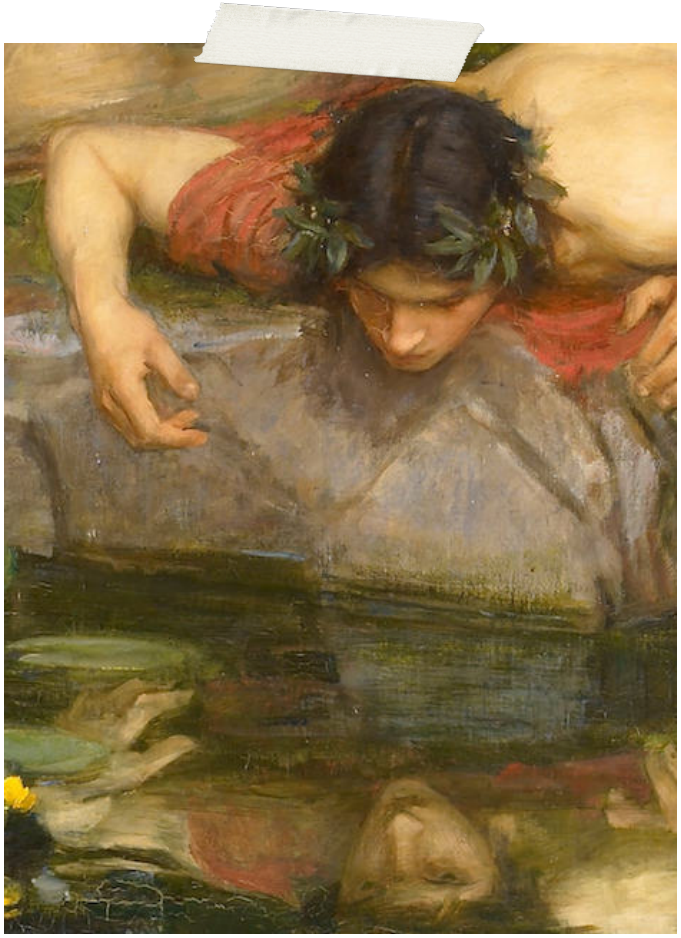
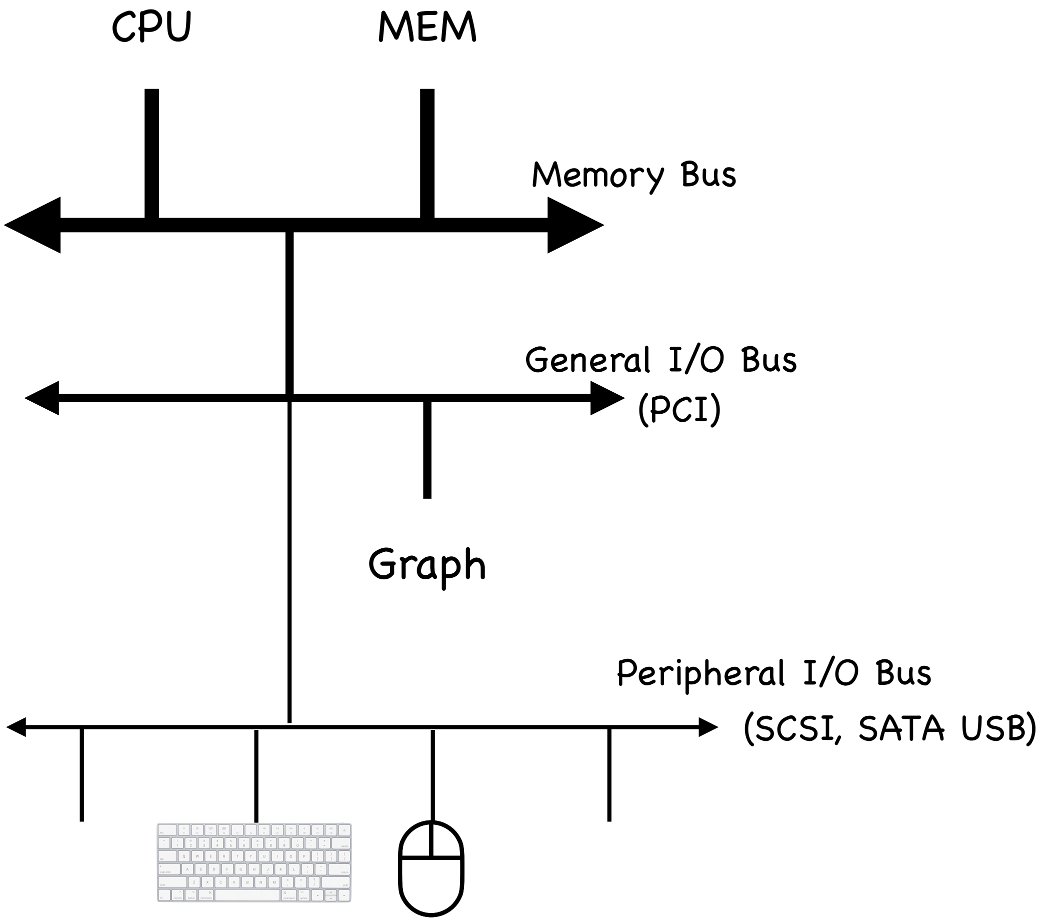
I/O Devices

