Extinction Event: Z80

How will Modern/Retro Survive?

45 min

Sean Harrington, Aquarius Evangelist

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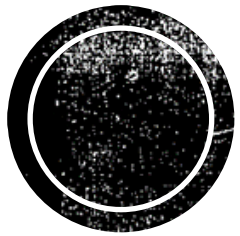
aquarius.plus

Goals

- Brief history of Z80
- Identify systems that use Z80
- Profile EoL effects on users
- Chart paths forward
- Case Study: AQUARIUS+

About the Speaker

- Professional
  - Manager, Application Development, Ventura County Fire Department
  - Professor, California Lutheran University
  - Aquarius+ Development Team
- Educational & Didactic
  - CalARTS – Design, creative
  - BSCS & MSCS – Technical, business of IT
  - CLU – Software Engineering, AI, Data Structures & Algorithms, PM
- Technical
  - Aquarius+
  - C64 – VIC-II^2 board
  - Aquarius upgrades (Motherboard, Aquarius MX, Composite AV & HDMI adapters...)



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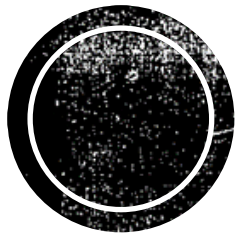
- Wikipedia, "Zilog Z80"

Who will save us?


Who will save us?
Z80



Z80:
A Brief History

In which we review the creation and development of the 48-year-old CPU

Federico Faggin
Father of the Z80

- Italian-American physicist, **engineer**, & entrepreneur
- Olivetti
  - Programma 101, first programmable digital calculator (1964)
- Fairchild
  - SGT MOSFETs (1969)
  - 3708 MUX (1968)
- Intel
  - 4004 & 8008 (1971)
  - 4040 & 8080 (1974)
- Zilog – Formed new company with Ralph Ungermann
  - Z80 (1976) – Engineered by Masatoshi Shima

Z80:
Genealogy

Intel

4004 → 4040

8008 → 8080

8080 → 8086

8086 → x86

x86 → x64

Zilog

Z80

Z80 → Z180

Z80 → Z280

Z180 → Z280

Z180 → Z380

Z280 → Z380

Littelfuse

Z80 → eZ80

Other Manufacturers

Z80 → MK3880

MK3880 → LH0080

Z80 → Z84C00

Z84C00 → µPD780C

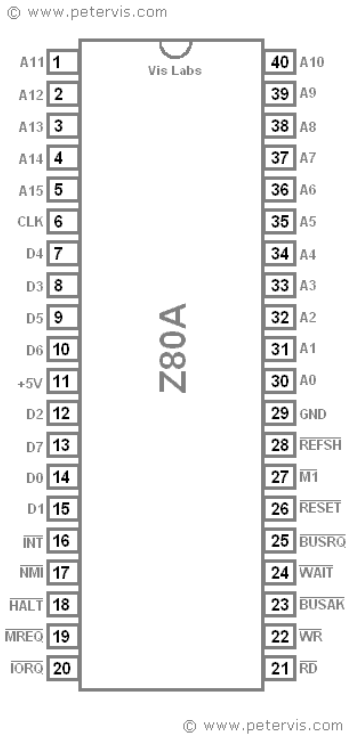
Z80 → NSC800

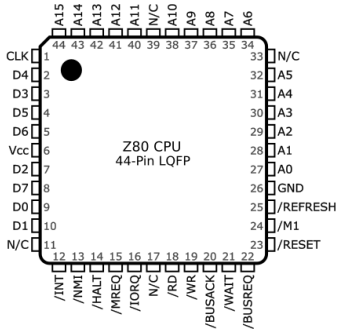
Open Source

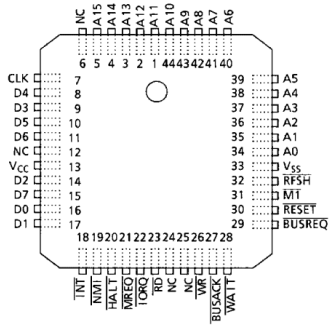
Z80 → T80 (VHDL)

T80 (VHDL) → TV80 (Verilog)

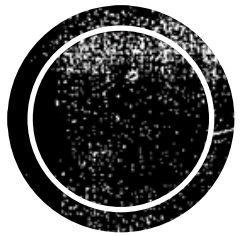
Z80:
Footprints







DIP-40 **QFP-44** **PLCC-44**



Z80-Based Systems

In which we identify the range of hardware that incorporated the CPU

Z80-Based Systems
Computers and Game Consoles

- Amstrad CPC
- Aquarius+
- Bally Astrocade
- ColecoVision
- Coleco ADAM
- GameBoy/Color
- Jupiter Ace
- Kaypro I/II
- LYNX
- Mattel Aquarius
- MSX
- NABU PC
- Osborne I
- PC-6000 to 8800
- Sega GameGear
- Sega Master System
- Sharp MZ/X1
- SG-1000
- Sony SMC-70
- Spectrum Next
- Timex Sinclair
- Toshiba Pasopia
- TRS80 I/II/3/4
- V-Tech Laser 200
- Zenith Z-100
- ZX80/81
- ZX Spectrum

Z80-Based Devices
Embedded & Add-On

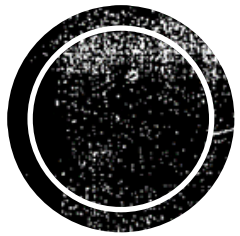
- Capcom CPS
- Commodore 128
- CP/M C64 Cartridge
- Franklin Ace 1200
- MS Z80 Softcard, Apple II CP/M
- Sega MegaDrive/Genesis
- Video Genie
- Texas Instruments Calculators:
  - TI-73
  - TI-81
  - TI-82
  - TI-83
  - TI-84
  - TI-85
  - TI-86

Z80-Based Arcade Games

A list of 75 out of Hundreds

- 10 Yard Fight
- **1942/1943**
- Alpine Ski
- Arabian
- Arkanoid
- Asteroids Deluxe
- Ataxx
- Bagman
- Bank Panic
- Bio Attack
- Blueprint
- Bosconian
- **Centipede**
- Commando
- Congo Bongo
- Crazy Climber
- Demolition Derby
- **Dig Dug**
- Domino Man
- **Donkey Kong/Jr.**
- Elevator Action
- Eliminator
- Exed Exes
- Exerion
- Fire Trap
- **Frogger**
- Front Line
- **Galaga**
- Gorf
- Grand Champion
- Hellfire
- Higemaru
- Journey
- Jump Bug
- Jump Coaster
- Jungle Hunt
- Kangeroo
- Karate
- Kick Man
- Kozmik Krooz'r
- Legend Of Kage
- Moon Cresta
- Omega Race
- **Pac-Man/Ms./Jr.**
- **Pole Position**
- Pooyan
- Popeye
- Rally X
- **Rampage**
- Ring King
- Robby Roto
- Sarge
- Satan's Hollow
- Solar Fox
- Space Fury
- Space Zap
- **Spy Hunter**
- Star Trek
- Stratovox
- Tac/Scan
- Tapper
- Timber
- Time Pilot
- Time Tunnel
- Tin Star
- **Tron**
- Two Tigers
- Up'n Down
- Vulgus
- Wacko
- Wild Western
- Wizard of Wor
- Wonder Boy
- Xevious
- **Zaxxon**

Games in **BOLD** are commonly listed among top arcade games of all time.



