Platform System Interface

Design and Evaluation of Computing as a Whole

Daniel Maslowski

Agenda

- Designing a Computer
- Discovering a Computer
- Platforms and Systems
- Layers and Interfaces
- Research and Development

Designing a Computer

Design and Research (from 1960s on)

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Design helps find *solutions*.

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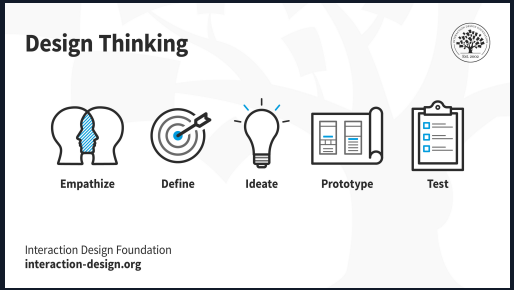

Image by Interaction Design Foundation, CC BY-SA 3.0

https://www.interaction-design.org/literature/topics/design-thinking

The Nature of Design Practice and Implications for Interaction Design Research

http://www.ijdesign.org/index.php/IJDesign/article/viewFile/240/139

Dieter Rams' Ten Principles of Good Design (late 1970s)

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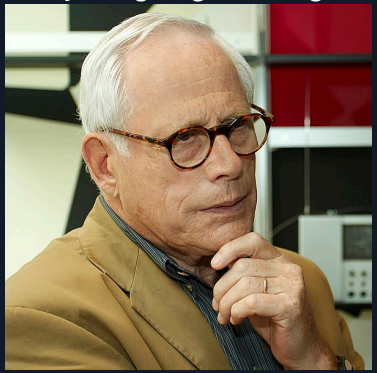
"Is my design a good design?"



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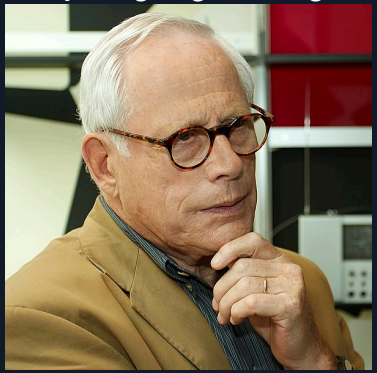

Good design…

1. is innovative.
2. makes a product useful.
3. is aesthetic.
4. makes a product understandable.
5. is honest.
6. is unobtrusive.
7. is long-lasting.
8. is thorough down to the last detail.
9. is environmentally friendly.
10. is as little design as possible.

https://en.wikipedia.org/wiki/Dieter_Rams

Holistic Architecture[1]

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"Who *made* this..?!"

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"Why didn't they *consider this*?
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Holistic architecture means to design
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Holistic Architecture[1]

"Who *made* this..?!"

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Holistic architecture means to design for a *whole* system.

That is not easy and requires *knowledge* and *experience*.

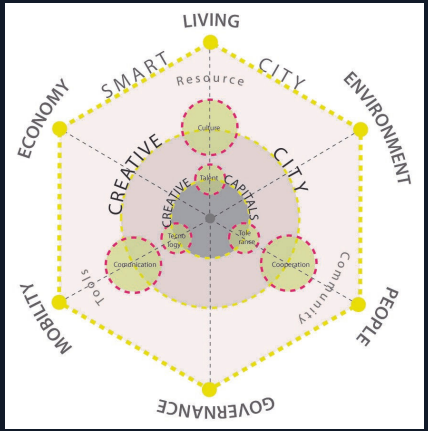

Image by Maurizio.Carta, CC BY 3.0

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Explicit and Implicit Knowledge

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> *Implicit Knowledge is knowledge that is gained through incidental activities, or without awareness that learning is occurring.*

https://trainingindustry.com/glossary/implicit-knowledge/

Tacit and Tribal Knowledge

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> *Tribal knowledge refers to any unwritten knowledge within a company that is not widely known.*

https://www.lucidchart.com/blog/what-is-tribal-knowledge

Computer Knowledge

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A lot of knowledge about computers is hard to pass on and takes time to learn. Manuals can be very sparse and require experience to read.

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At the same time, it is a mystery to figure out what ideas are transferable, what is common between vendors and products, and what is specific.

