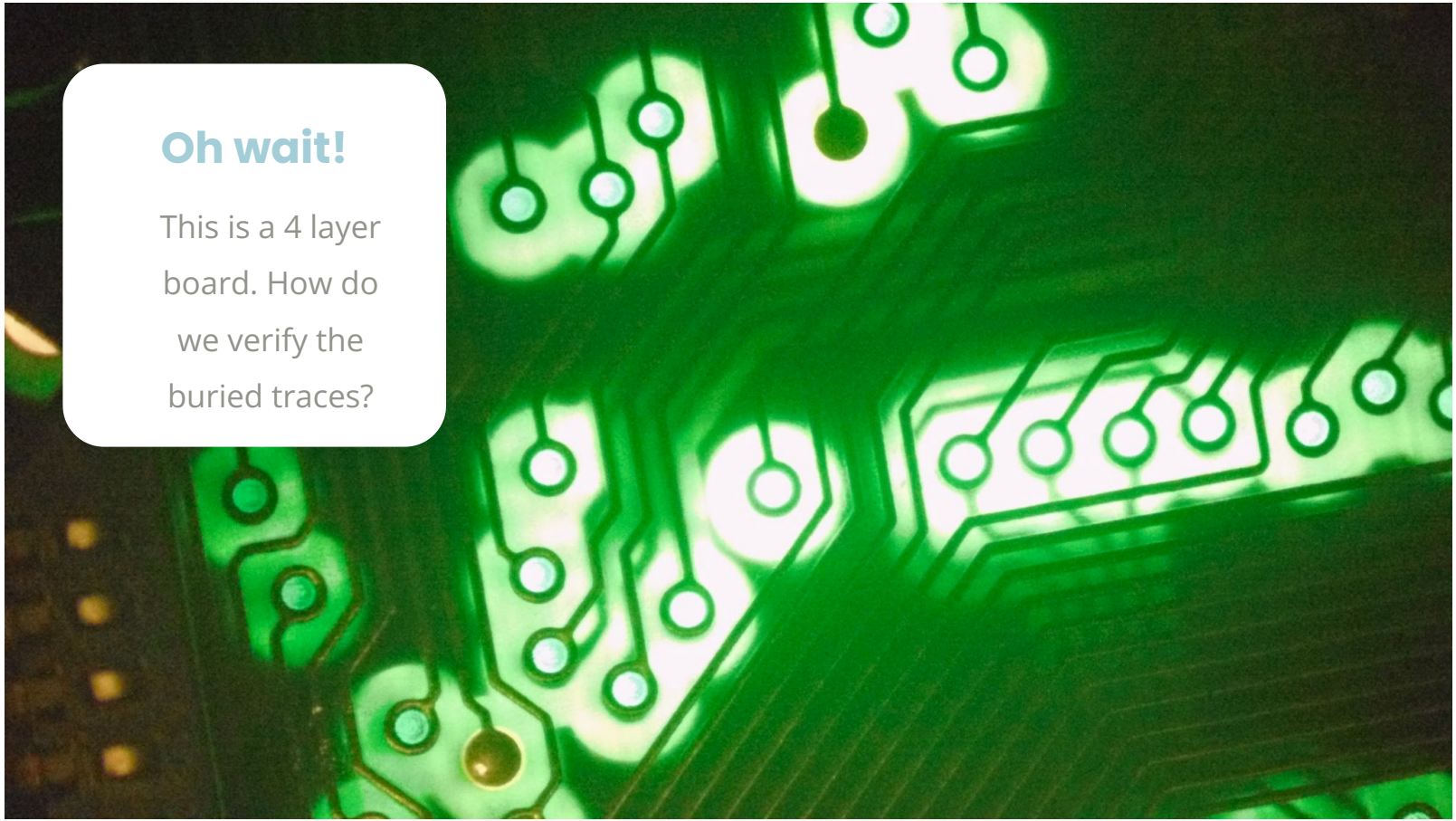
Making of the Schematics

Two revisions of the original board

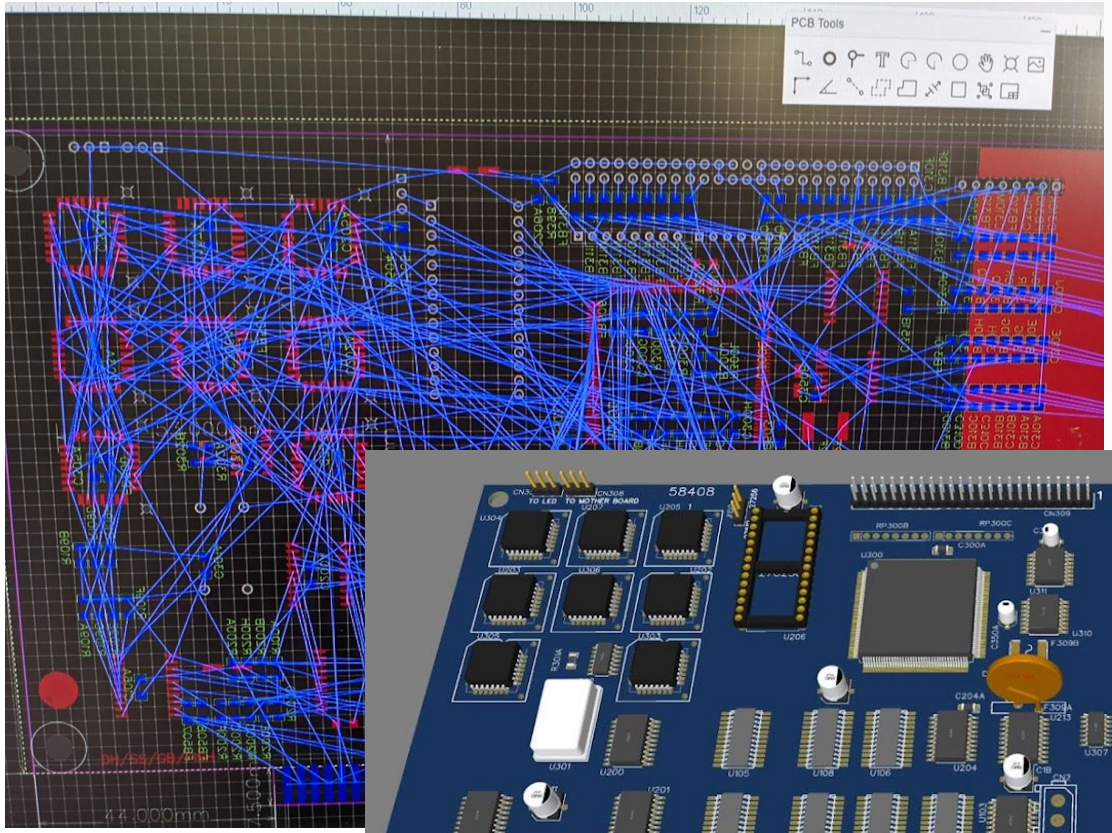
- Revision A: Commodore, Inc.
  Has a few last minute fixes using bodge wires
- Revision B: DKB Software, Inc.
  Identical (?) but bodge wires routed on inner layers instead



