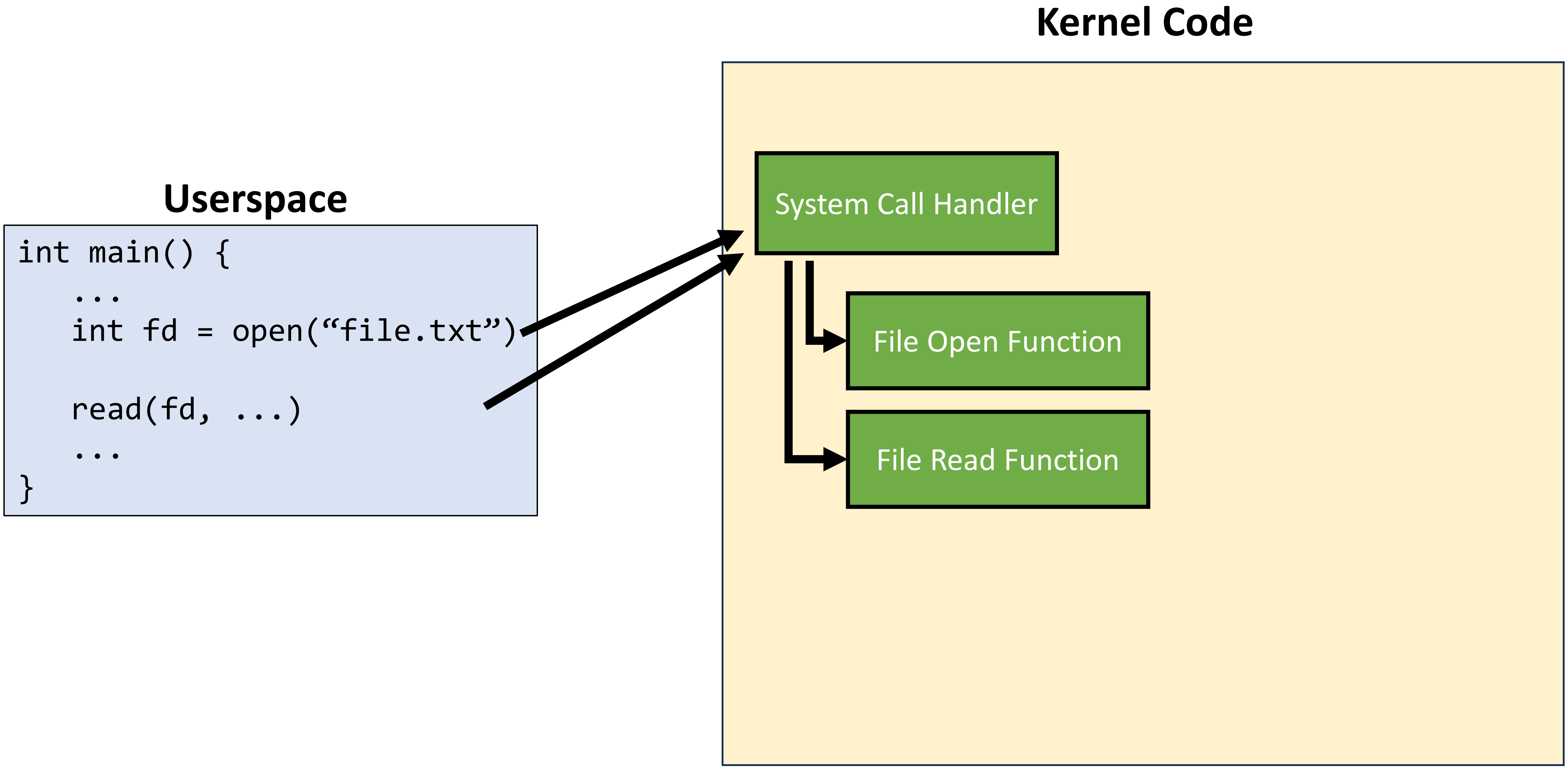
Devices

BYU Electrical & Computer Engineering
IRA A. FULTON COLLEGE OF ENGINEERING

Linux System Calls



At the end of last class we looked at the list of syscalls:

- https://chromium.googlesource.com/chromiumos/docs/+/HEAD/constants/syscalls.md

Where are the system calls to talk to hardware devices?