Electromechanical Computers

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Harvard Mark I
1944, general-purpose computer
First programmers: Richard Milton Bloch, Robert Campbell, Grace Hopper

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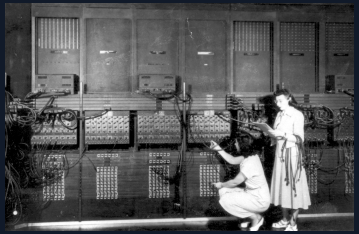

ENIAC

1945, first programmable, general-purpose digital computer

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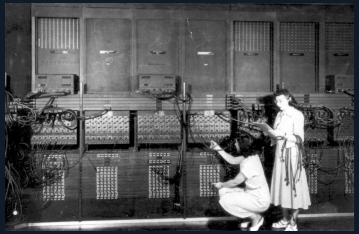
Electronic Computers



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Betty Holberton invented breakpoints.

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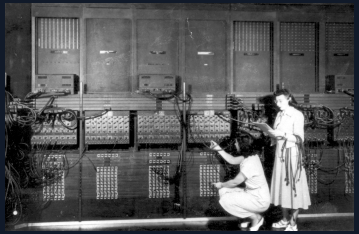

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It just turned 75 on December 23. :-)

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> *John Bardeen, Walter Brattain and William Shockley invented the first working transistors at Bell Labs, the point-contact transistor in 1947. Shockley introduced the improved bipolar junction transistor in 1948, which entered production in the early 1950s and led to the first widespread use of transistors.*

https://en.wikipedia.org/wiki/History_of_the_transistor

https://www.pbs.org/transistor/index.html

Assembly Language (1947)

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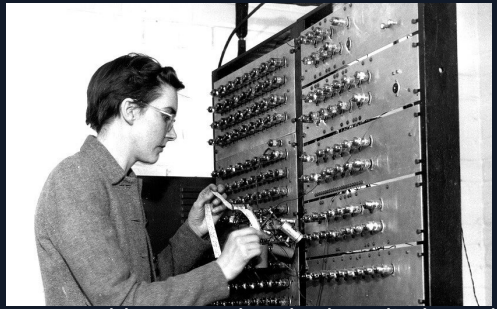

Kathleen Booth, who has died aged 100, co-designed of one of the world's first operational computers and wrote two of the earliest books on computer design and programming; she was also credited with the invention of the first "assembly language", a programming language designed to be readable by users

https://www.telegraph.co.uk/obituaries/2022/10/25/kathleen-booth-computer-pioneer-who-made-major-breakthrough/

Electronic Delay Storage Automatic Calculator (1949)[2]

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PREFACE

This statement is the first part (Part A) of a description of the electronic calculating machine which has been built at Cambridge. The statement is so prepared that it can stand by itself; it gives a general idea of the way in which the machine works, and is divided into the following five sections:-

Part B will give a more detailed description of the way in which the different organs of the machine are designed to carry out their functions.

Part C will show the arithmetical operations and representative types of clerical process that the machine can carry out; it will also show what has to be done to analyse a complete problem so that it can be given to the machine.

[2] https://www.leo-computers.org.uk/images/How%20EDSAC%20Works.pdf

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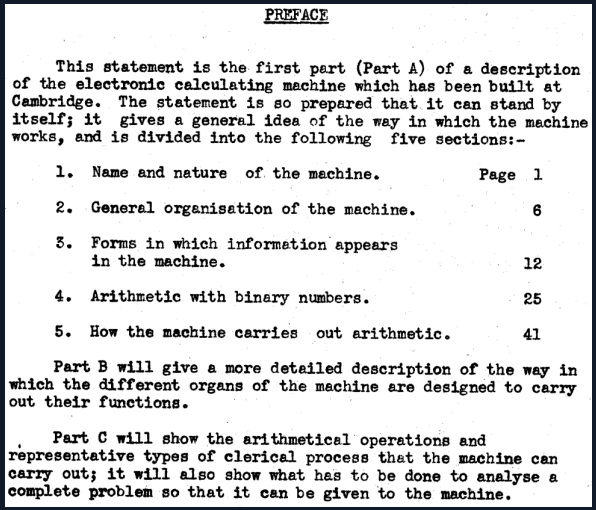

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Assembly language: “initial orders”