Routing the board

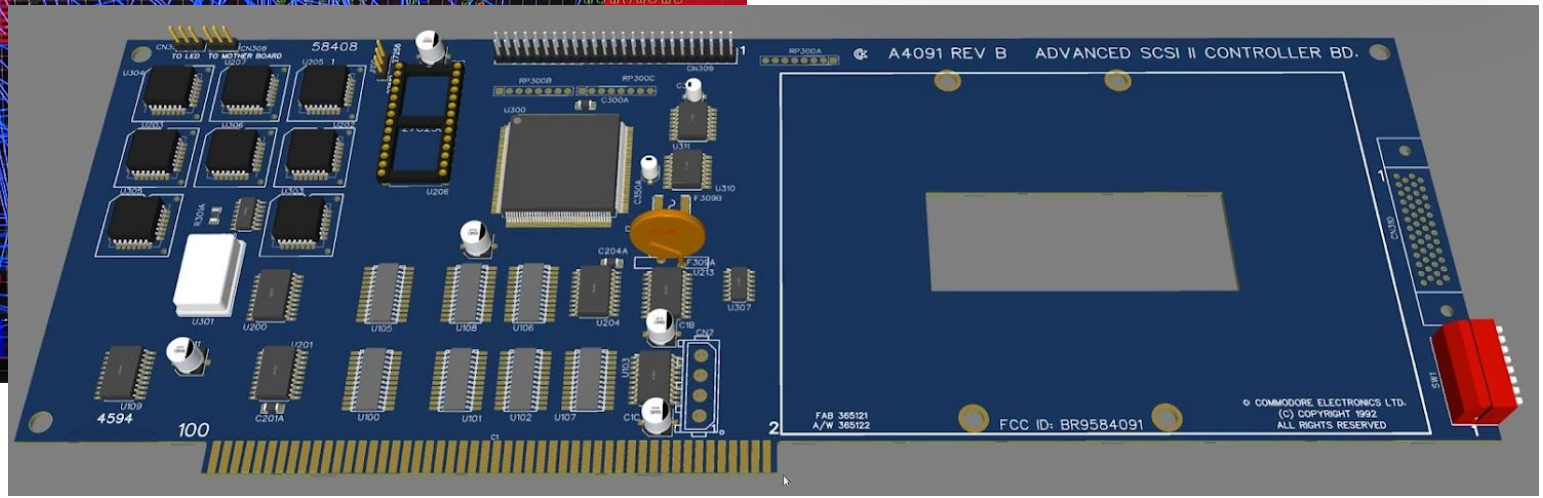


Routing the board

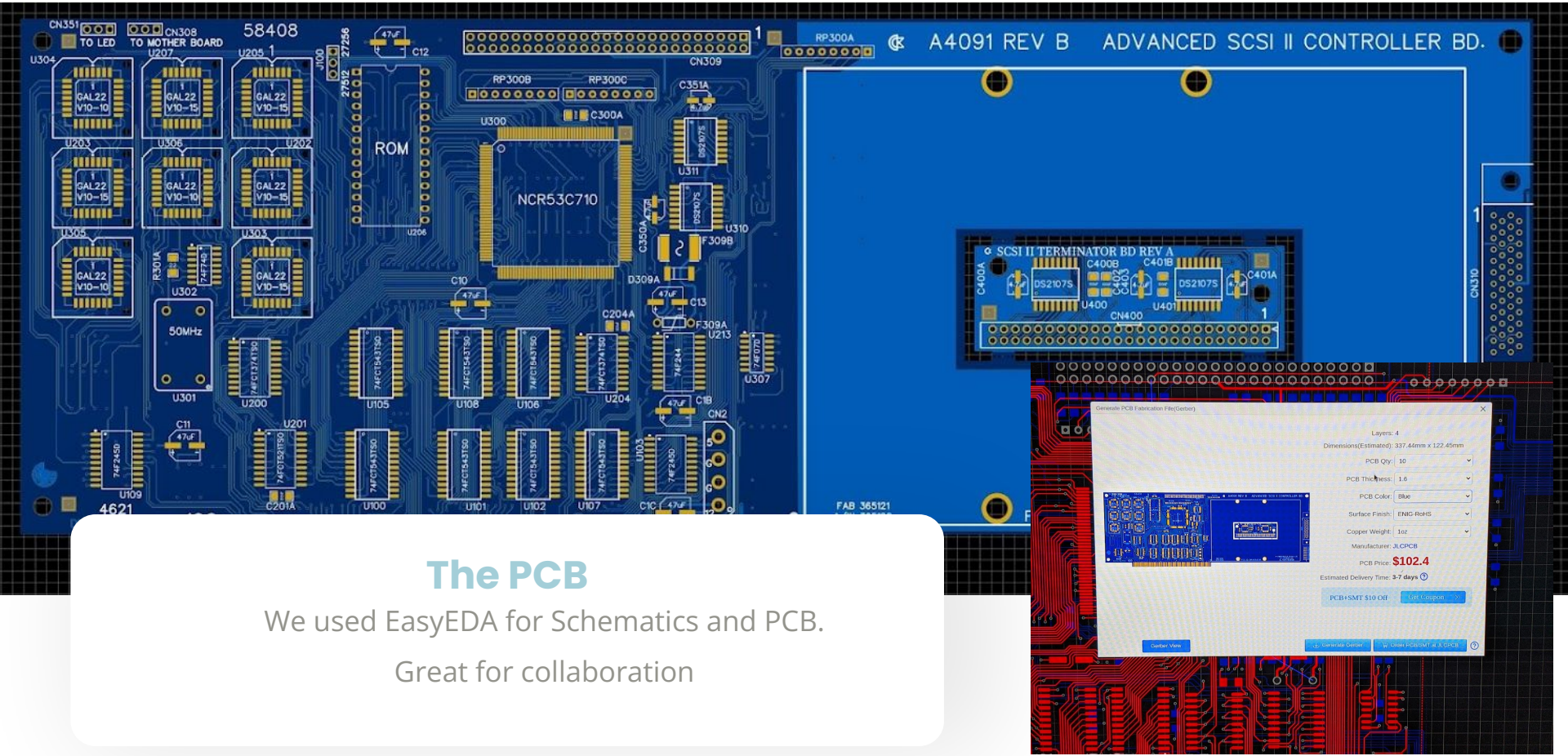


Goals

- close to the original
- Get it working
- Clear labeling, easy to build



Routing the board



The PCB

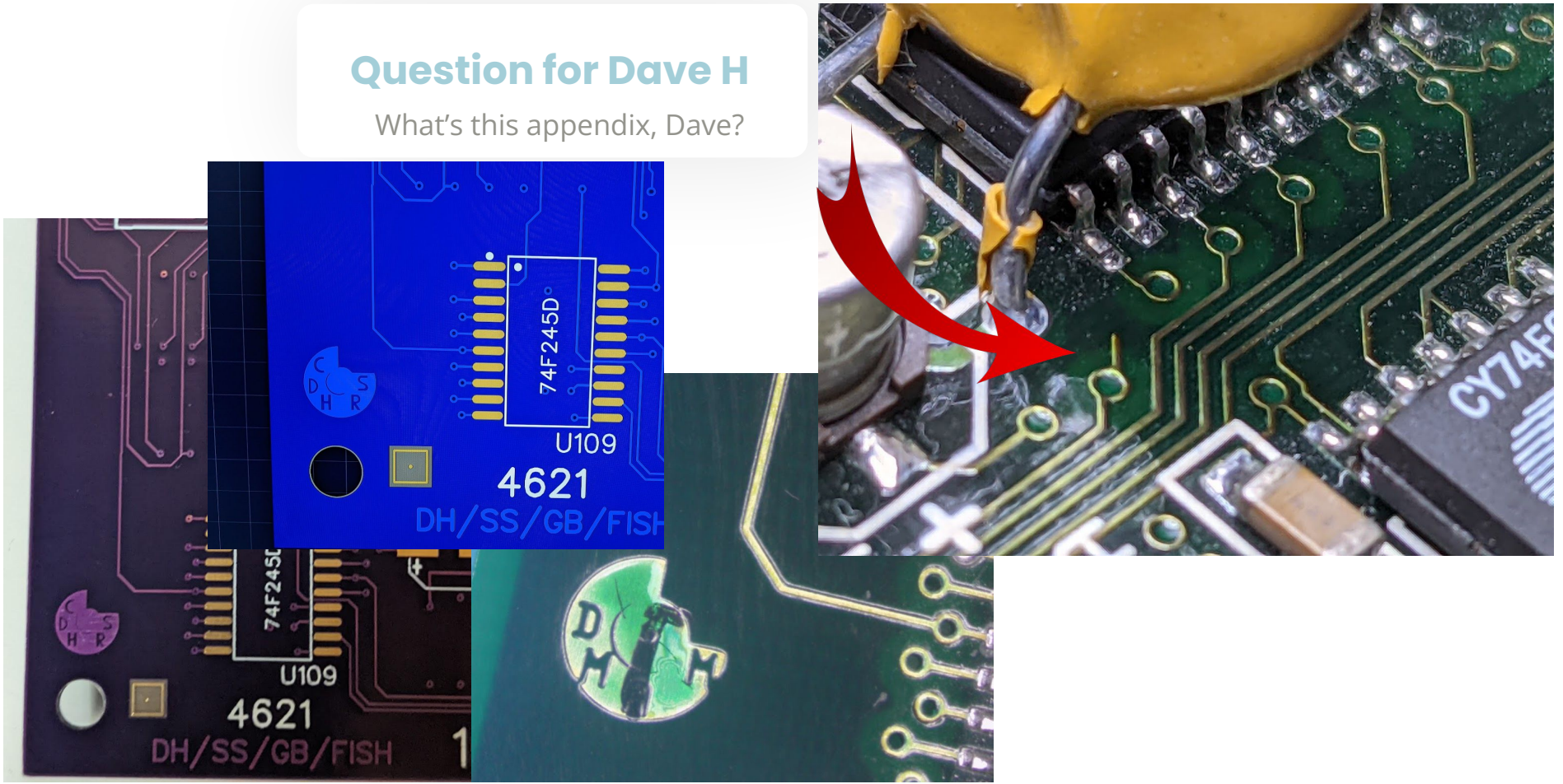
We used EasyEDA for Schematics and PCB.