- UART
- Disk
- Video card
- Physical memory
- USB devices

Calling Function in Drivers

Userspace

```
int main() {
    ...
    uart_get_input() ???
    ...
}
```

Don't our device drivers provide functions that we can call to access the devices?

Device Files

- Look like ordinary files in the filesystem, but are special files
- They are interfaces to the driver that controls the device
- By using system calls that operate on files, our code can interface with the driver.
- They are not real files…

Have you used a device file before?

Pseudo-devices [edit]

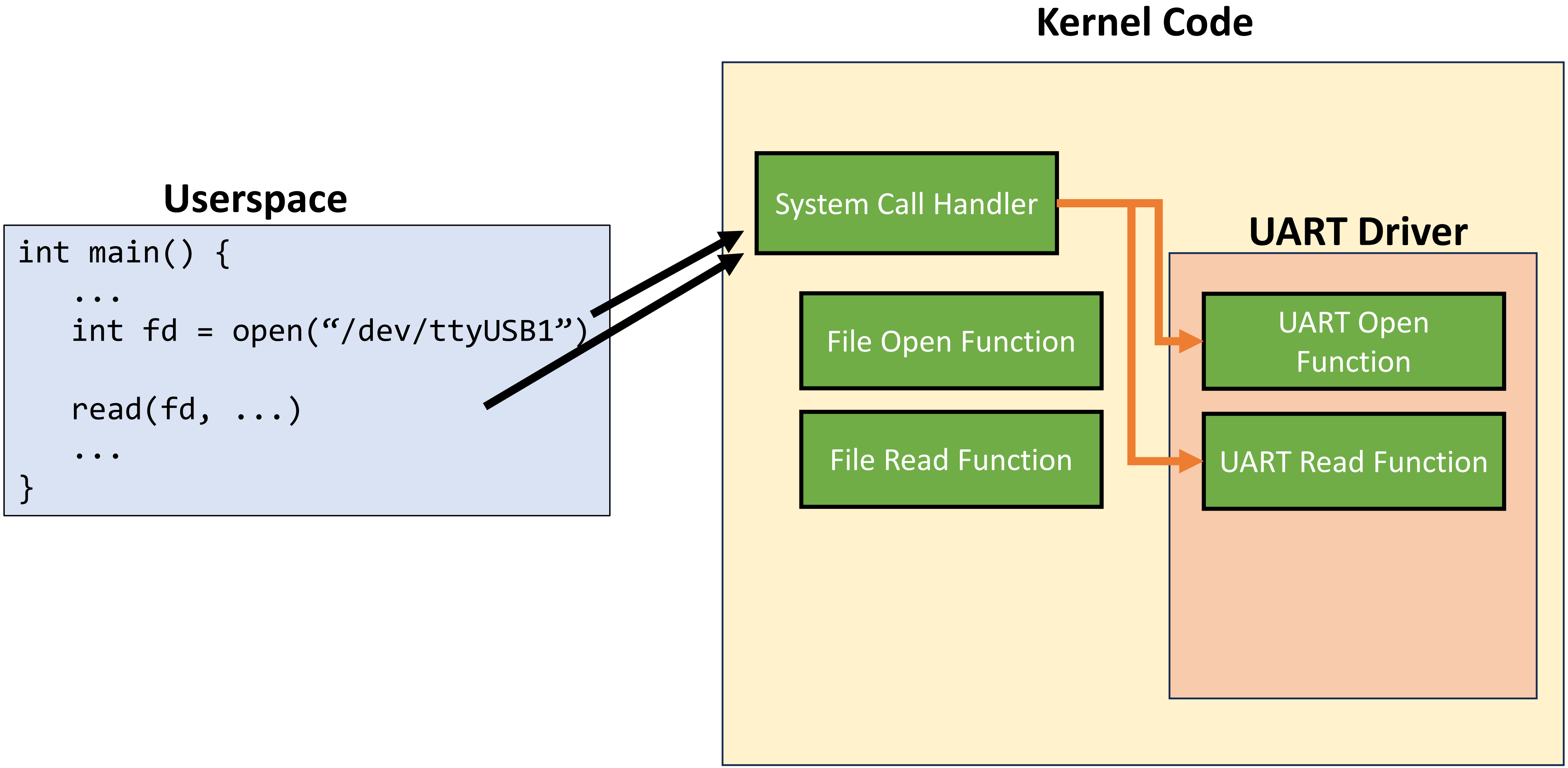
Device nodes on Unix-like systems do not necessarily have to correspond to physical devices. Nodes that lack this correspondence form the group of *pseudo-devices*. They provide various functions handled by the operating system. Some of the most commonly used (character-based) pseudo-devices include:

- `/dev/null` – accepts and discards all input written to it; provides an end-of-file indication when read from.
- `/dev/zero` – accepts and discards all input written to it; produces a continuous stream of null characters (zero-value bytes) as output when read from.
- `/dev/full` – produces a continuous stream of null characters (zero-value bytes) as output when read from, and generates an `ENOSPC` ("disk full") error when attempting to write to it.
- `/dev/random` – produces bytes generated by the kernel's cryptographically secure pseudorandom number generator. Its exact behavior varies by implementation, and sometimes variants such as `/dev/urandom` or `/dev/arandom` are also provided.
- `/dev/stdin`, `/dev/stdout`, `/dev/stderr` – access the process's standard streams.
- `/dev/fd/`*n* – accesses the process's file descriptor *n*.

Additionally, BSD-specific pseudo-devices with an `ioctl` interface may also include:

- `/dev/pf` – allows userland processes to control PF through an `ioctl` interface.
- `/dev/bio` – provides `ioctl` access to devices otherwise not found as `/dev` nodes, used by `bioctl` to implement RAID management in OpenBSD and NetBSD.
- `/dev/sysmon` – used by NetBSD's envsys framework for hardware monitoring, accessed in the userland through `proplib(3)` by the `envstat` utility.[8]

Linux System Calls



ECEN427 PYNQ Hardware System

- https://byu-cpe.github.io/ecen427/documentation/hardware/

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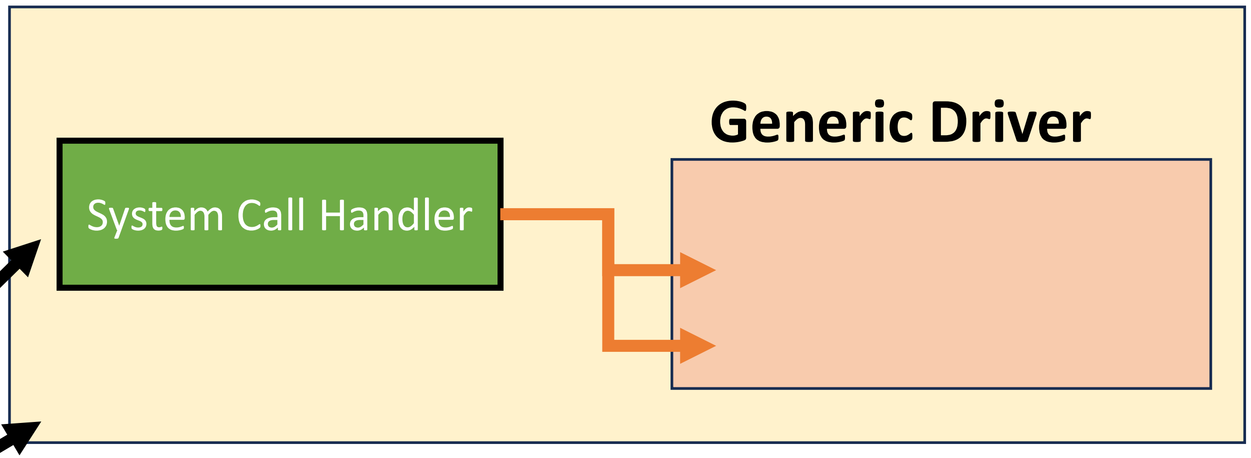
Do we really need a separate driver for every hardware device?

