I/O Devices

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Fall 2026



Three Pieces

- Virtualization
  - Virtual CPUs
  - Virtual memory
- Concurrency
  - Threads
  - Synchronization
- Persistence
  - How to make information persist, despite computer crashes, disk failures, or power outages?
  - Storage
  - File systems

Modern System Architecture

- Intel 13th Gen Intel Core Desktop Processor (a.k.a Raptor Lake)



44.8GB/s/module

25.6GB/s/module

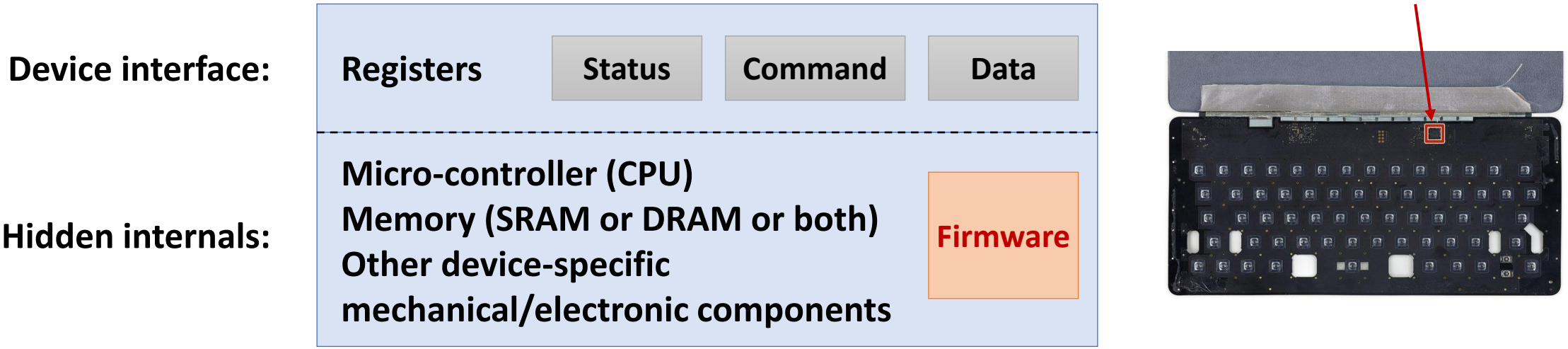
~4GB/s/lane

~2GB/s/lane

Source: https://arstechnica.com/gadgets/2022/09/intels-first-13th-gen-core-cpus-include-few-surprises-but-many-cores/

A Typical I/O Device

- Control: Special instructions (e.g., `in` & `out` in x86) vs. memory-mapped I/O (e.g., `load` & `store`)
- Data transfer: Programmed I/O (PIO) vs. DMA
- Status check: Polling vs. Interrupts



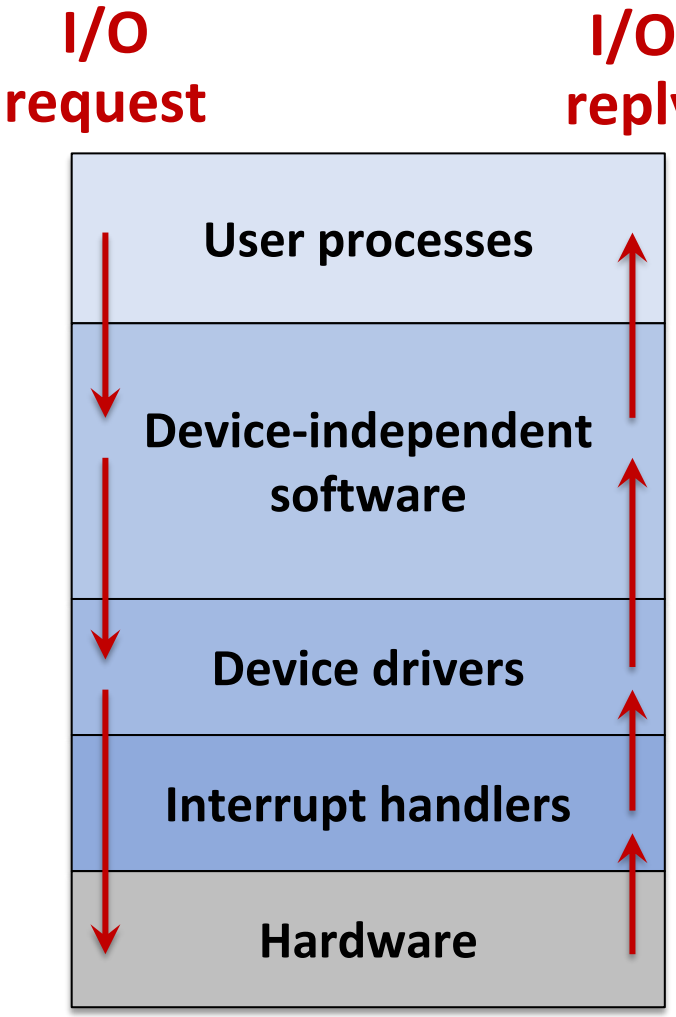
Source: https://www.ifixit.com/Teardown/Smart+Keyboard+Teardown/53052

Classifying I/O Devices

- _____ device
  - Stores information in fixed-size blocks, each one with its own address
  - Typically, 512B or 4KB per block
  - Can read or write each block independently
  - Disks, tapes, etc.

- Character device
  - Delivers or accepts a stream of characters
  - Not addressable and no seek operation supported
  - Printers, networks, mouse, keyboard, etc.

I/O Stack



Make I/O call, format I/O, spooling

Naming, protection, blocking, buffering, allocation

Set up device registers, check status

Wake up driver when I/O completed

Perform I/O operation

Device Drivers

- Device-specific code to control each I/O device
  - Require to define a well-defined model and a standard interface
- Implementation
  - Statically linked with the kernel
  - Selectively loaded into the system during boot time
  - Dynamically loaded into the system during execution (especially for hot pluggable devices)
- Variety is a challenge
  - Many, many devices
  - Each has its own protocol

OS Reliability





OS Reliability and Device Drivers

- Reliability remains a crucial, but unresolved problem
  - 5% of Windows systems crash every day
  - Huge cost of failures: stock exchange, e-commerce, etc.
  - Growing "unmanaged systems": digital appliances, CE devices
- OS extensions are increasingly prevalent
  - 70% of Linux kernel code
  - Over 35,000 drivers with over 120,000 versions on WinXP
  - Written by less experienced programmers
- Extensions are a leading cause of OS failure
  - Drivers cause 85% of WinXP crashes
  - Drivers are 7 times buggier than the kernel in Linux