Great for collaboration

The Level of Detail

Question for Dave H

What's this appendix, Dave?



Help from around the world

Thank you

- Dave Haynie
- Szymon Gosk
- Tim Eire

… and Jeffrey Brace for answering my late night calls!

Brackets

Custom Metal

- Zorro orientation matches ISA, not PCI
- Acts as drive mount reinforcement

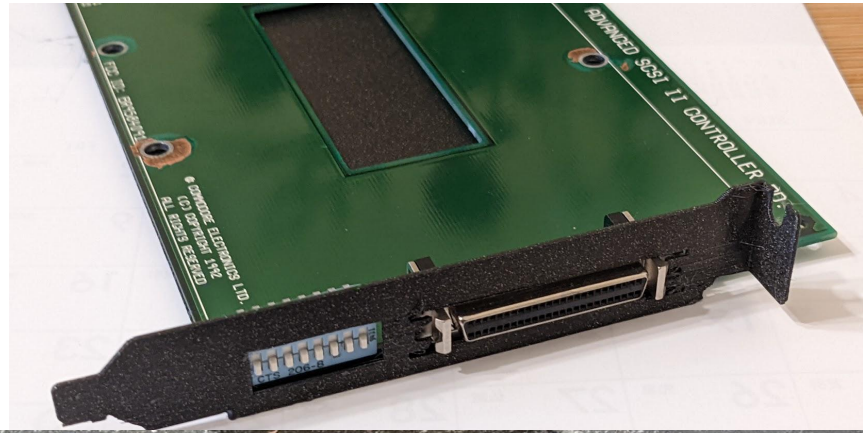
Brackets

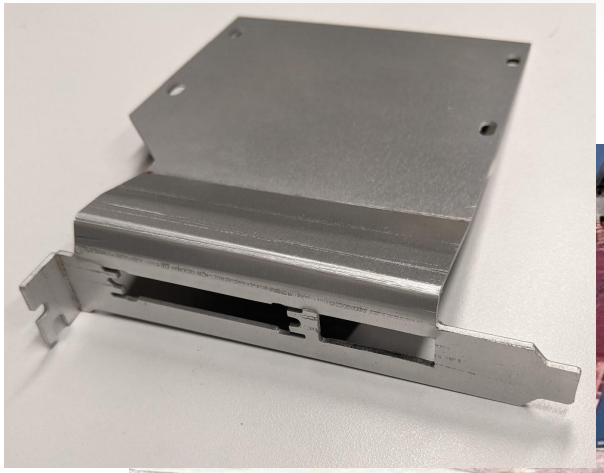
Brackets

More experiments

- Bending metal is .. hard.

- PLA / ABS looks nice, but is too flexible

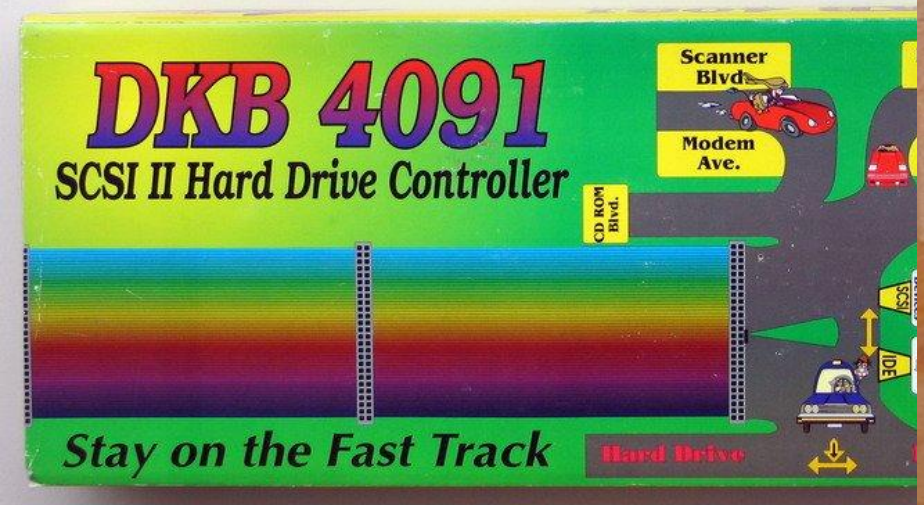




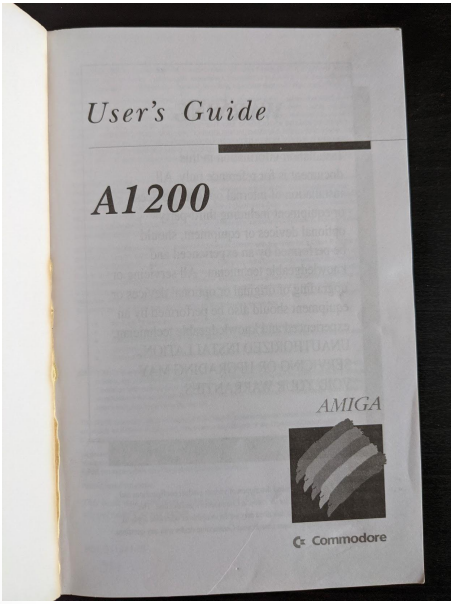
Artwork

A new challenge

- Way harder to come by than the board!
- Pictures courtesy BBOAH
- Which version do you like better?



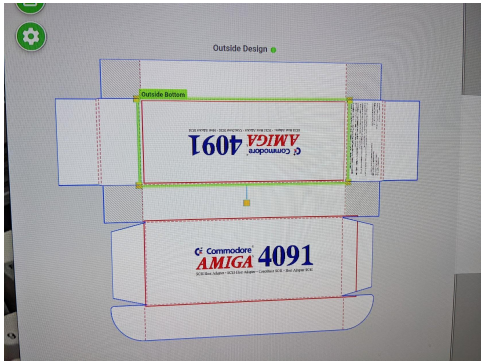
The Manual

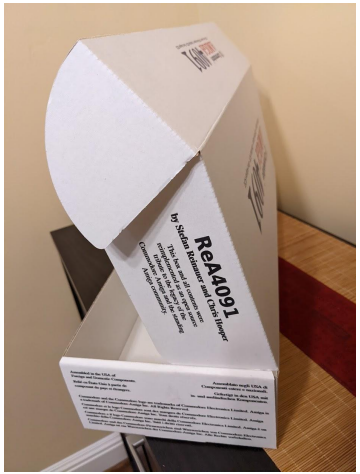


A thousand paper cuts...

- Original manual had 3 languages
- Pages were nearly translucent
- Cutting a booklet of 84 pages is tricky... for a firmware engineer