Can we make a generic driver?

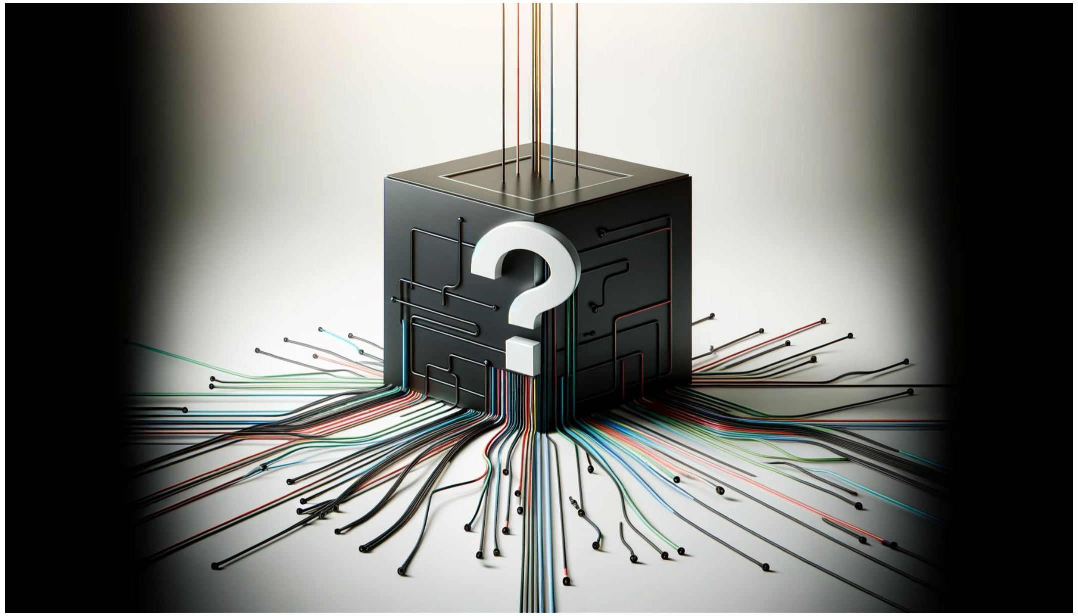
Kernel Code



Userspace

```
int main() {
    ...
    int fp = open("/dev/...")

    ?????(..., ...)
    ...
}
```



What kinds of things do you need to do with a hardware device you know nothing about?