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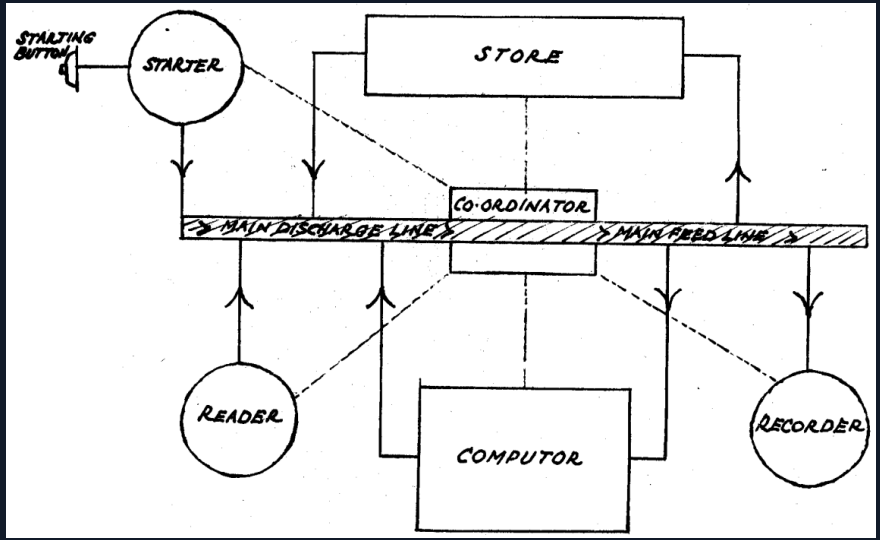
EDSAC Diagram



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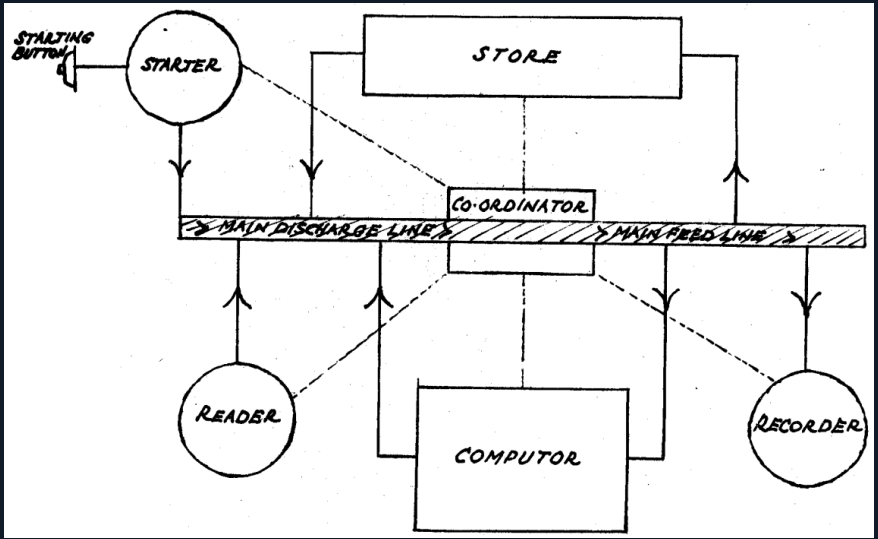

design picked up by J. Lyons & Co. Ltd. for *business* purposes - LEO I

Integrated Circuit

1958, Jack Kilby at Texas Instruments

1959, Robert Noyce at the Fairchild Semiconductor

https://www.pbs.org/transistor/background1/events/icinv.html

Home Computers

Home Computers

https://en.wikipedia.org/wiki/Home_computer

“1977 Trinity”: Commodore PET 2001-8, Apple II, TRS-80 Model I

Photo by Tim Colegrove, CC BY-SA 4.0,
https://commons.wikimedia.org/wiki/File:Trinity77.jpg

Personal Computers

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Kenbak-I

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Paradigm shift

The computer now has a *consumer* rather than only a *programmer*.
It is run by an *operating system* instead of an *operator*.

Microprocessors

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1971, Intel 4004, first CPU, 4-bit

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IBM PC (model 5150)

1981, based on Intel 8088

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First Laptop: Gavilan SC

1983, based on Intel 8088

> *Jack Hall, an award-winning industrial designer, was chosen to work out the ergonomics, mechanics and overall appearance of the Gavilan.*

https://en.wikipedia.org/wiki/Gavilan_SC

Discovering a Computer

Computer = Processor + Memory + Peripherals

… almost *everything* is or contains a computer today.

Everyday Electronics

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Shopping Center and Supermarket

- parking lots: sensors and capacity displays
- elevators, escalators, automatic doors
- price tags (e-ink displays)
- barcode scanners and electronic payment

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- gadgets, wearables…
- routers, IP cameras, network storage…
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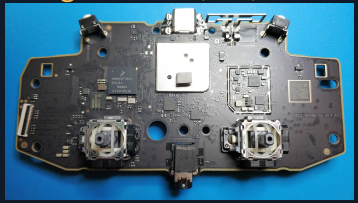
Smart Home/Building/City

Idea: Automation, energy saving, data collection

Example: lights that turn on when approaching and off after leaving

Entertainment or Education

Google Stadia (RIP)