The Box

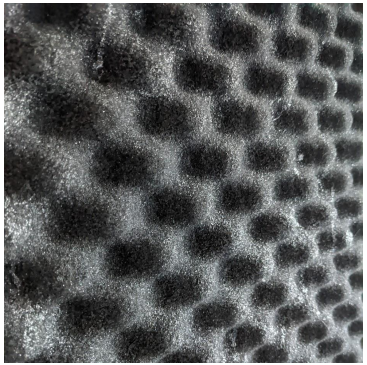


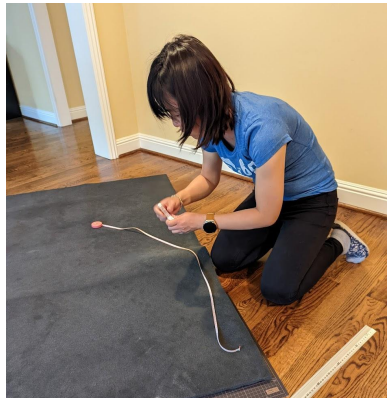


A new challenge

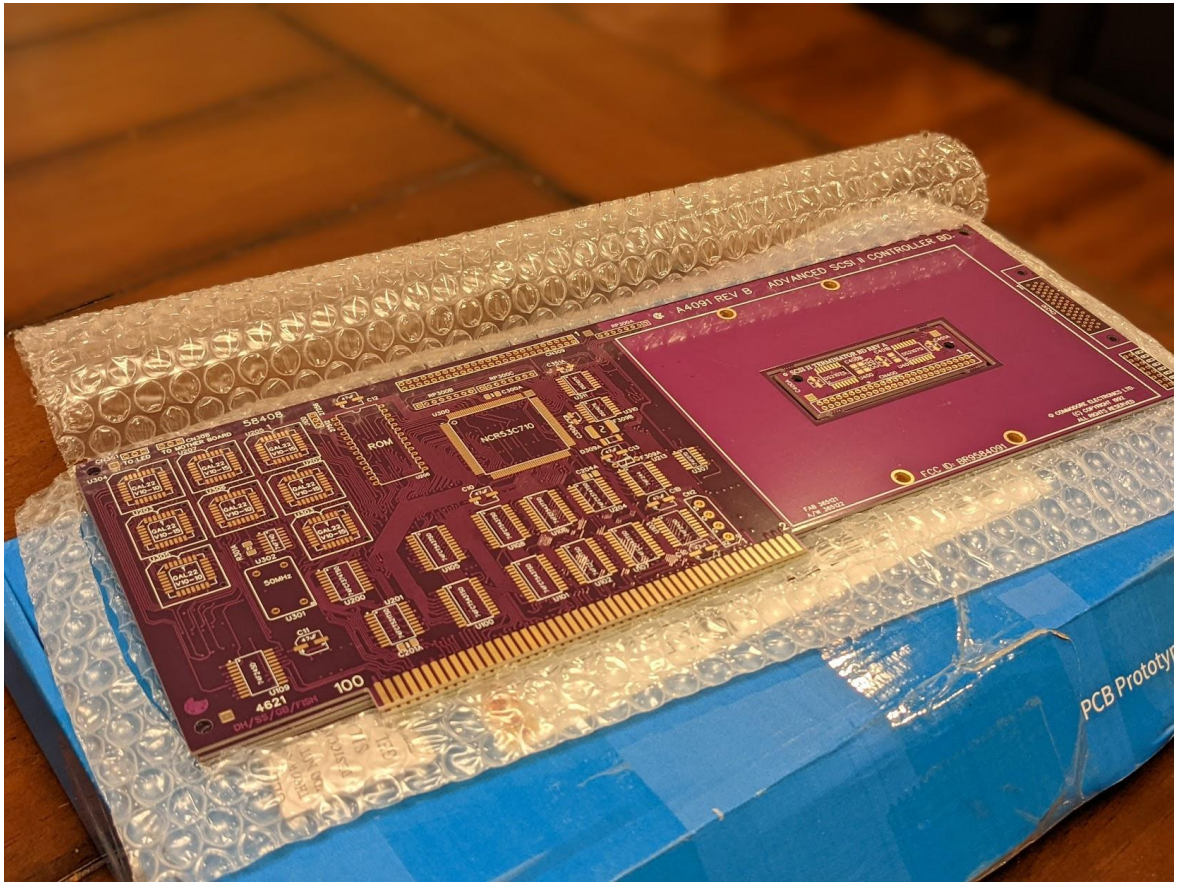
How big is this #$%^& thing?

Katsu’s Foam Pit





Getting ready: Bringup



It works! $%&*#! It doesn’t work

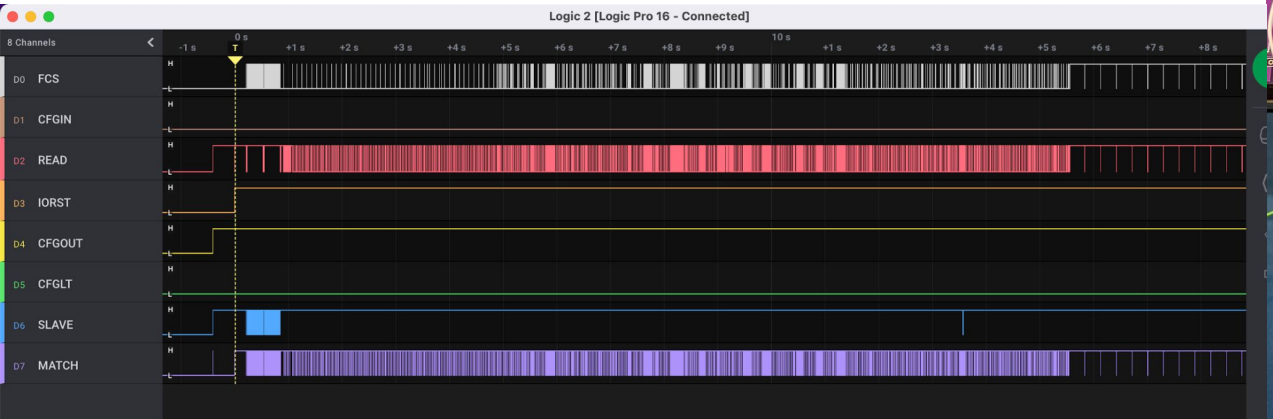
First board assembly

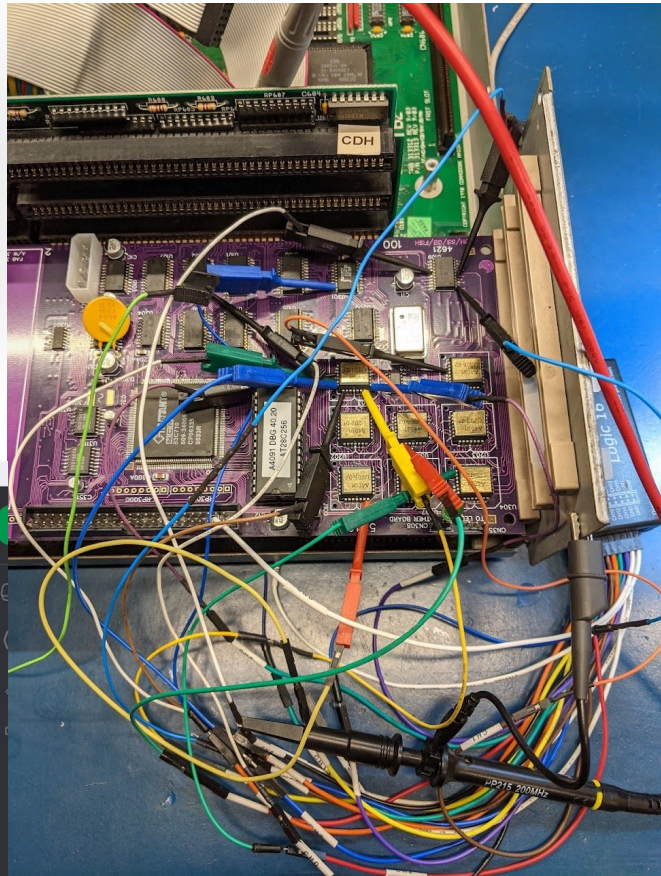
- First boot: Board shows up
- No boot, no cookie!
- Endless loop in DiagROM

Getting serious: Logic Analyzer

Zorro III, meet Saleae Logic16

… why did the Amiga just stop talking?





