

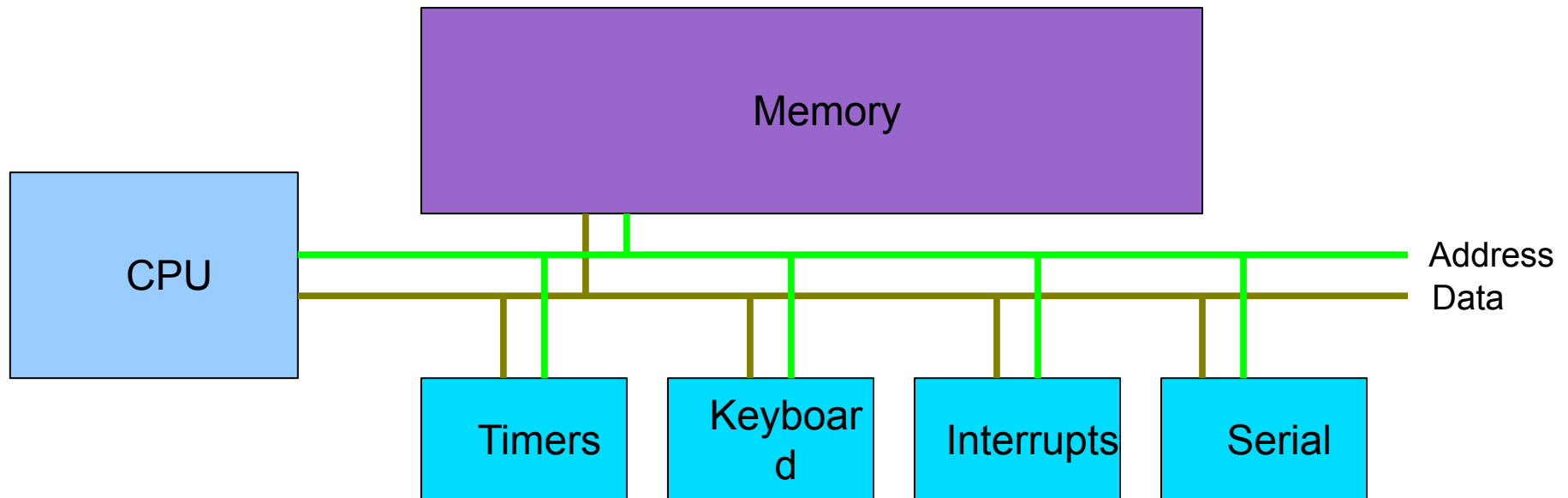
PCI Drivers



ECE 373

Talking to Hardware

- Fast memory
- Slow everything else
 - Clock, printer, UART, keyboard, mouse, interrupt controller, soundboard, disk controllers, joystick, ..



Memory Mapped I/O

- Memory spaces reserved for devices
- Read and write to memory locations tied to devices
- Easy to design and implement
- Easy to program

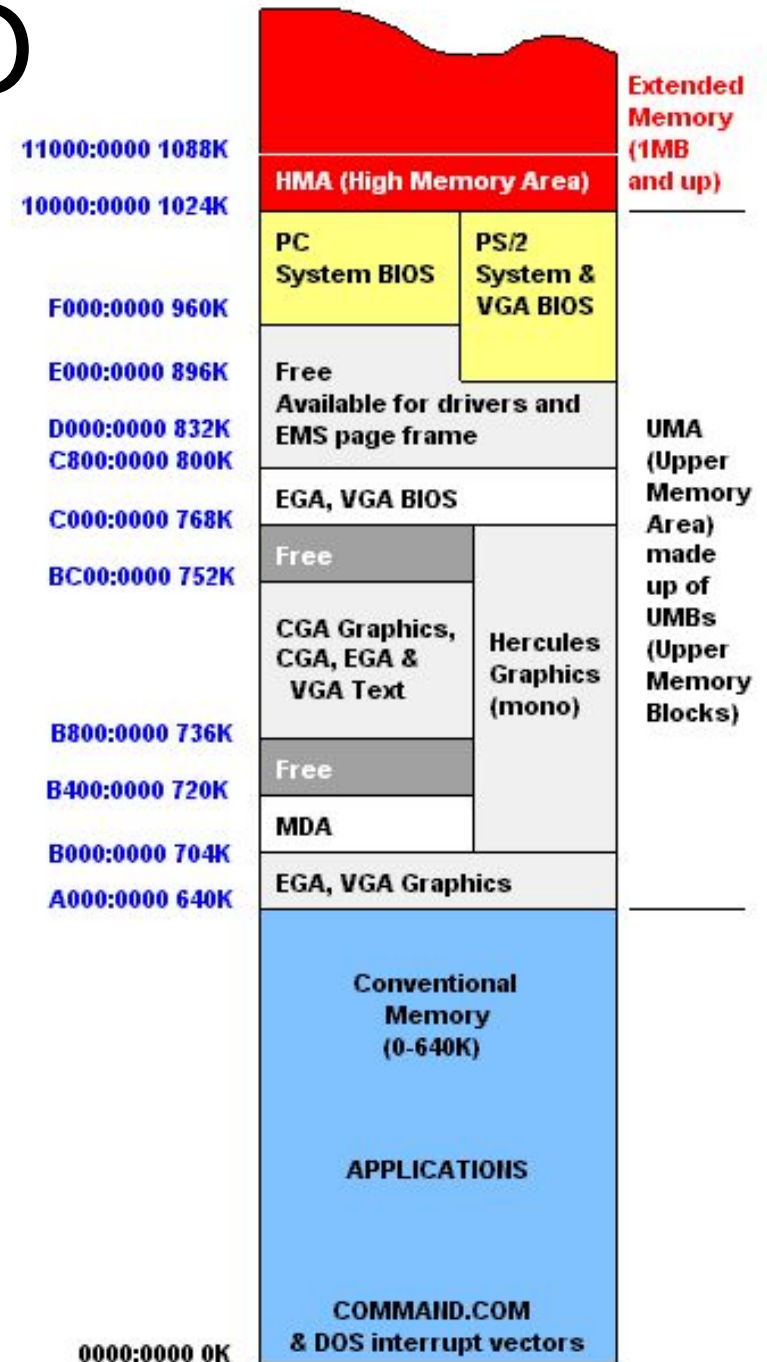
```
#define VIDEO_BASE 0x800000
#define MAX_X      1024
#define MAX_Y      1024

void draw_pixel(int x, int y, pixel)
{
    *(VIDEO_BASE + (x * MAX_X) + y) = pixel;
}
```