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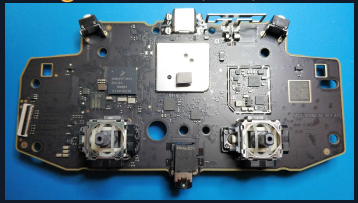

EOL: January 18, 2023

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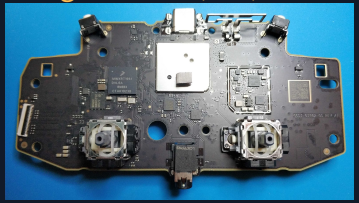

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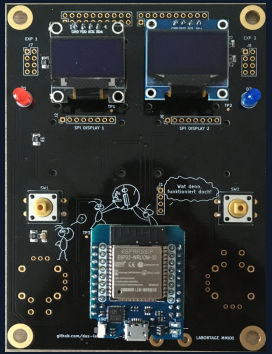

Labor Badge

- modular
- reusable
- discoverable
- programmable

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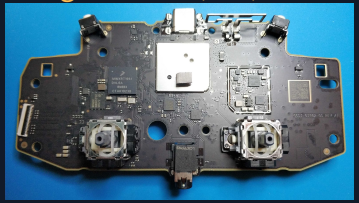

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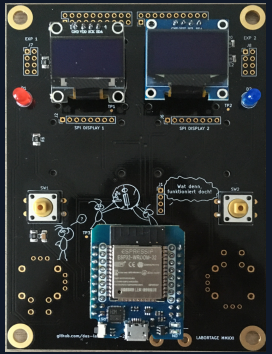

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Help wanted:
Design other SoM carrier boards

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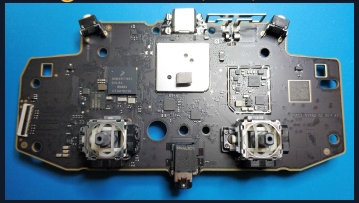

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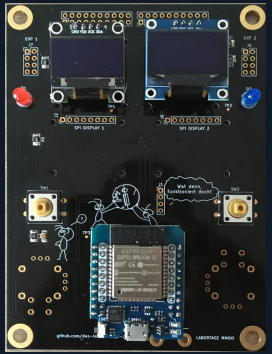

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Console hacking is still a thing; see Nintendo and PlayStation. :-)

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Anachro

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What is Anachro? Anachro is two things: A Network Protocol, and a PC architecture for a microcontroller-based system.

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Neotron

https://neotron-compute.github.io/Neotron-Book/

https://github.com/Neotron-Compute/Neotron-Pico

A Neotron system powered by the Raspberry Pi Pico, in a micro-ATX form-factor.

Bringing Up the Neotron PICO - A retro-style mATX PC; Jonathan Pallant, Ben Jordan and Bil Herd

https://www.youtube.com/watch?v=X1-mt4mrZ9E

More Computers

More Computers

moss

https://github.com/mosscomp/moss

> *moss is a vertically-integrated computer with the following design goals:*
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> - *Exceedingly understandable by users.*
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https://www.rehsdonline.com/post/start-to-an-80286-system
https://www.youtube.com/playlist?list=PL7sb-_3xk_CAMDL_dj9l-plqSrEzcqx1G

Mobile Devices

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MNT Reform Laptop

The Much More Personal Computer

https://mntre.com/

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PinePhone

An Open Source Smartphone Supported by All Major Linux Phone Projects

https://www.pine64.org/pinephone/

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Racklet

https://racklet.io/

> *Racklet is a fully-integrated, miniature server rack.*

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- *open* tools for flashing, debugging and image composition
- firmware, *from the start*, documented (U-Boot, oreboot, …)
- Linux or other OS, *mainline friendly* (git fork, *not* source dump)
- all code usable with upstream toolchains, or provide toolchains in a *reproducible* form (not only binaries for a specific architecture/OS)

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OSHWA Certification: https://certification.oshwa.org/

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Why would that ever be necessary, even?

Open Source Firmware Foundation (OSFF)

https://osfw.foundation/

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*The OSFF is meant to be an **umbrella organization** for all parties interested in open-source firmware and acts as the first point of contact in the open-source firmware ecosystem.*

Fiedka the Firmware Editor

https://fiedka.app/

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Features

- analyze firmware images
- visualize flash usage
- explore file systems
  - UEFI
  - PSP (AMD)
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Work in progress

- SBoM (Software Bill of Materials)

Platforms and Systems

What are Platforms?

What are Platforms?

A computing platform or digital platform is an environment in which a piece of software is executed.

It may be the hardware or the operating system (OS), even a web browser and associated application programming interfaces, or other underlying software, as long as the program code is executed with it.