Assumptions

GALs

- Original A4091 uses -10 and -15 parts
- Original A4091 uses both PALCE and GAL parts
- ATF22V10 is a compatible replacement
- Faster chips never hurt

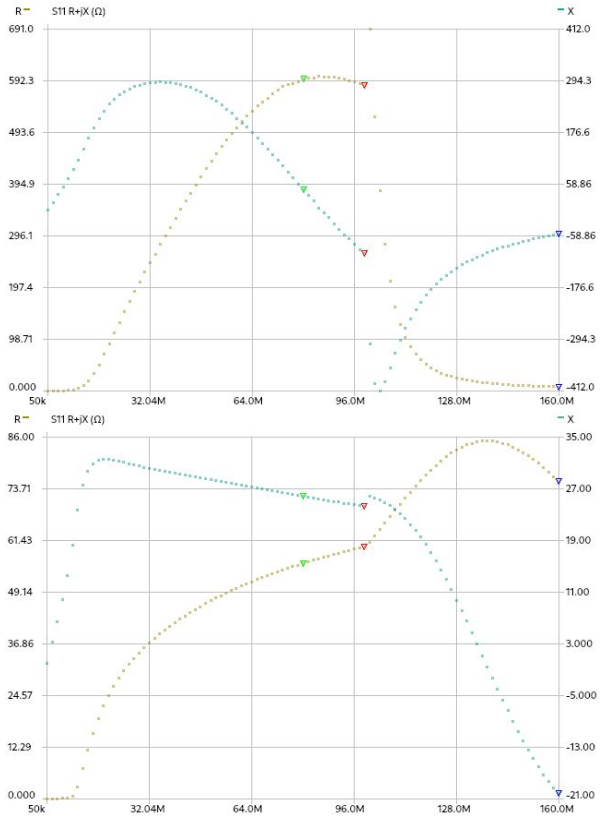
Ferrite Beads

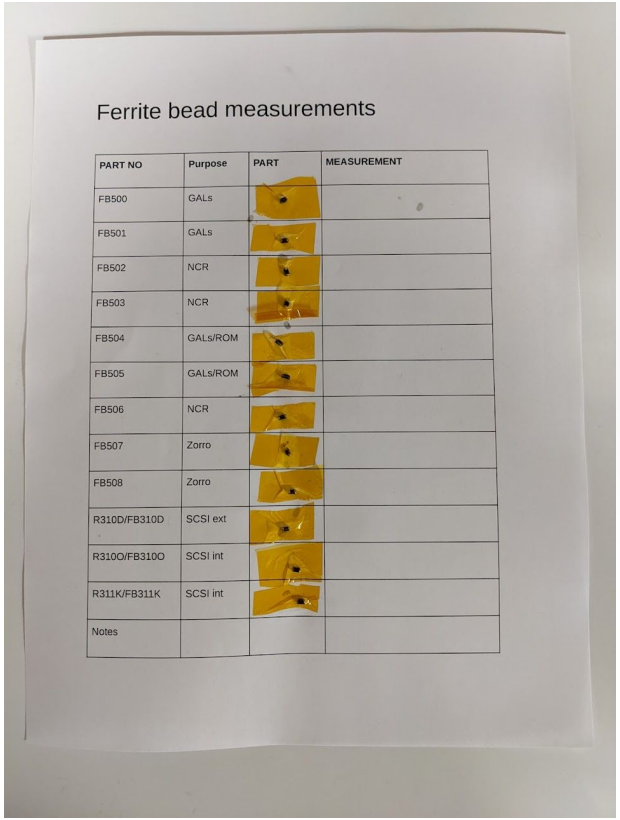
- A4000T design uses 600 Ohm beads in many places
- eBay beads are just as good as ones from Mouser
- How do we measure these things?

Assumptions are made and most assumptions are wrong.

- Albert Einstein

Getting more serious: Network Analyzer



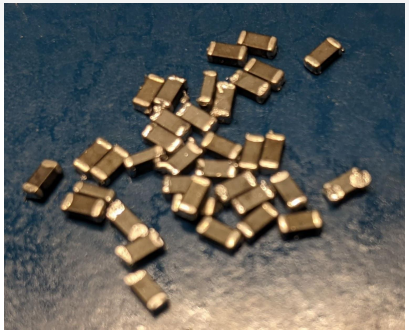


Ferrite bead measurements

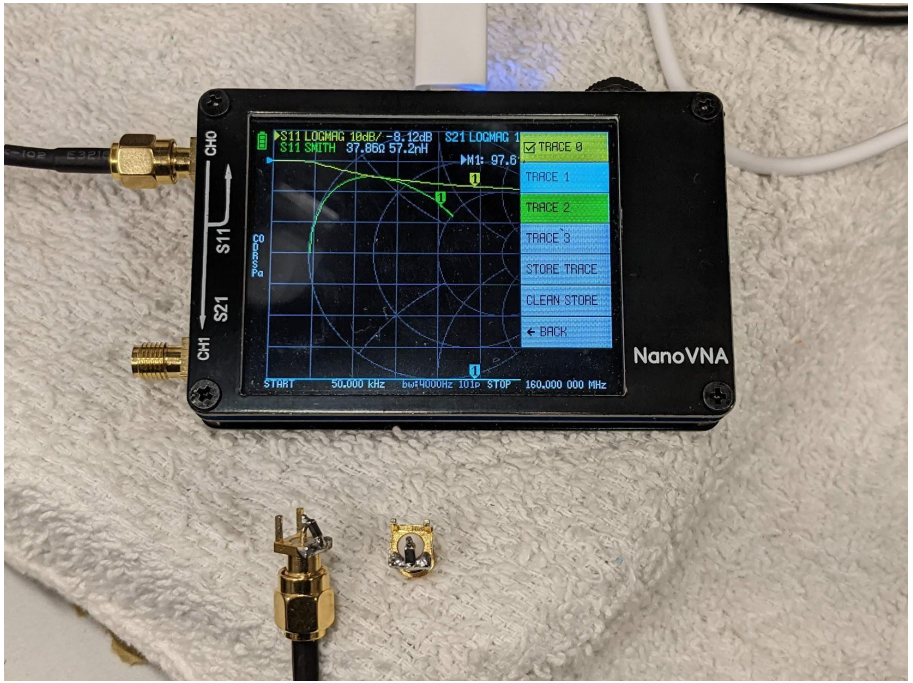
PART NO	Purpose	PART	MEASUREMENT
FB500	GALs		
FB501	GALs		
FB502	NCR		
FB503	NCR		
FB504	GALs/ROM		
FB505	GALs/ROM		
FB506	NCR		
FB507	Zorro		
FB508	Zorro		
R310D/FB310D	SCSI ext		
R310O/FB310O	SCSI int		
R311K/FB311K	SCSI int		
Notes			