Z80 Users

In which we identify **personas** for enthusiasts of Z80-based systems

Randy Kindig's
Categories of Vintage Computer Enthusiasts

Category	Attributes	How Affected by Z80 EoL
▪ Purists	▪ Like old original hardware as it was originally built and used, back in the day	▪ Aging original components must be sourced online or through repair person
▪ Emulation	▪ Like the old machines, but don't have the resources to purchase, operate, and maintain them	▪ Unaffected
▪ Mixture	▪ Like original hardware, but don't enjoy the limitations	▪ The more flexible the person's attitude, the more open they are to alternative options to repairing or upgrading their system

Sean Harrington's
Personas of Vintage Computer Enthusiasts

Persona	High Level Use Case	How Affected by Z80 EoL
▪ User	▪ USES original hardware, emulator, or both, for enjoyment	▪ Depends on their desire to continue using hardware when a repair or upgrade is needed
▪ Collector	▪ COLLECTS original hardware and software	▪ Will probably stockpile spare Z80 chips for repairs
▪ Developer	▪ Creates new SOFTWARE for legacy systems	▪ Generally unaffected unless next generation CPU is used
▪ Engineer	▪ Designs new HARDWARE for legacy systems OR new Modern/Retro systems	▪ Will virtualize legacy components and improve manufacturability

Survey: Modern vs. Retro
Which is Better?

Games: Three
Cost: US$600
Weight: 92 lbs
Cab. Volume: 14 cu ft.
Elec. Volume: ¼ cu ft.
Power Draw: 15 watts
Service: none

Audience: **Users**

Arcade1Up Atari Star Wars

Original Atari Star Wars

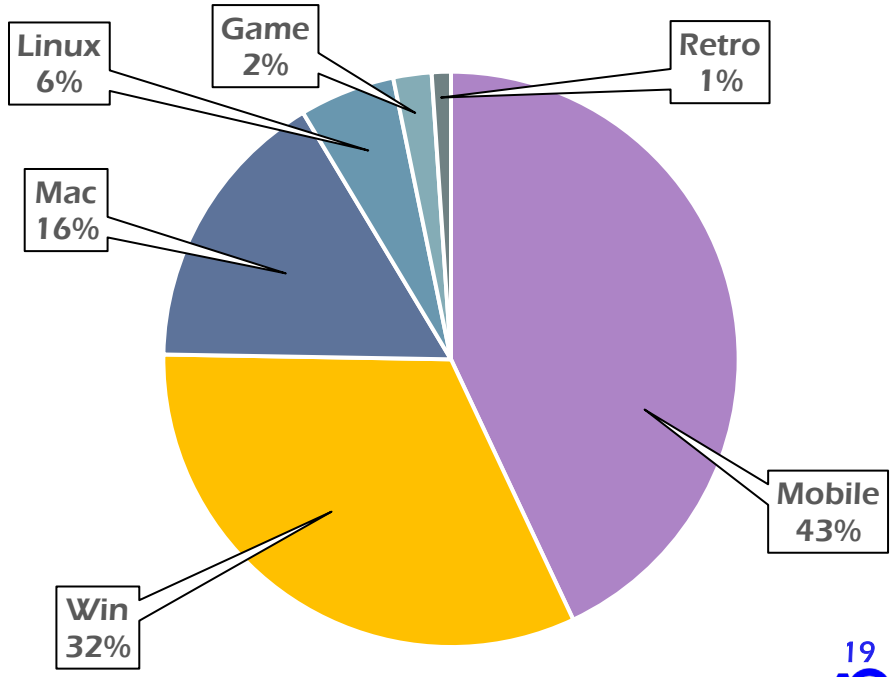
Games: One
Cost: US$6000
Weight: 320 lbs
Cab. Volume: 35 cu ft.
Elec. Volume: 10 cu ft.
Power Draw: 600 watts
Service: frequent

Audience: **Collectors**

They're both great solutions for the right persona.

Survey: Screen Time
!!! Hardware Only !!!

- Everyone start with their hand raised...
- Lower your hand if you spend most of your time on a...
- Mobile device
- Windows computer
- MacOS computer
- Linux computer
- Modern game console
- Retro computer or game system



Conclusions:

- **Most of the time, we're *USERS* of *systems***
- Very few of *us* are **COLLECTORS** of *systems*
- Some of *us* are **DEVELOPERS** of *software* for *systems*
- Not enough of *us* are **ENGINEERS** of *systems*

We're All Users:
Tools of Vintage Computer Enthusiasts

Persona	High Level Use Case	Tools Used for Retro
▪ User	▪ USES original hardware, emulator, or both, for enjoyment	▪ Social media, email, browser, apps, & emulators running on modern systems
▪ Collector	▪ COLLECTS original hardware and software	▪ Same as users + eBay, computer fairs and swap meets
▪ Developer	▪ Creates new SOFTWARE for legacy systems	▪ Same as users + IDEs, compilers, and graphics tools
▪ Engineer	▪ Designs new HARDWARE for legacy systems OR new Modern/Retro systems	▪ Same as users + Verilog/VHDL tools, design tools, simulators, PCB manufacturing tools

Moore's Law: OBEY!

Sean's Journey

- Typewriter: 1978 - 1984
- Aquarius: 1984 - 1986
- C64: 1985 - 1987
- Mac SE: 1987 - 1992
- Mac IIfx: 1991 - 1994
- Mac IIci: 1994 - 1997
- Mac 8550: 1997 - 1999
- Win XP: 1999 – 2004
- Vista: 2004 - 2007
- Win 7: 2007 - 2012
- Win 8: 2012 - 2015
- Win 10: 2015 - 2021
- Win 11: 2021 - present

This was Jeffrey Brace's favorite slide at VCF West 2023.