Computing platforms have different abstraction levels, including a computer architecture, an OS, or runtime libraries.

A computing platform is the stage on which computer programs can run.

https://en.wikipedia.org/wiki/Computing_platform

Platform System Interface (PSI)

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Goal: Derive a specification, summarizing firmware projects, their boot flows, how they interact as a platform with the actual operating system.

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How: Extract features, compare approaches, reevaluate, improve.

Computer Architecture: Buses

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https://en.wikipedia.org/wiki/Bus_(computing)

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Wires

Example I2C: VCC, GND, SCL (clock), SCA (data)
Many I2C buses are in your laptop, even within HDMI and VGA ports.
They are often used for connecting sensors, e.g., for temperature.
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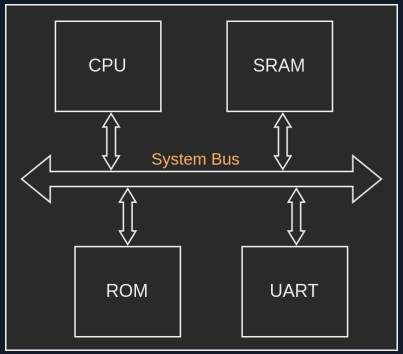
Conventions and Standards

Example: USB
https://www.electronics-notes.com/articles/connectivity/usb-universal-serial-bus/basics-tutorial.php
Those make up *interfaces*, enabling a *market* through compatibility.

Internal Buses

Internal Buses



There are even buses *within* chips.

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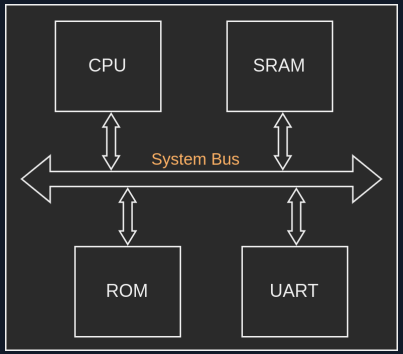

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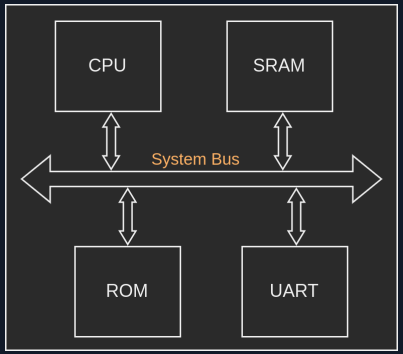

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Example:
Advanced High-Performance Bus (AHB)

AHB is part of AMBA (Advanced Microcontroller Bus Architecture).

https://developer.arm.com/Architectures/AMBA

Complexity in Computers

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x86 (CISC, very complex)

https://www.intel.com/content/www/us/en/developer/articles/technical/intel-sdm.html

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RISC-V (open specifications)

https://riscv.org/announcements/2022/12/risc-v-sees-significant-growth-and-technical-progress-in-2022-with-billions-of-risc-v-cores-in-market/

> *RISC-V combines a modular technical approach with an open, royalty-free license model*

Call for Simplicity: Reduction

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> *Developers are drawn to complexity like moths to a flame often with the same result.*

https://nealford.com/books/productiveprogrammer

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The *opposite* is **Simplicity**.

Software Architecture

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Software architecture is for developers to live inside.

Kevlin Henney, Refactoring Is Not Just Clickbait, NDC Oslo 2022
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> *Most architects and developers pursue the Latest and Greatest with great fervor, yet the history of engineering, including software projects, contains rich lessons that we risk repeating ad nauseam.*

https://joyofcoding.org/2017/speaker/neal-ford/

UEFI vs NERF and FASR

https://uefi.org/about

> *These extensible, globally-recognized specifications bring new functionality and enhanced security to the evolution of devices, firmware and operating systems, as well as facilitate interoperability between platforms and systems that comply with next-generation technologies.*

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https://learn.microsoft.com/en-us/windows-hardware/drivers/bringup/firmware-attack-surface-reduction

Microsoft has started working with partners to overcome the compatibility issues

Layers and Interfaces

The Problem with Layers

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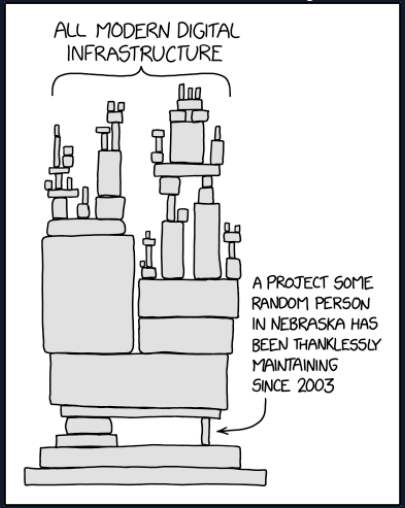