Ferrite Beads

- One late night, driving over to Chris' House with a prepped sheet of beads



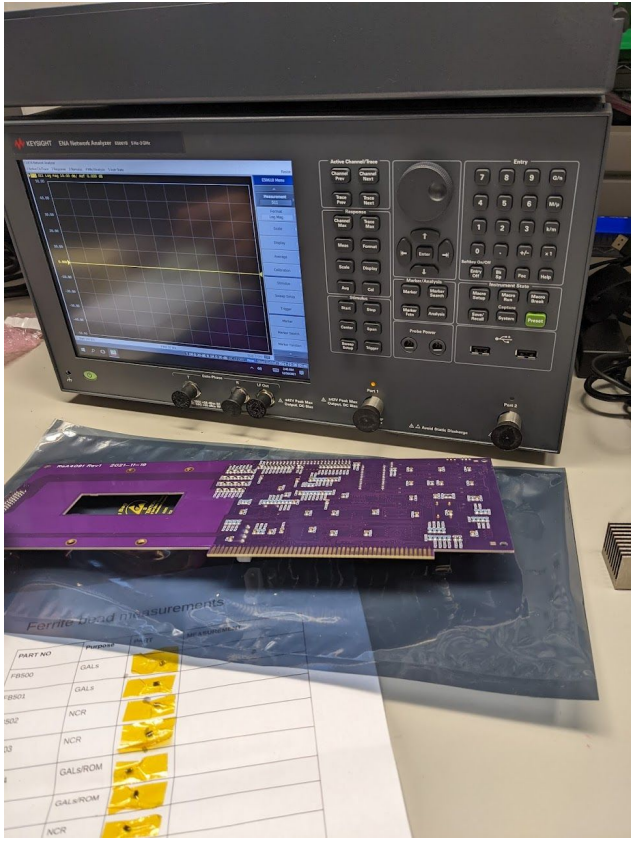
Getting more serious: Network Analyzer

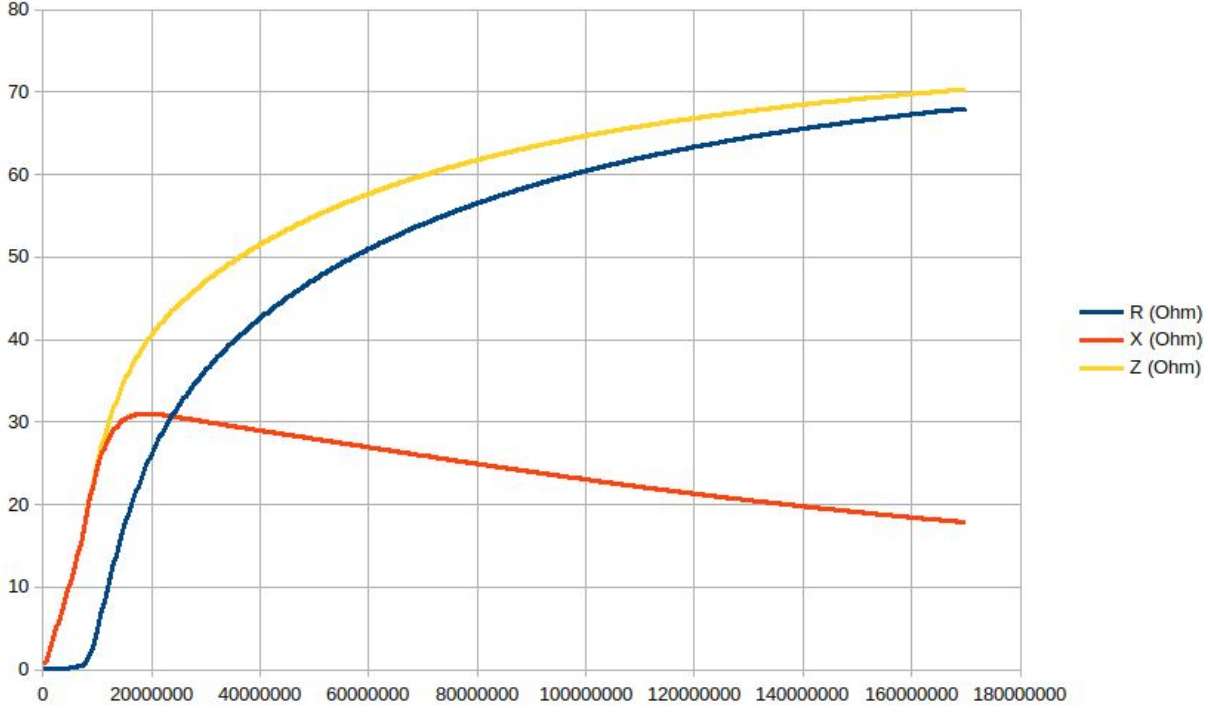


NanoVNA

- Lucky find in Chris' magical garage!
- Amazing bang for the buck!
- It's got some weaknesses
- Be sure to calibrate. Every. Single. Time.

Getting more serious: Network Analyzer

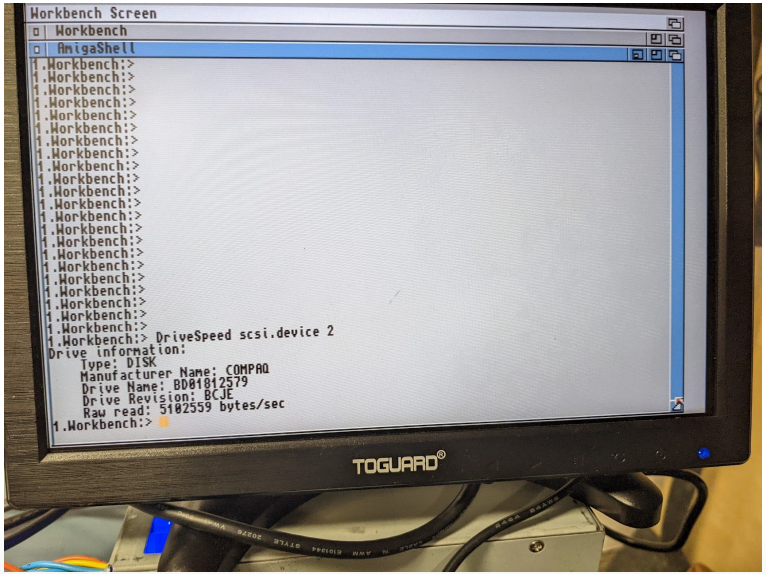


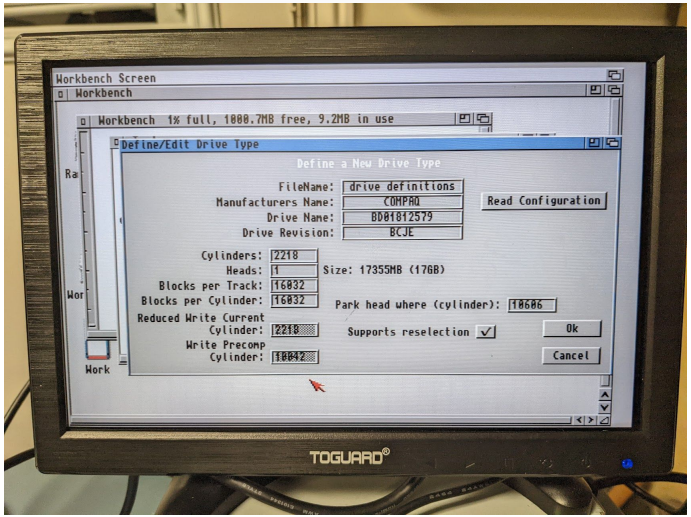


Success!

Time to collect hard disks

- Tested with 20+ hard drives
- External DVD, ACARD, Tape Drives
- SCSI I, II, III (w/ adapter)



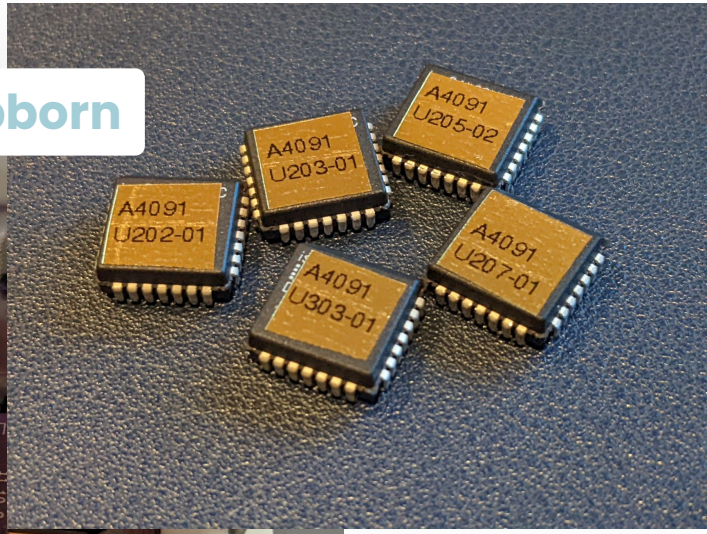


Benchmarks

- Right now: 5.1 MB/s with “drivespeed”
- Zorro III Burst not (currently?) supported

Boys and GALs

Amiga 3000 remained stubborn



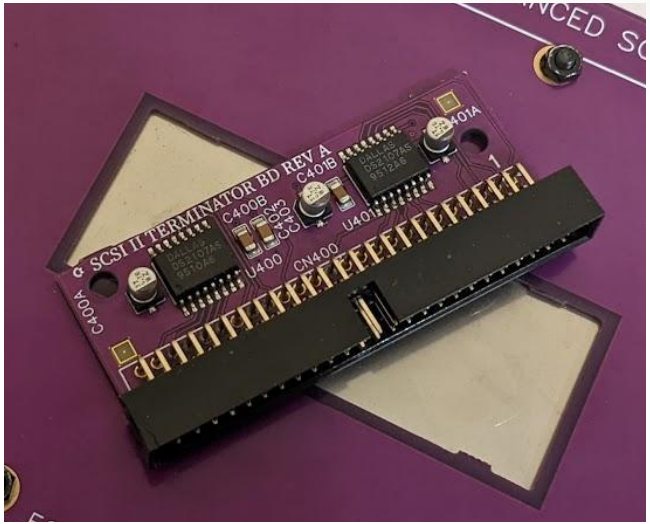
Timing is everything?

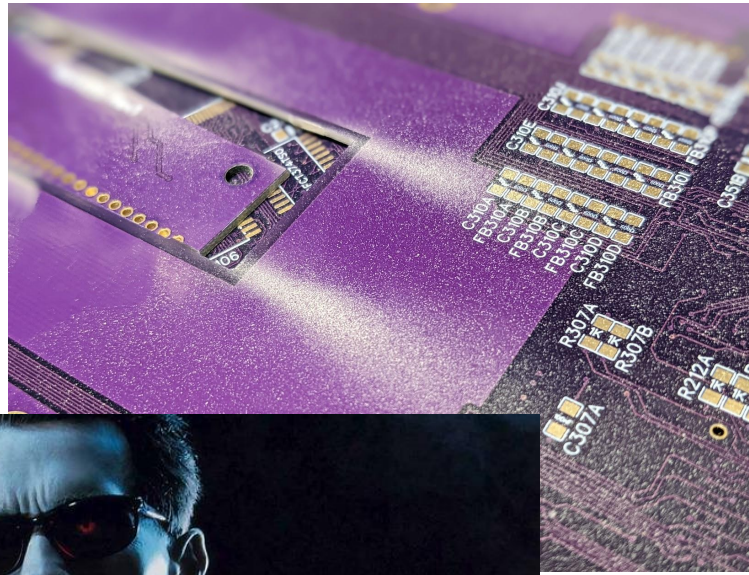
- The Amiga 3000 is a lot more sensitive
- Lattice vs Atmel propagation times!