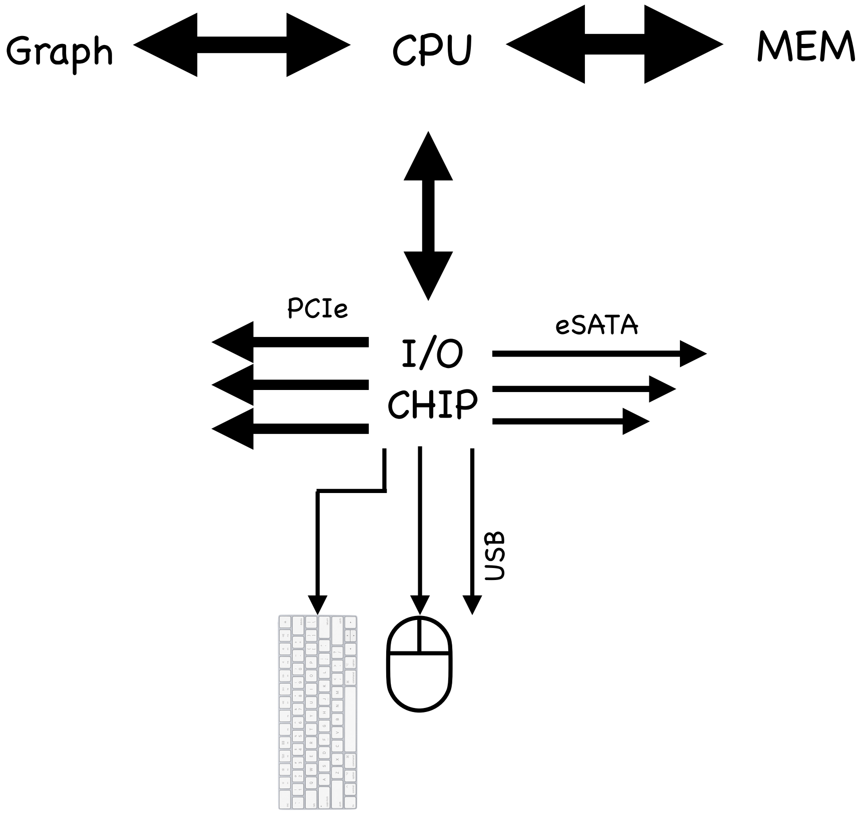
You Need to Get Out More!

- How does a computer connect with the outside world?



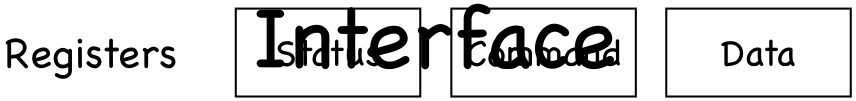
I/O Architecture





Interacting with a Device

Interface


Registers

Status

Command

Data

(what the OS sees)

Abstraction

(what the user sees)

Internals

(what is needed to
implement the abstraction)

Interacting with a Device

Interface

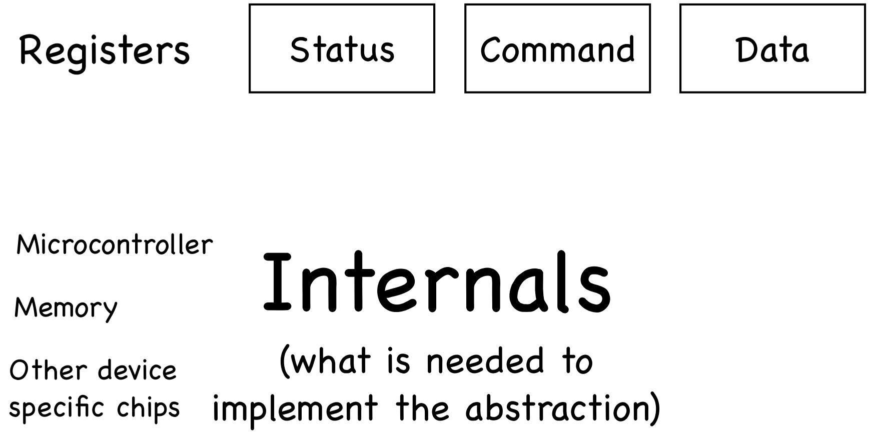
Registers Status Command Data

(what the OS sees)