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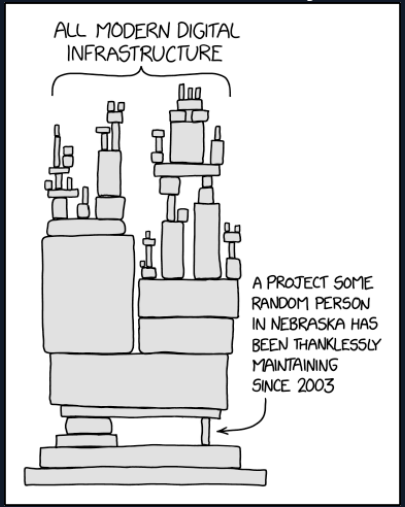

Comic by Randall Munroe, CC BY-NC 2.5
https://xkcd.com/2347/

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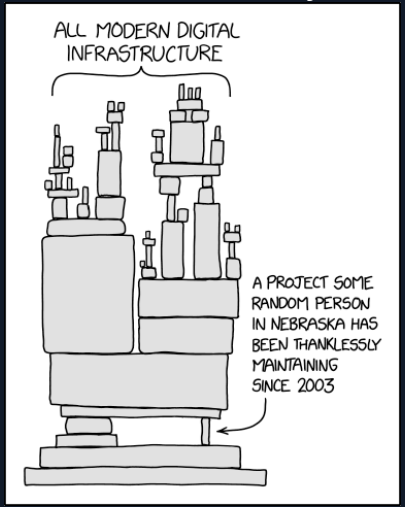

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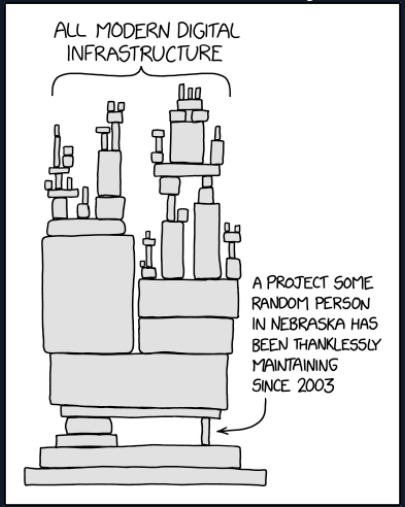

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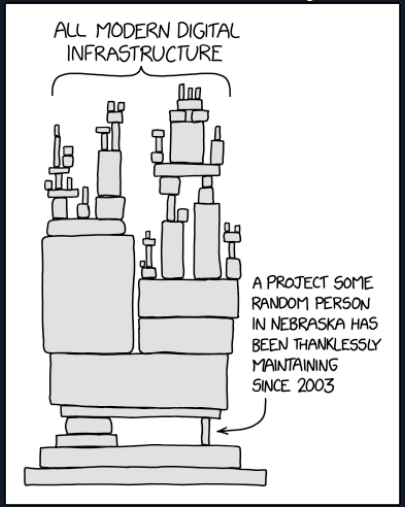

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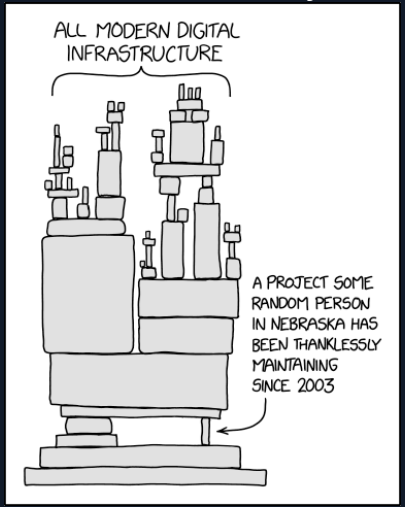

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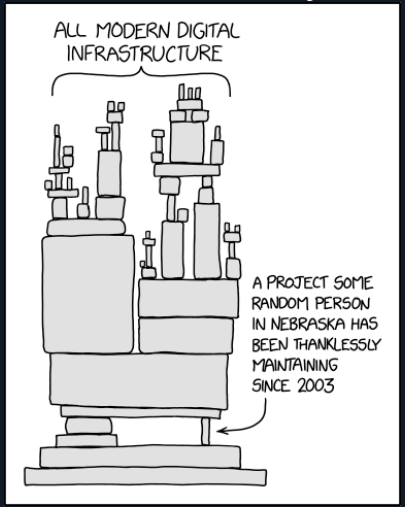

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Example LinuxBoot: Put Linux in SPI flash to replace part of vendor UEFI PI (platform init).