I'll be BACKKK....

... comes with a Terminator

- Dremel responsibly, my friends!



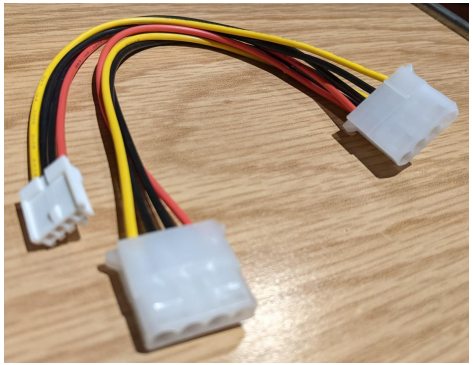


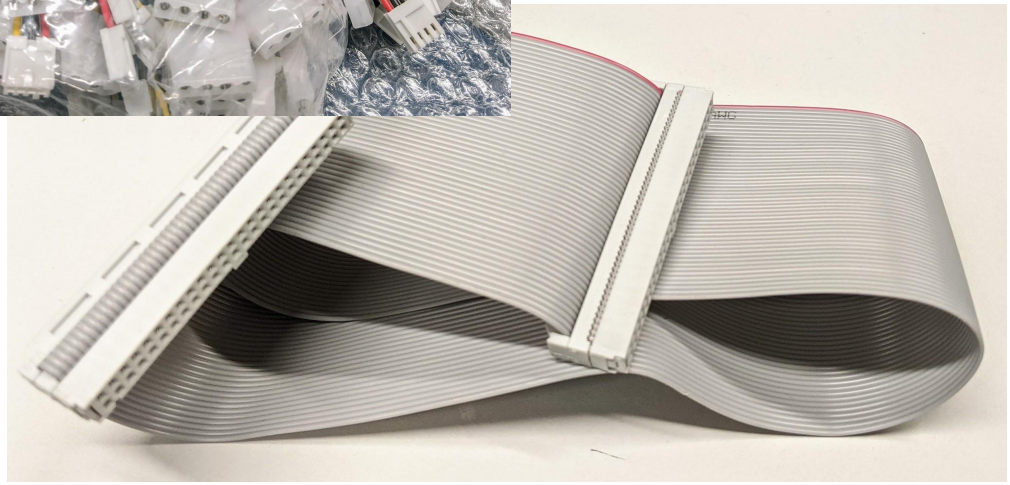
The disk for your drives

The most elusive part

Not strictly needed anymore but hey!

Cables!

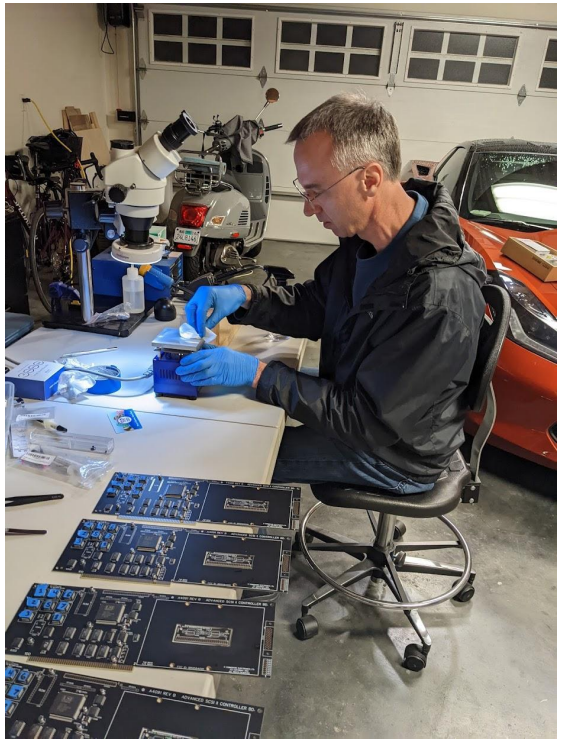




The factory

It’s a silicon valley garage!

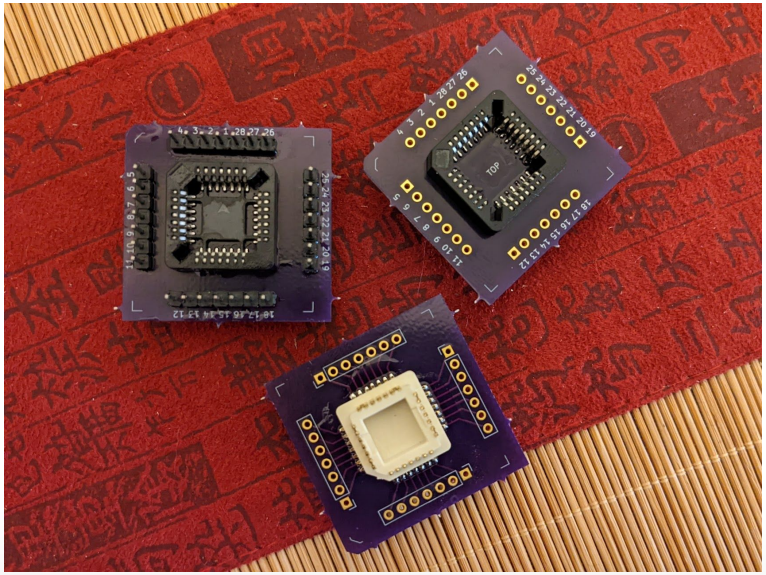
No, honey, it’s only temporary, I promise!

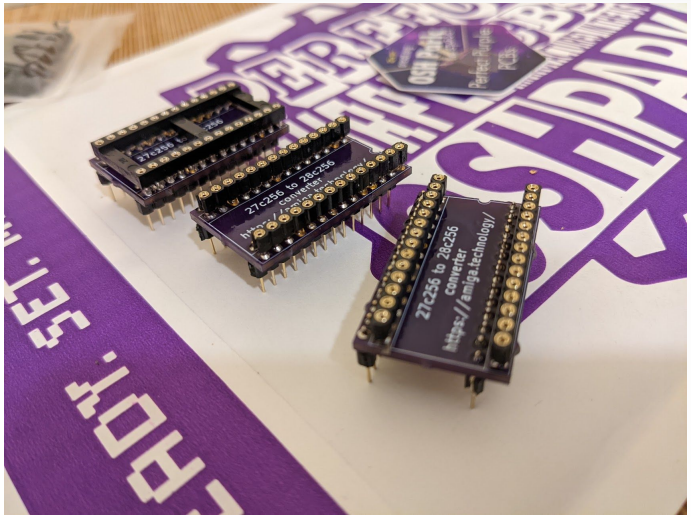


Custom HW along the way

27C256 vs 28C256

- Different, incompatible pin-out
- 28C256 is reflashable (EEPROM)
- Moved to 27C512 which works without adapter + 2x the space





Debugging GALs

- Attaching probes is painful
- Over the top and plug versions

Custom HW along the way

3D printing FTW!