Waypoints:
40 Year Span

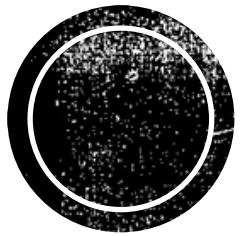
Computers, circa 1984

- 8-bit Data Bus
- Through hole components
  - Glue logic chips
  - Specialty chips
  - 0.1" pins
  - TTL – 5v logic
- 2-Layer PCBs
- External video, RF, Composite
- 19.2 kbps serial, wired

Computers, circa 2024

- 64-bit Data Bus
- Surface mount components
  - Governor/SoC modules
  - FPGA/CPLD/GAL chips
  - QFP & BGA "pins"
  - 0.8v to 3.3v logic
- 4 to 6-Layer PCBs
- Integrated video, HDMI
- USB, WiFi, Bluetooth, I^2C bus, Gb Ethernet

Repairability & upgradability has suffered.



Paths Forward

In which we present options for dealing with the end of Z80 manufacturing

The Z80 is Dead!

Long live the Z80!

Mitigation:
How to Z80 without a Z80

For an **engineer** to develop a supportable, manufacturable, & sustainable system, a few options can be considered:

- **Source/stockpile original replacement parts**

Sourcing Original Parts

Marketplaces

- eBay & Facebook MP
- Festivals & swap meets
- Social media
- Thrift & antique stores
- Attics, closets, sheds
- eWaste/recycling centers

Sourcing Issues

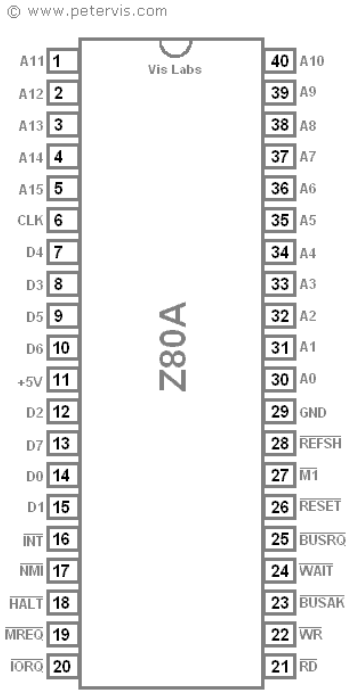
- Availability
- Counterfeit devices
- Overpay, over invest
- Clock speeds
- Hand assembly/repair
- Optimization for automated assembly

Footprints in the Sand
(Silicon)

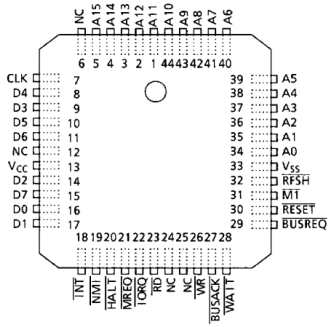
Hand Assembly

Pic-N-Place Friendly

DIP-40



PLCC-44



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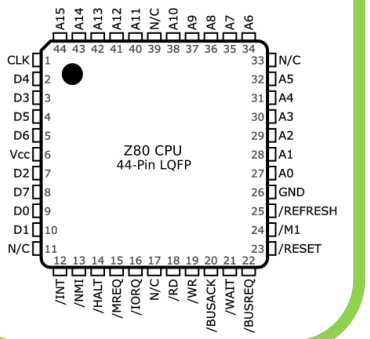

Problem: What if you can't get a Z80 at all?

July 31, 2024:
Z-Day

About Project Aquarius+ Computer, Standard PCB

External › Inbox ×

PCBWay Online Services Team 12:20 AM (8 hours ago)

to me

Hi, Sean,

About project Aquarius+ Computer, Standard PCB, the moel Z84C0010AEG is now out of stock, is it possible for you to recommend us some substitutions?

Looking forward to your reply.

Best Regards.

2024-07-31

Brynn

Tel:86-571-85103032 | brynn@pcbway.com

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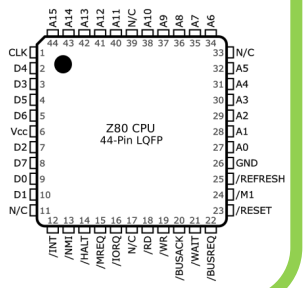
QFP-44



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- **Hardware Update**

Hardware Update

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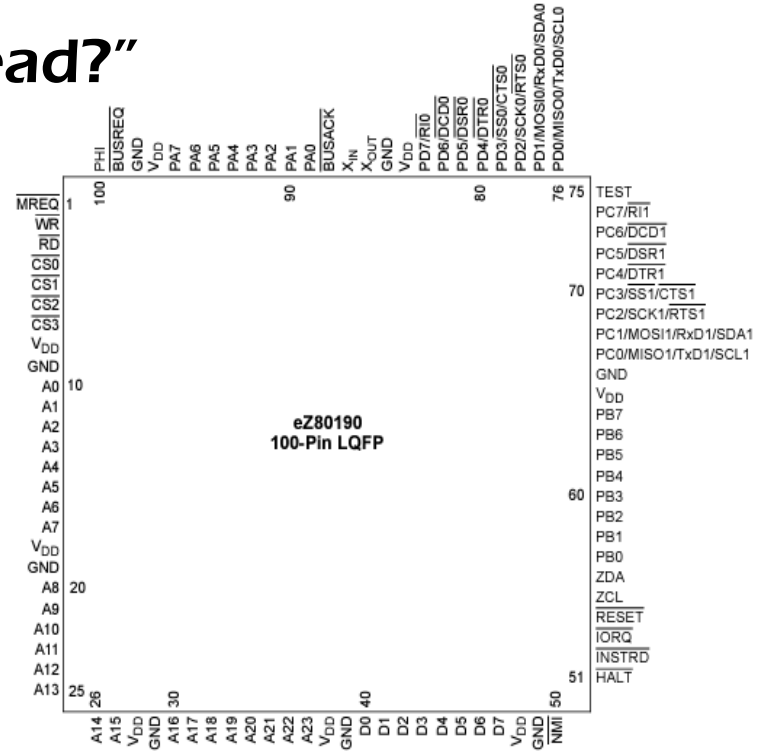
eZ80:
The Heir Apparent?

"Can't you just drop in an eZ80 instead?"

- Cost: $10 vs. $6
- 100 pins vs 40-44 pins
- New control pins
- Tighter pin density = more PCB layers
- Power: 3.3v vs 5.0v = level shifters
- Onboard SRAM
- Timing, timing, timing



Result: You've designed a whole new system.