Internals

(what is needed to
implement the abstraction)

Interacting with a Device



Registers

Status

Command

Data

Microcontroller

Memory

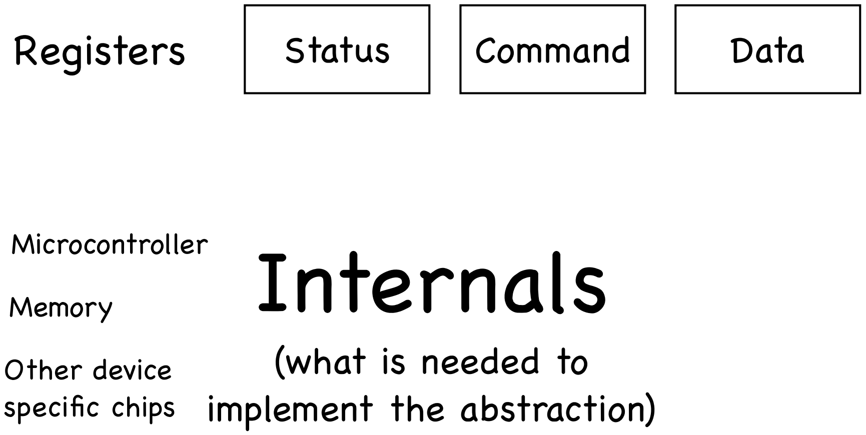
Other device specific chips

Internals

(what is needed to implement the abstraction)

Interacting with a Device

- OS controls device by reading/writing registers



Registers

Status	Command	Data

Microcontroller

Memory

Other device specific chips

Internals

(what is needed to implement the abstraction)

```
while (STATUS == BUSY)
      ; // wait until device is not busy
write data to DATA register
write command to COMMAND register
     // starts device and executes command
while (STATUS == BUSY)
      ; // wait until device is done with request
```

Tuning It Up

- CPU is polling
  - use interrupts
  - run another process while device is busy
  - what if device returns very quickly?
- CPU is copying all the data to and from DATA
  - use Direct Memory Access (DMA)

```
while (STATUS == BUSY)
      ; // wait until device is not busy
write data to DATA register
write command to COMMAND register
     // starts device and executes command
while (STATUS == BUSY)
      ; // wait until device is done with request
```

From interrupt-driven I/O to DMA

- Interrupt driven I/O

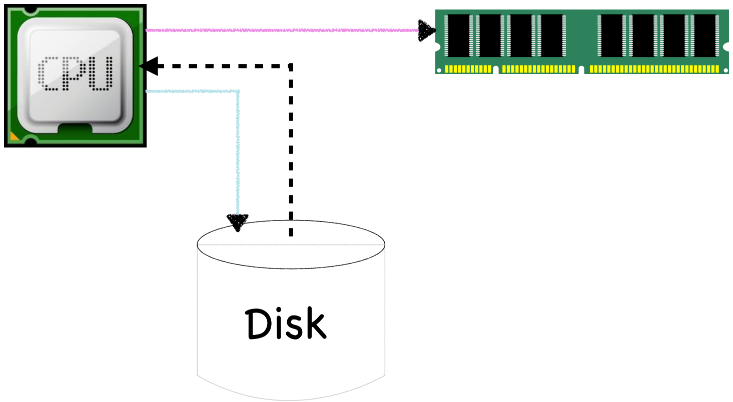
  Device ◀ ▶ CPU ◀ ▶ RAM

  for

  CPU issues read request

  device interrupts CPU with data

  CPU writes data to memory



From interrupt-driven I/O to DMA

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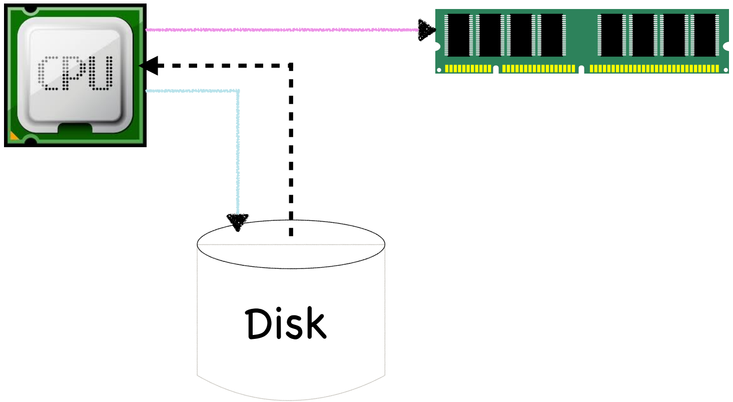