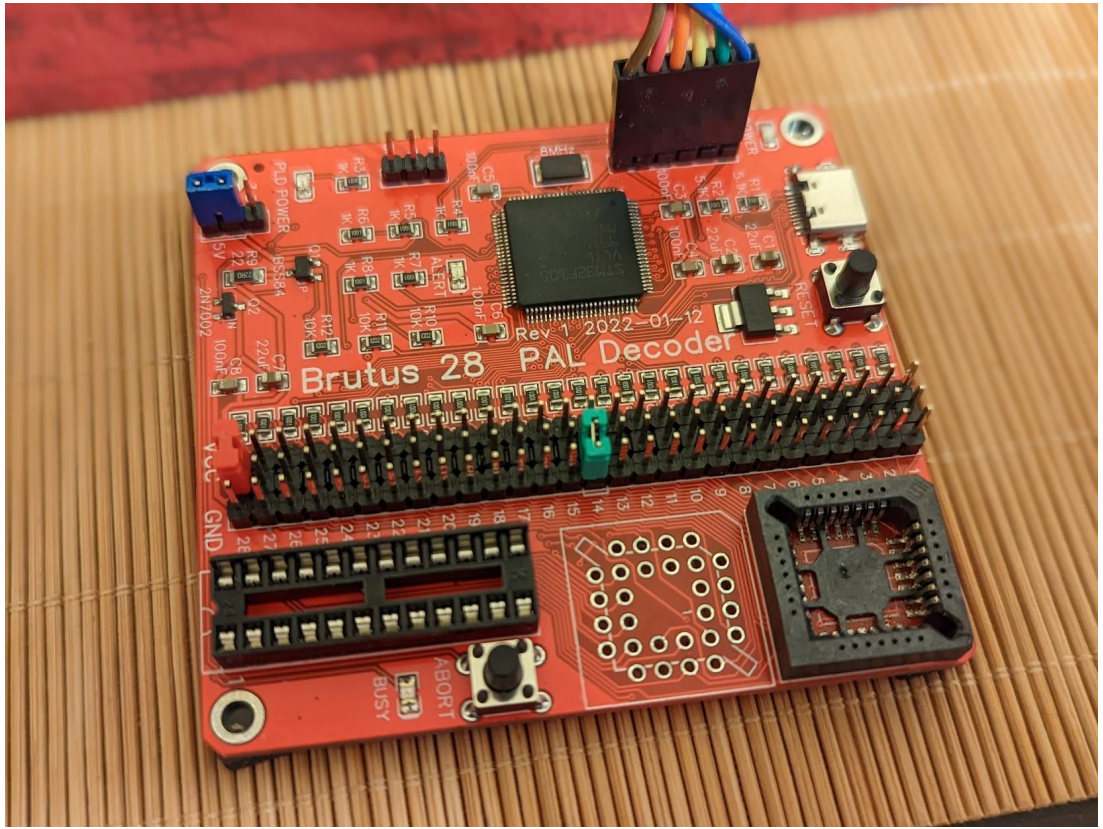
- SCSI2SD carrier
- Home-printable slot bracket

  ⇒ Be warned, it's fragile!

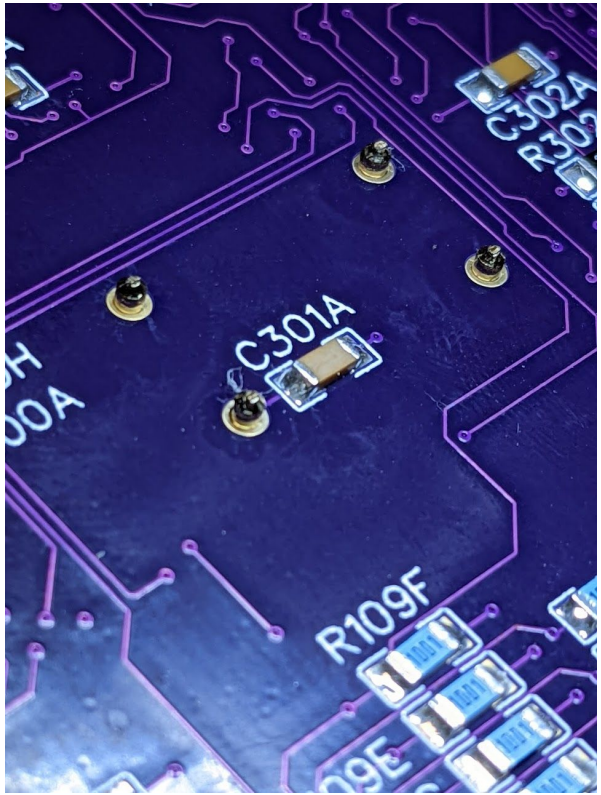
Custom HW along the way

Brutus 28 PAL Decoder

- Kai su, teknon?
- Brute force passive PAL decoding



Building prototypes & production



Rework and Inspection

- Who needs solder?
- Lots of beads

Software - 2nd.scsi.device

What software is driving the A4091?

- Latest released version: 40.13
- 40.20 was spotted in the wild
- CosmosAmiga published a “patched 40.14”
- Drivers contain host portion in Assembler / C and controller portion requiring NCR script assembler that’s virtually unobtainable
- No NSD, no TD64 (but 3.2.1 is tested to support large drives via SCSI-direct)
- A4000T shares almost the same driver (minus the Zorro III part and other minor changes)
- Newer versions unlikely w/ “the situation” of the Amiga community.

Software - Script Compilers & NetBSD

If it’s not open source, it’s a waste of time

- Chris Hooper started rewritten driver based on NetBSD code
- Modern driver design
- Uses open source NCR script compiler from NetBSD
- Decoupled device and partition table handling in separate tasks, please adopt this, community!
- Current speed: 4.2MB/s
- NSD + TD64 support!

Software - a small comparison

a4091.device

```
9.Workbench:4091> devtest a4091.device 0 -pd
TD_GETGEOMTRY          18874368 sectors x 512  C=9216 H=64 S=32  Type=0
TD_CHANGENUM           Success Count=1
TD_CHANGESTATE         Success Disk present
TD_PROTSTATUS          Success Unprotected
TD_GETDRIVETYPE        Fail -3 IOERR_NOCMD (unsupported)
TD_GETNUMTRACKS        Fail -3 IOERR_NOCMD (unsupported)
HD_SCSICMD             Success V='SCSI2SD' P='9GB' R='512' DT=0x0 Linked Sync
CMD_READ               Success
ETD_READ               Success
TD_READ64              Success
NSCMD_DEVICEQUERY      Success
NSCMD_TD_READ64        Success
TD_SEEK                Success
ETD_SEEK               Success
TD_SEEK64              Success
NSCMD_TD_SEEK64        Success
CMD_WRITE              Success
ETD_WRITE              Success
TD_WRITE64             Success 4GB:Success
NSCMD_TD_WRITE64       Success 4GB:Success
TD_FORMAT              Success
ETD_FORMAT             Success
TD_FORMAT64            Success 4GB:Success
NSCMD_TD_FORMAT64      Success 4GB:Success
CMD_STOP               Success
CMD_START              Success
```

C= scsi.device

```
9.Workbench:4091> devtest 2nd.scsi.device 0 -pd
TD_GETGEOMTRY          18874367 sectors x 512  C=1174 H=1 S=16076  Type=0
TD_CHANGENUM           Success Count=0
TD_CHANGESTATE         Success Disk present
TD_PROTSTATUS          Success Unprotected
TD_GETDRIVETYPE        Fail -3 IOERR_NOCMD (unsupported)
TD_GETNUMTRACKS        Fail -3 IOERR_NOCMD (unsupported)
HD_SCSICMD             Success V='SCSI2SD' P='9GB' R='512' DT=0x0 Linked Sync
CMD_READ               Success
ETD_READ               Fail -3 IOERR_NOCMD (unsupported)
TD_READ64              Fail -3 IOERR_NOCMD (unsupported)
NSCMD_DEVICEQUERY      Fail -3 IOERR_NOCMD (unsupported)
TD_SEEK                Success
ETD_SEEK               Fail -3 IOERR_NOCMD (unsupported)
TD_SEEK64              Fail -3 IOERR_NOCMD (unsupported)
CMD_WRITE              Success
ETD_WRITE              Fail -3 IOERR_NOCMD (unsupported)
TD_WRITE64             Fail -3 IOERR_NOCMD (unsupported)
NSCMD_TD_WRITE64       Fail -3 IOERR_NOCMD (unsupported)
TD_FORMAT              Success
ETD_FORMAT             Fail -3 IOERR_NOCMD (unsupported)
TD_FORMAT64            Fail -3 IOERR_NOCMD (unsupported)
NSCMD_TD_FORMAT64      Fail -3 IOERR_NOCMD (unsupported)
CMD_STOP               Success
CMD_START              Success
```

Stop talking, where is it?

The Future

Some ideas!

- Next step: Open Source schematics and gerbers
- Support Zorro III Burst
- Consolidate GALs and other logic in a larger CPLD
- Upgrade to NCR53C720/725 (68030 bus friendly)
- Add RAM
- Half size Zorro card (Mediator / PCI friendly design)
- What would you like to see? (Or work on?)