Mitigation:
How to Z80 without a Z80

For an **engineer** to develop a supportable, manufacturable, & sustainable system, a few options can be considered:

- Source/stockpile original replacement parts
- Hardware Update
- **Virtualize**

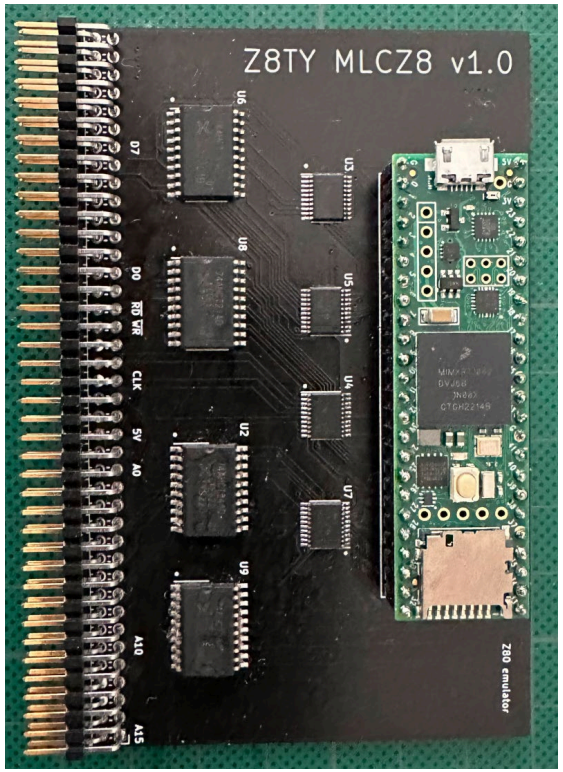
Virtual Z80:
Best Open-Source Cores

- **T80** - https://opencores.org/projects/t80
  - Written in **VHDL**
  - Started: 4/21/2002
  - Last Updated: 9/6/2018
- **TV80** - https://opencores.org/projects/t80
  - Translated to **Verilog**
  - Started: 5/14/2004
  - Last Updated: 1/30/2019

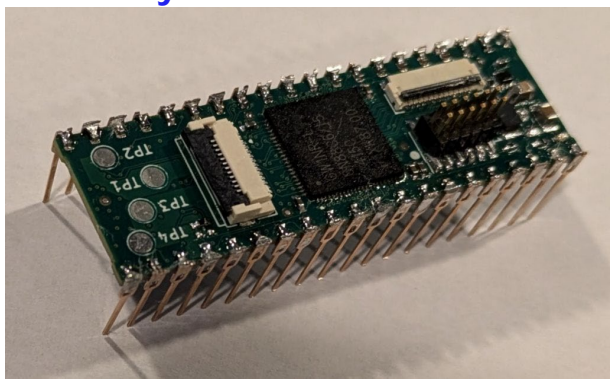
Result: with FPGA, you can scale your Z80 to greater speeds, and you've probably already virtualized other chips anyway.

Virtual Z80:
Drop-In Replacements

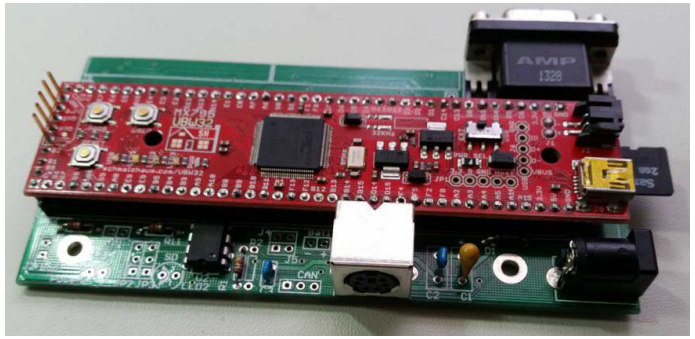
MSX CPU Card: Z80 on a Teensy 4.1



UnIC Z80 on a GW1NR FPGA
by Andros Tantos



TRS-80 Model 1 on a PIC32



Result: Harder than buying a Z80 DIP-40 from eBay?

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How to Z80 without a Z80

For an **engineer** to develop a supportable, manufacturable, & sustainable system, a few options can be considered:

- Source/stockpile original replacement parts
- Hardware Update
- Virtualize

Best in Class:
Modern/Retro FPGA Z80 Systems

Spectrum Next

- US$410
- 2MB RAM, Standard
- RGB, VGA, HDMI
- SD Card (tape supported)
- 3 Virtual AY PSGs, 8 DACs
- ESP8266 WiFi
- Z80 CPU
  (virtual in FPGA)

Aquarius+

- US$209
- 512Kb RAM
- VGA
- SD Card (tape supported)
- 2 Virtual AY PSGs, 1 DAC
- ESP32 WiFi, Bluetooth LE
- Z80 CPU
  (physical OR virtual in FPGA)

AQUARIUS+ WHY?

In which we discuss the challenges of reimagining a 40-year-old flop

Aquarius & Aq+:
Price-to-Features Comparison

Aquarius Bundle – 1984
+ Data Recorder

- **US$350 (Scaled for inflation)**
- 6k Usable RAM (with 4k RAM cart)
- Data Recorder, serial tape storage
- 2 @ Aquarius Joypad Controllers
- Static system ROM
- Single PSG
- RF video out
- Character graphics only

Aquarius+ Signature – 2024
+ USB Keyboard & Mouse + Xbox Controller

- **US$300**
- 256k Usable RAM
- 32Gb SD Card, random access storage
- Xbox Bluetooth LE controller
- WiFi system updates
- Dual PSGs + DAC
- VGA out
- Advanced graphics (sprites, tilemaps, bitmaps, etc.)

Aquarius & Aq+: Specification Comparison

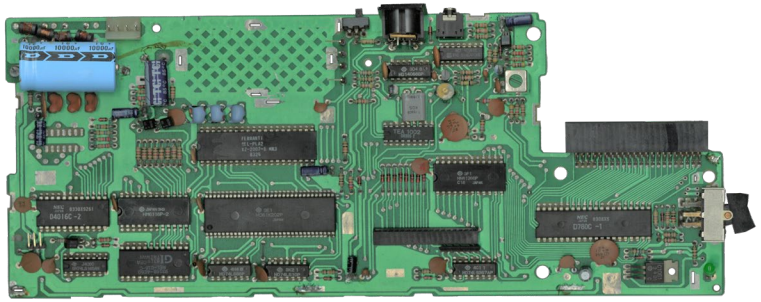
Original Mattel Aquarius

- Zilog Z80 processor running at ~3.8Mhz
- 4k of onboard RAM
  - 1k of Character RAM
  - 1k of Color RAM
- Expansion bus for ROMs and RAM
- RF Modulator for video out
- Chicklet-style keyboard with 50 rubber keys
- Printer and Data Recorder ports
- PLA1 and PLA2 for system management
- TEA1002 video chip
- 8k SYSTEM ROM