Firmware and Ownership

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Pico Host Boot Loader

phbl is the program run from the x86 reset vector that loads and invokes the phase1 host operating system package

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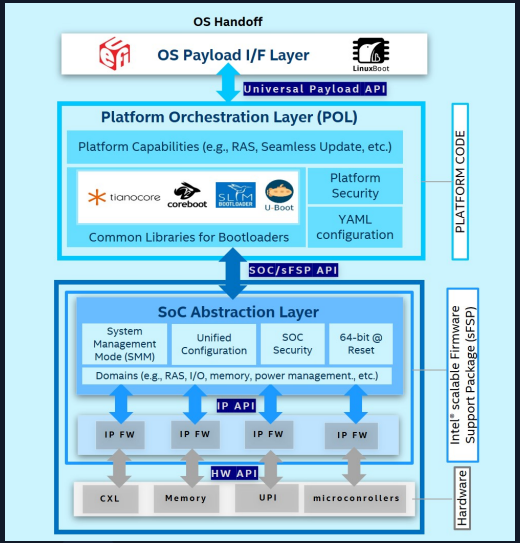
Components can live *on the same layer*.
Not having ownership results in being stuck with layers.

Intel's Universal Scalable Firmware[3]



Note: (s)FSP components are distributed in binary form, hard to audit or fix.

They make up a large portion of the code and bury the understanding of the platform.
Their APIs carry potential for error and vulnerabilities.

[3] https://universalscalablefirmware.github.io/documentation/1_terminology.html

Silicon Interface Design

https://osfw.foundation/workstreams/silicon-interface-design/

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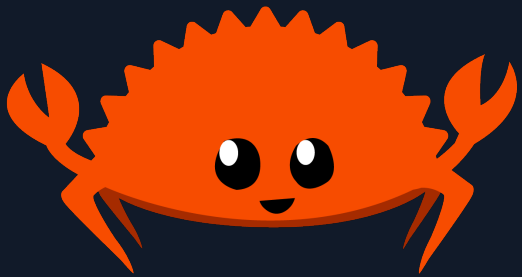
> *Integrating binary blobs that handle parts of the silicon initialization is a common technique within the open-source firmware ecosystem to retain control over parts of the code, from a SoC vendor perspective.*

oreboot

oreboot is firmware written in Rust.



https://github.com/oreboot

Ferris the crab from https://rustacean.net/

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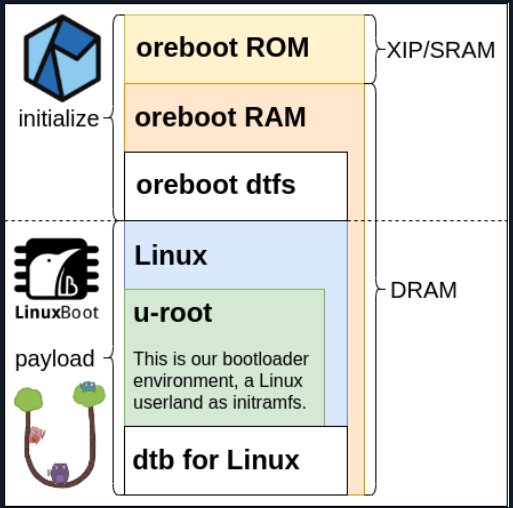

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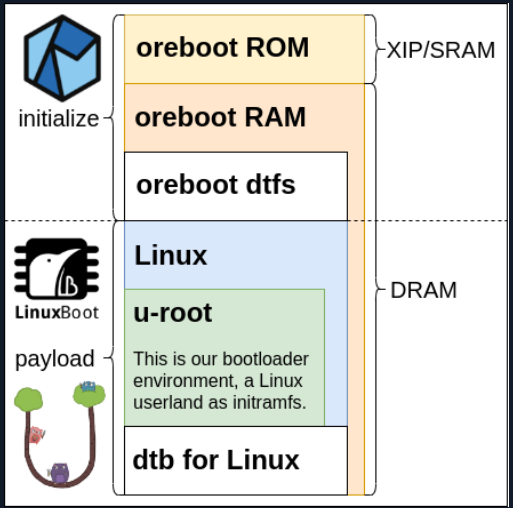

XIP/SRAM

- early init, MMIO
- PLLs, clocks, GPIOs
- UART, say hello
- DRAM controller
- storage setup
  - SPI flash, SD card, eMMC…

DRAM

- what didn't fit in SRAM
  - extract payload
  - set up handlers
- run payload (done)

https://github.com/oreboot/oreboot/blob/main/Documentation/boot-flow.md

Firmware Runtime Services

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Idea: Define interfaces in a software part of a platform.