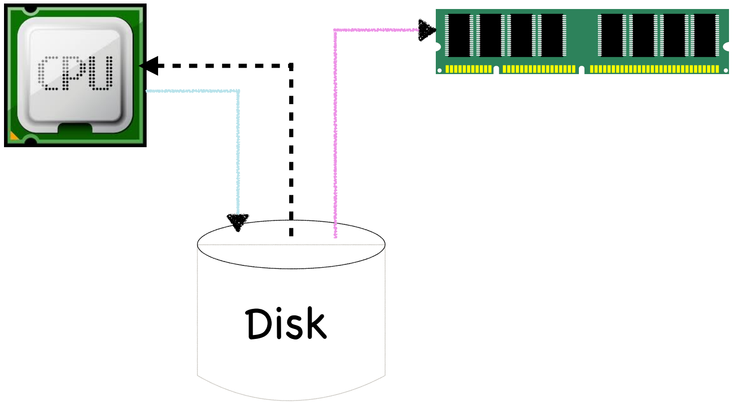
- + Direct Memory Access

  Device ◀ ▶ RAM

  CPU sets up DMA request

  Device puts data on bus & RAM accepts it

  Device interrupts CPU when done



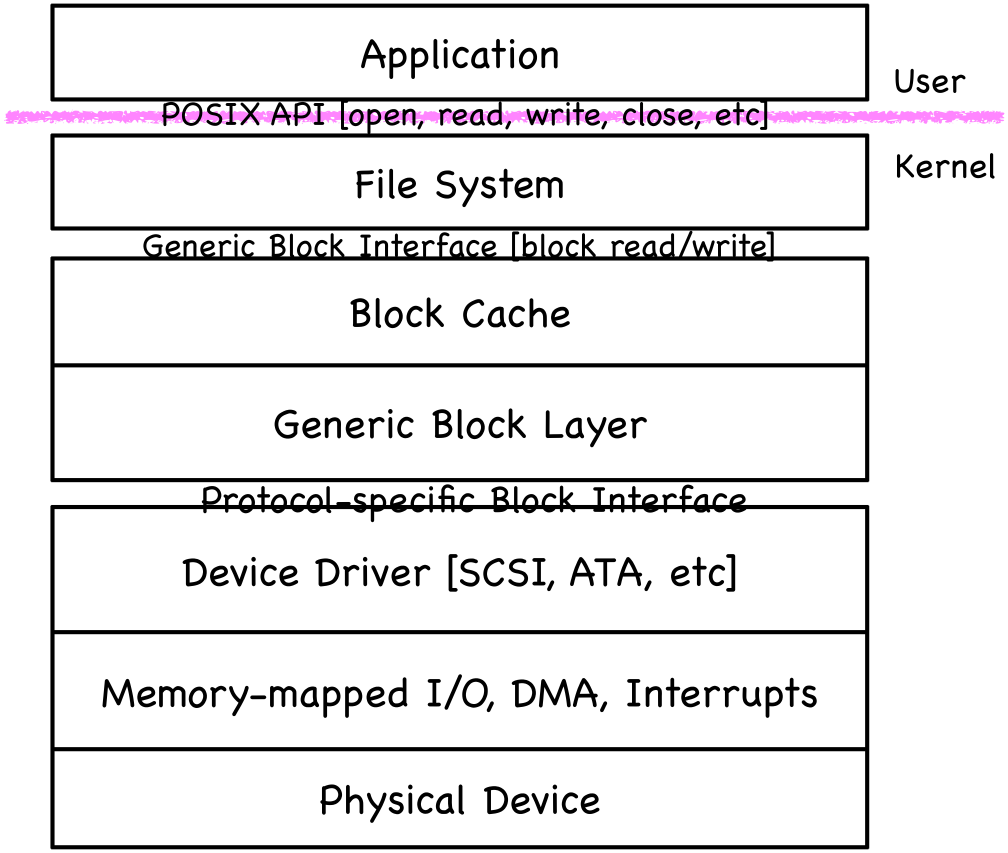
Communicating with devices

- Explicit I/O instructions (privileged)
  - in and out instructions in x86
- Memory-mapped I/O
  - map device registers to memory location
  - use memory load and store instructions to read/write to registers

How can the OS handle a multitude of devices?

- Abstraction!
  - Encapsulate device specific interactions in a device driver
  - Implement device neutral interfaces above device drivers
- Humans are about 70% water…
  - …OSs are about 70% device drivers!

File System Stack (simplified)



Application

User

POSIX API [open, read, write, close, etc]

Kernel

File System

Generic Block Interface [block read/write]

Block Cache

Generic Block Layer

Protocol-specific Block Interface

Device Driver [SCSI, ATA, etc]

Memory-mapped I/O, DMA, Interrupts

Physical Device