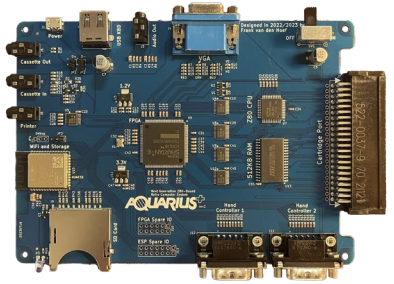
Aquarius+

- Zilog Z80 processor running at ~3.8Mhz + Turbo mode
- 512kb of paged RAM in four 16k banks
  - 2k of Character RAM
  - 2k of Color RAM
- Legacy expansion bus, controller, printer, and cassette ports
- VGA output with sprites, bitmaps, tiles, & 80 column mode
- USB keyboard + mouse input
- SD card for high-speed data storage and retrieval
- Spartan 6 FPGA for system devices (sound, IO, etc.)
- ESP32 S3 with WiFi and Bluetooth connectivity
- OTA system updates delivered wirelessly

Aquarius & Aq+:
PCB Size Comparison



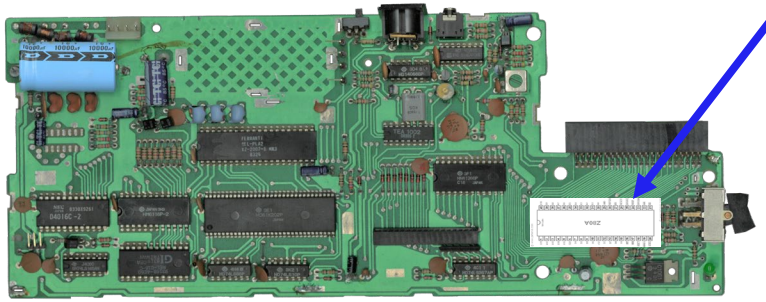
Mattel Aquarius

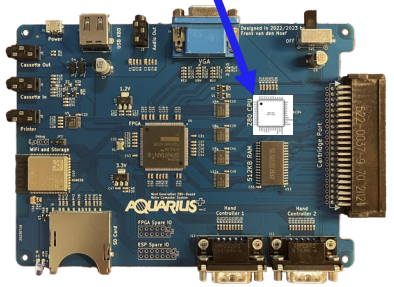


Aquarius+

Aquarius & Aq+:
PCB Size Comparison

Z80 CPU





Mattel Aquarius

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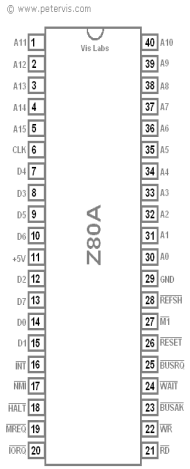

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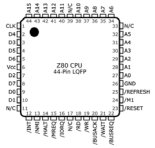

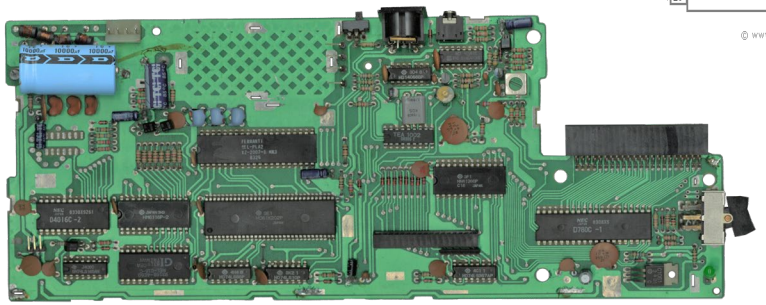

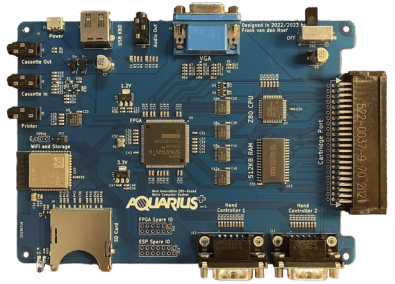

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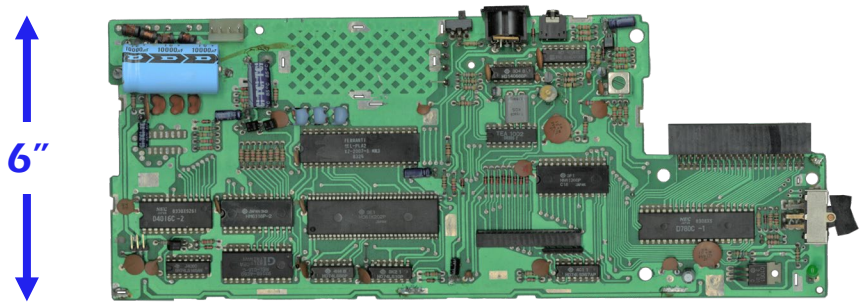
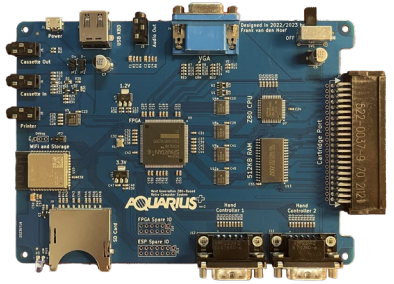


6″

14″

Mattel Aquarius



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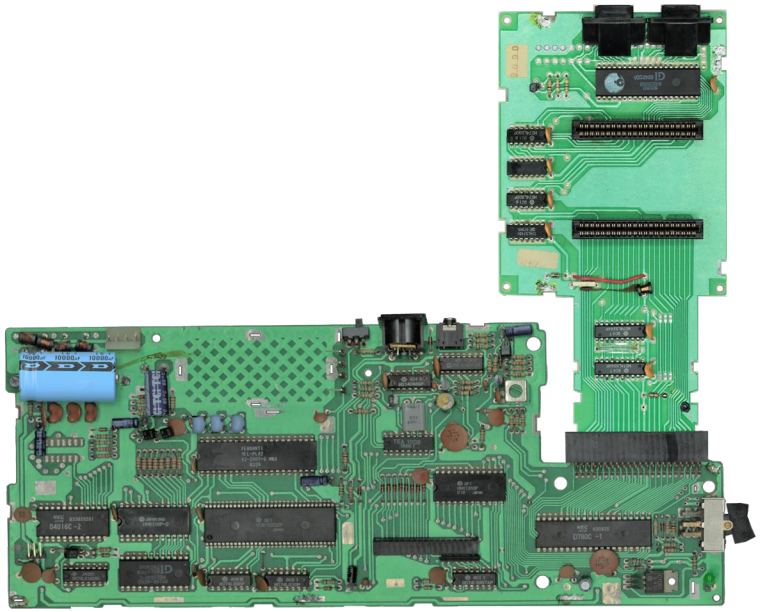
Aquarius+