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Vulnerability REsearch

Vulnerabillity Category	Count	Average Impact
PEI Memory Corruption	3	CVSS: 8.0 (High)
SMM Memory Corruption	57	CVSS: 8.0 (High)
DXE Memory Corruption	10	CVSS: 7.7 (High)
Mitigation Failures	2	CVSS: 6.0 (HighMedium)

Whoops! They also present an attack surface.

RISC-V Runtime Services

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RISC-V PRS TG (Platform Runtime Services Task Group) is concerned with specs around ACPI, UEFI, SBI, and possible other interfaces.

https://lists.riscv.org/g/tech-prs

https://github.com/riscv-admin/prs

RISC-V Environment Calls

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Example, writing a **B** character to the serial console:

```
li a0, 'B'   # argument
li a7, 0x01  # extension "console putchar"
ecall
```

From Registers to Memory Access

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What else can we do?

Research & Development

Capabilities

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CHERI (Capability Hardware Enhanced RISC Instructions)

> *is a joint research project of SRI International and the University of Cambridge to revisit fundamental design choices in hardware and software to dramatically improve system security*

https://www.cl.cam.ac.uk/research/security/ctsrd/cheri/
https://community.arm.com/arm-community-blogs/b/architectures-and-processors-blog/posts/creating-the-morello-technology-demonstrator

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Generic Tagging for RISC-V Binaries

> *COGENT removes the burden of compiler development from RISC-V hardware defenses that rely on embedding instruction meta-data into binaries*

https://arxiv.org/pdf/2212.05614.pdf

Hardware Vulnerabilities

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Micro-architectural side-channel attacks refer to a side-channel attack that exploit information leakage from the hardware infrastructure itself.

https://orenlab.sise.bgu.ac.il/AttacksonImplementationsCourseBook/06_Cache_Attacks_Guest_Lecture

Hardware Security

Hardware Security

Trusted Execution Environment (TEE)

> *The TEE is a secure area of the main processor of a connected device that ensures sensitive data is stored, processed and protected in an isolated and trusted environment. As such, it offers protection against software attacks generated in the Rich Operating System (Rich OS).*

https://globalplatform.org/wp-content/uploads/2018/05/Introduction-to-Trusted-Execution-Environment-15May2018.pdf

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Confidential Computing

Idea: Process data on remote infrastructure without exposing it to the provider or other parties involved.
https://confidentialcomputing.io/

Getting Started With Hardware Design

Getting Started With Hardware Design

Talks

- Combat complexity - build your own open OS and hardware; Michael Engel, foss-north 2021
  https://conf.tube/w/p/b9a072ab-1c4d-4912-905c-3f68096582ca?playlistPosition=14
- The Genius of RISC-V Microprocessors; Erik Engheim, ACCU 2022
  https://www.youtube.com/watch?v=L9jvLsvkmdM
- Linux on Open Source Hardware with Open Source chip design; Drew Fustini, 36C3
  https://www.youtube.com/watch?v=mnOBTD9dgsg

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- Linux on Open Source Hardware with Open Source chip design; Drew Fustini, 36C3
  https://www.youtube.com/watch?v=mnOBTD9dgsg

Literature

- https://opencircuitsbook.com
- Patterson and Hennessy - Computer Organization and Design RISC-V Edition: The Hardware Software Interface

Design Your Own Computer

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FPGA Boards

- OrangeCrab https://1bitsquared.de/products/orangecrab
- ULX3S https://radiona.org/ulx3s/

Design Your Own Computer

FPGA Boards

- OrangeCrab https://1bitsquared.de/products/orangecrab
- ULX3S https://radiona.org/ulx3s/

Chip Design

- LiteX (SoC framework) https://github.com/enjoy-digital/litex
- FuseSoC (package manager) http://fusesoc.net/
- https://github.com/T-head-Semi/openc906 (e.g., in D1 and BL808)
- Libre SoC https://libre-soc.org/
- FOSSi Foundation https://www.fossi-foundation.org/
- Zero to ASIC Course https://www.zerotoasiccourse.com/

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Fabbing

https://developers.google.com/silicon

Will Your Design be a Good Design?

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Daniel Maslowski

https://github.com/platform-system-interface/psi-spec

https://metaspora.org/platform-system-interface-computing-as-whole.pdf