Linux System Calls

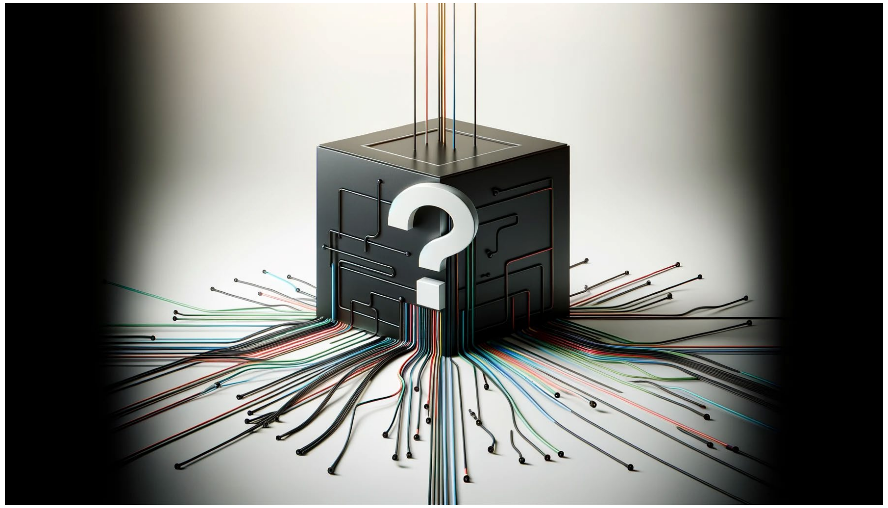
Kernel Code

System Call Handler

Userspace I/O (UIO)

Read/Write Registers

Interrupt



Userspace

```
int main() {
    ...
    int fd = open("/dev/...")

    ?????(..., ...)
    ...
}
```

What system calls would you use to talk to this driver?

Before learning more, let’s pause and cover a few more operating system concepts…

`mmap()`

Map files (or devices) into memory

Process States

- Last lecture we talked briefly about processes, and how the operating system virtualizes the CPU in order to run multiple processes.
- The OS scheduler is responsible for selecting which process will run in the next **time slice**.
- Sometimes processes "block" and need to wait for an OS operation to complete.
  - Example: process calls `read()` to get data from a file on disk. This can take several milliseconds.
  - Rather than blocking all execution, the process goes to sleep, and the OS can wake it back up when the data is ready.

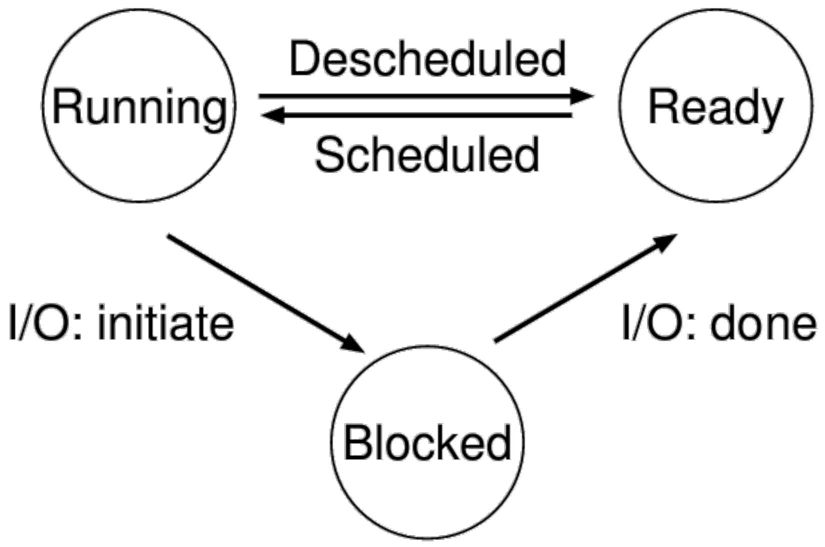


Figure 4.2: **Process: State Transitions**

Userspace I/O

- **Read/Write addresses (registers):**
  - `mmap()`
  - Access registers via pointer returned from mmap
- **Enable interrupts:**
  - `write()` a 1
  - *You must write 4 bytes*
- **Wait for interrupt:**
  - `read()`
  - *You must read 4 bytes*

ECEN427 PYNQ Software System

- https://byu-cpe.github.io/ecen427/documentation/software-stack/

Userspace I/O Drivers

- The UIO linux driver is not meant to actually serve as the device driver
- It provides an interface that allows you to write drivers in userspace.
- In lab 2, you will create userspace drivers for the buttons, switches and interrupt controller
  - These will interface with the UIO kernel driver to access the devices
- Example https://github.com/byu-cpe/ecen427_student/blob/main/userspace/drivers/uio_example/generic_uio_example.c