Aquarius & Aq+:
PCB Size Comparison

Mini Expander



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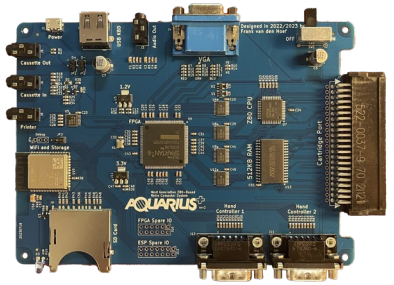
Mattel Aquarius



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Aquarius+

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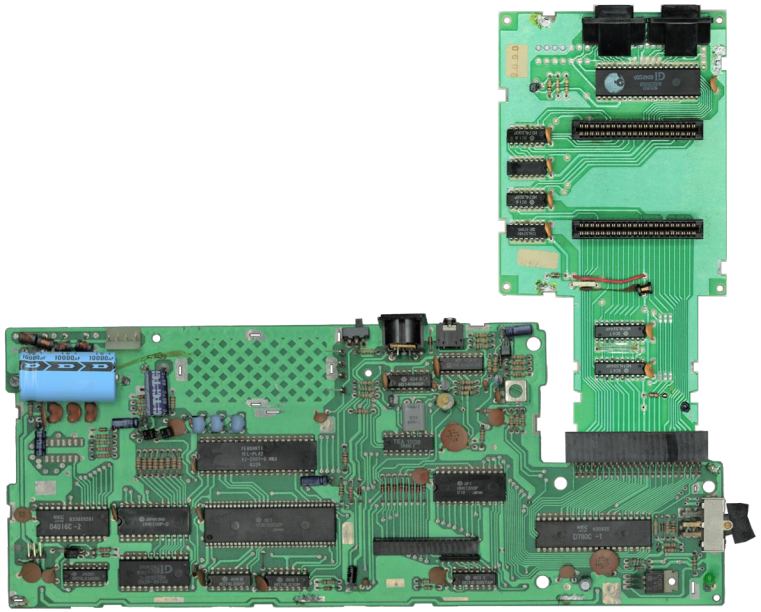
PCB Size Comparison

Mini Expander



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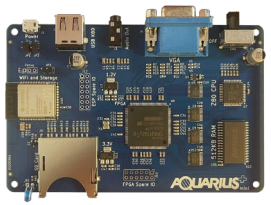
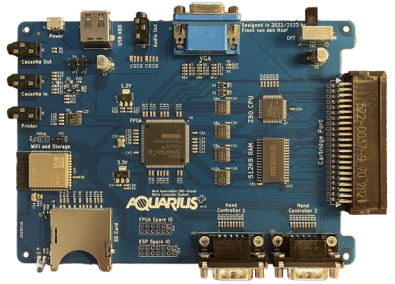
Mattel Aquarius

Aquarius+ Mini





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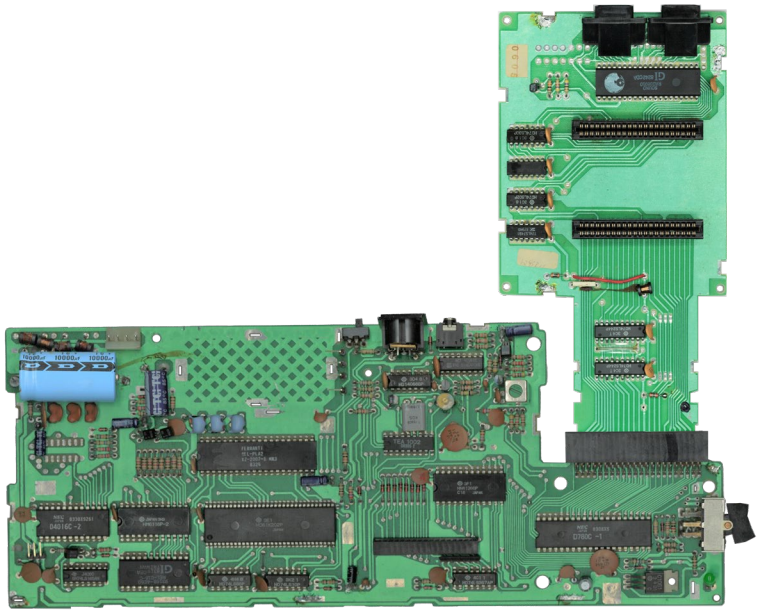
Aquarius+

Aquarius & Aq+:
PCB Size Comparison

Mini Expander



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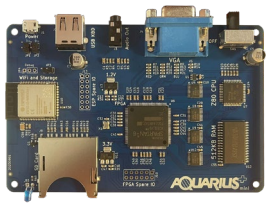
Mattel Aquarius

Aquarius+ Mini



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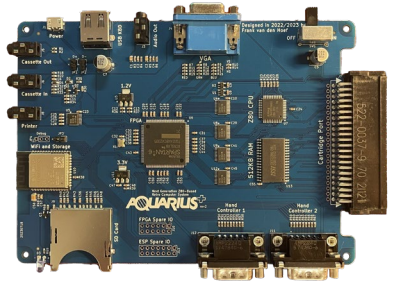

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Aquarius+

Aquarius+: Transitioning to a vZ80

Benefits

- Smaller PCB size
- Reduced component count
- Flexible case design
- Speed increase

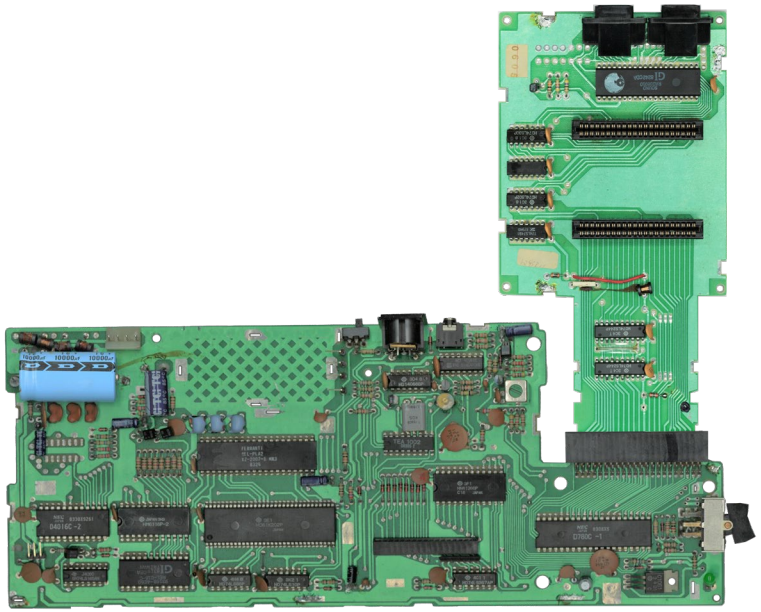
Challenges

- Lose “Z80 inside” credibility
- Kernel/SYSROM modifications
- Timing adjustments require better simulation tools
- Verilog / VHDL engineers are unicorns

The Aquarius+ will have vZ80 flexibility by Fall 2024

Aquarius & Aq+:
PCB Size Comparison

Mini Expander



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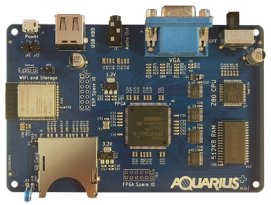
Mattel Aquarius

Aquarius+ Mini



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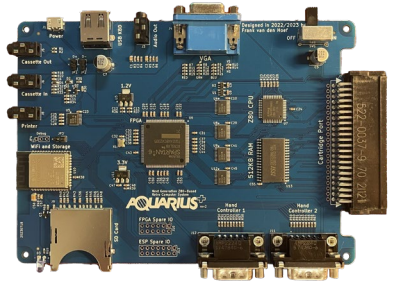

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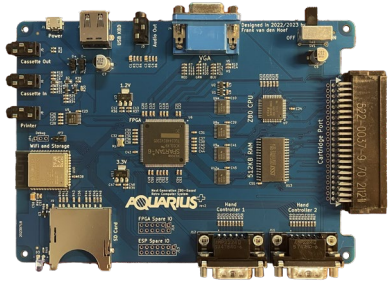
Aquarius+

Aquarius+:
PCB Size Comparison



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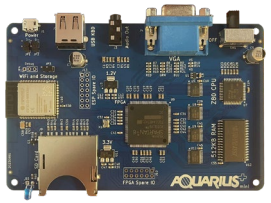
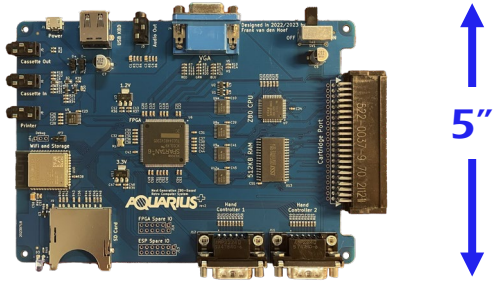
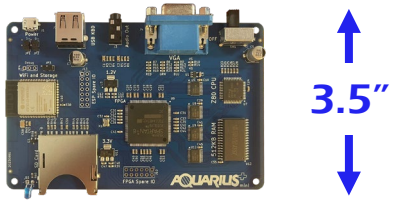
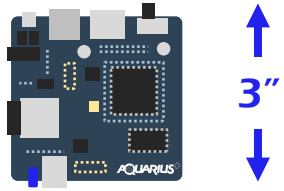


Aquarius+ Mini

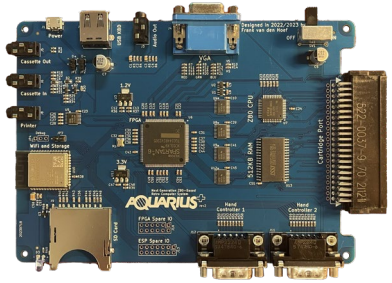
Aquarius+:
PCB Size Comparison





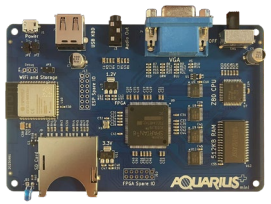


Aquarius+:
PCB Production Cost Comparison



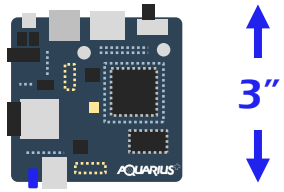
Aquarius+

- 146 @ SMD
- 13 @ TH/Manual
- US$70 @ 50 units



Aquarius+ Mini

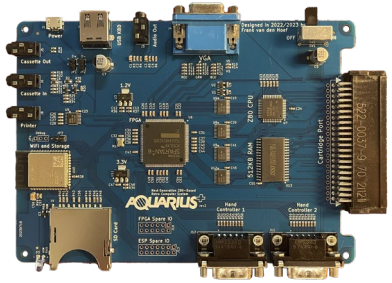
- 105 @ SMD
- 8 @ TH/Manual
- US$50 @ 50 units



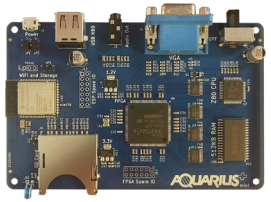
Aq+ vZ

- 85 @ SMD
- 8 @ TH/Manual
- US$35 @ 50 units (estimated)

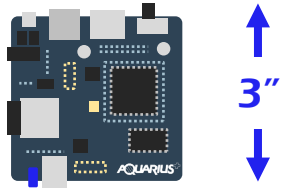
Aquarius+:
Production Form Factors



Aquarius+



Aquarius+ Mini



Aq+ vZ

- Aquarius+ Micro
- Aquarius+ Mobile
- Aquarius+ Laptop
- Aquarius+ Tablet
- Aquarius II+ (breadbin)

Aquarius+:
vZ80 Platform of the Future?

- Aquarius+ Micro
- Aquarius+ Mobile
- Aquarius+ Laptop
- Aquarius+ Tablet
- Aquarius II+ (breadbin)

- Amstrad CPC
- Bally Astrocade
- ColecoVision
- Coleco ADAM
- GameBoy/Color
- Jupiter Ace
- Kaypro I/II
- LYNX
- MSX
- NABU PC
- Osborne I
- PC-6000 to 8800
- Sega GameGear
- Sega Master System
- Sharp MZ/X1
- SG-1000
- Sony SMC-70
- Timex Sinclair
- Toshiba Pasopia
- TRS80 I/II/3/4
- V-Tech Laser 200
- Zenith Z-100
- ZX80/81
- ZX Spectrum

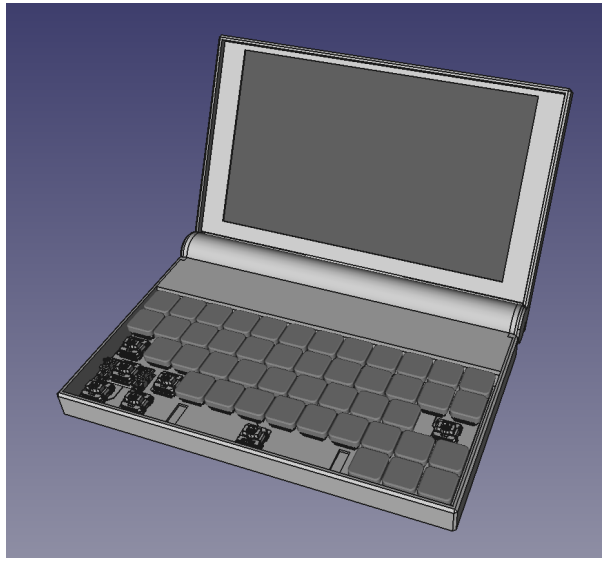
Aquarius+:
Modern/Retro Platform of the Future?

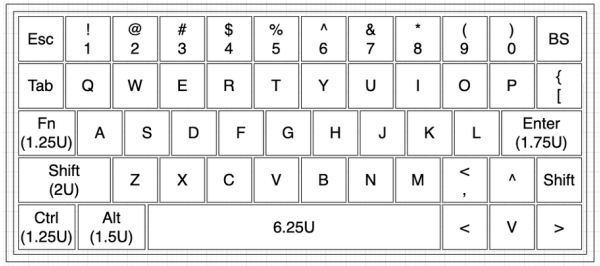
- Acorn Electron
- Altair 8800
- Apple II
- Atari 2600
- Atari 400/800
- BBC Micro
- C64
- C128
- Commodore PET
- Dragon 32
- FujiNet
- IBM PC/PC Jr/XT
- IMSAI 8080
- Intellivision
- Magnavox Odyssey
- NEC PC-88
- NES/Famicom
- PC Engine
- Sega MegaDrive/Genesis
- Tandy CoCo
- TI-99/4A
- VIC20
- Video Games

Isn't it basically a MiSTer at this point?

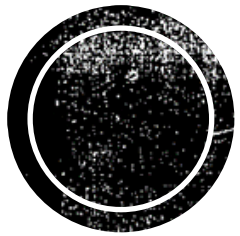
This Just In:
Frank's FPGA Laptop

- Dimensions (closed) 9.3x6.3x1.2" (237x160x29.5 mm)
- 9" display @ 1024x600
- Reduced (full-size, low-profile keys) QWERTY keyboard
- ESP32
- Lattice ECP5 FPGA (TQFP-144)
- NO DEDICATED CPU
- No details on RAM, ports, batteries, etc.





Came in morning of 8/3/2024.



Conclusion

In which we pull everything together, hopefully.

Z80 Users:
Embrace Modern/Retro!

- **Join a community**
- Download and try emulators for new and classic Z80-based systems
- Make your voices heard
- Become a **developer**! Programming BASIC is fun!

Z80 Collectors:
Document your hobby!

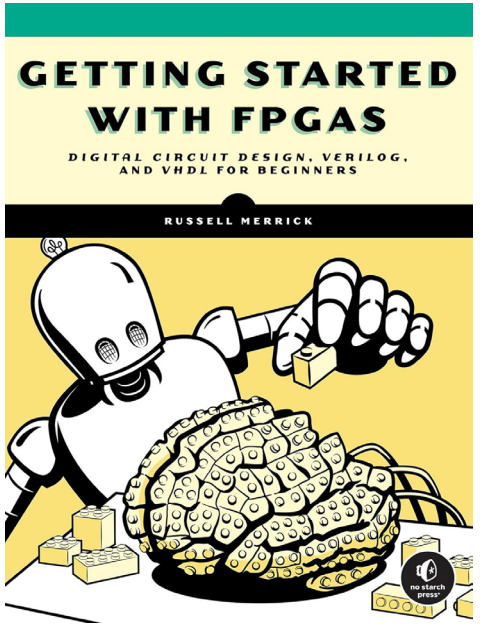
- **Join a community**
- Take pictures & collect technical documentation
- Identify reliable/reputable sources for replacement parts
- Expand and share your knowledge with the community & the world
- Become an **engineer**

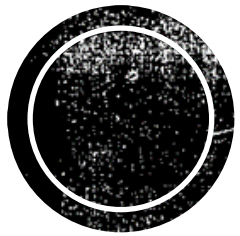
Z80 Developers:
Write more software!

- **Join a community**
- Explore new software development tools
- Port an existing Z80-based program to a new Z80 platform
- Work to improve libraries and info repositories
- Publish your software & document your methods
- Promote learning software development

Z80 Engineers:
Make more cool stuff!

- **Join a community**
- Expand your toolset
  - KiCAD
  - Fusion 360
  - 8bitWorkShop.com
- Learn Verilog / VHDL
- Collaborate on new Modern/Retro hardware





Have fun!

Happy Z80-ing!

More Great Talks
This Afternoon @ VCF West

Mastering PCB Design with KiCAD: From Concept to Creation

Marcel Erz – 2:00pm

Dive into the world of PCB design with KiCAD. This session is geared towards beginners. From crafting schematics to generating PCB layouts and ordering prototypes, you'll gain practical skills applicable to vintage computing and beyond.

Testing 678 Chips and Counting

Evie Salomon – 3:00pm

Repairing vintage machines can be extremely frustrating, as anybody who's worked on one knows. There are numerous troubleshooting tools that can be used, such as a multimeter, logic analyzer, or memory oscilloscope. But what if the problem is internal to an integrated circuit? Layers upon layers of buried logic can take forever to decipher. That's where automated testing can really come in handy.

Aquarius+ Giveaway
Enter to win!

- Badges $10 at VCF check-in counter
- Signed by Sean Harrington, front and back
- Each badge has a unique serial number
- Drawing to be held at 2:45pm on Saturday, 8/3/2024
- **Must be present with badge to win**
- Minimum chances to win are 2:50
- All proceeds benefit Vintage Computer Federation a 501(c)3 organization

Shout-outs!

- Marya Harrington
- Frank van den Hoef
- Curtis F Kaylor
- Mack Wharton
- Matt Pilz
- Roy Templeman
- Richard Chandler
- Jay Snellen
- Jay Mundy
- TJ Ferreira
- Christian Simpson
- Jan Beta
- Matt Heffernan
- Sellam Ismail
- *Derek Jackson*
- *John Chelner*
- *Bill Smith*
- *J.K. Shepherd*
- *John Henderson*

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Contact info

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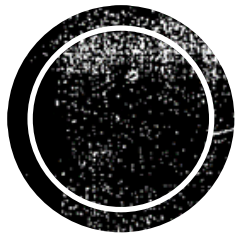
https://aquarius.1stage.com

https://github.com/fvdhoef/aquarius-plus



Questions?