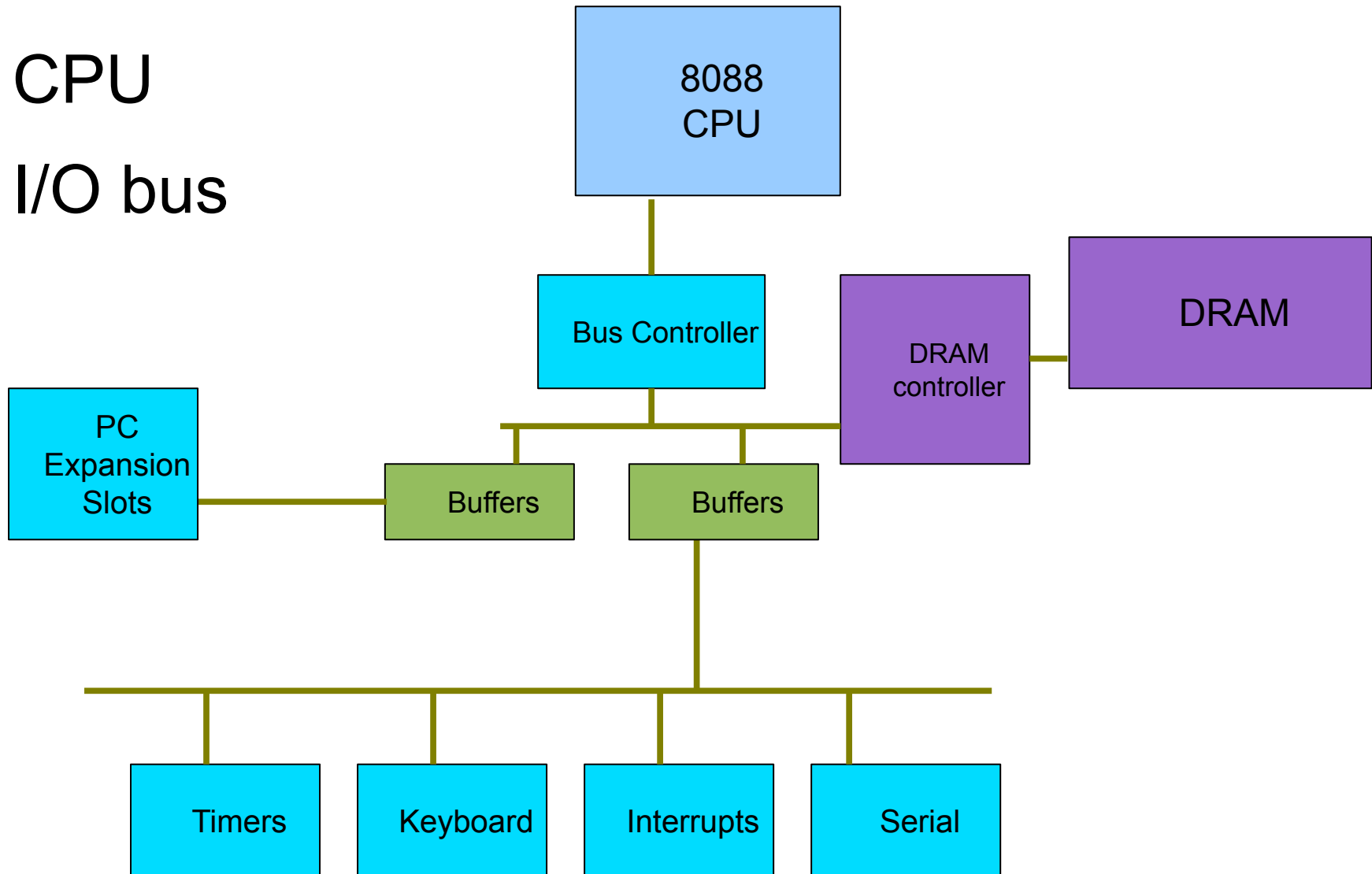
Memory Mapped I/O

- Example: IBM PC
- **Messy!**
 - Memory mapped graphics and other gee-gaws
 - PC architecture is **still** dealing with this mess
 - Shiny new Haswell looks exactly like a 80386 when it powers on...



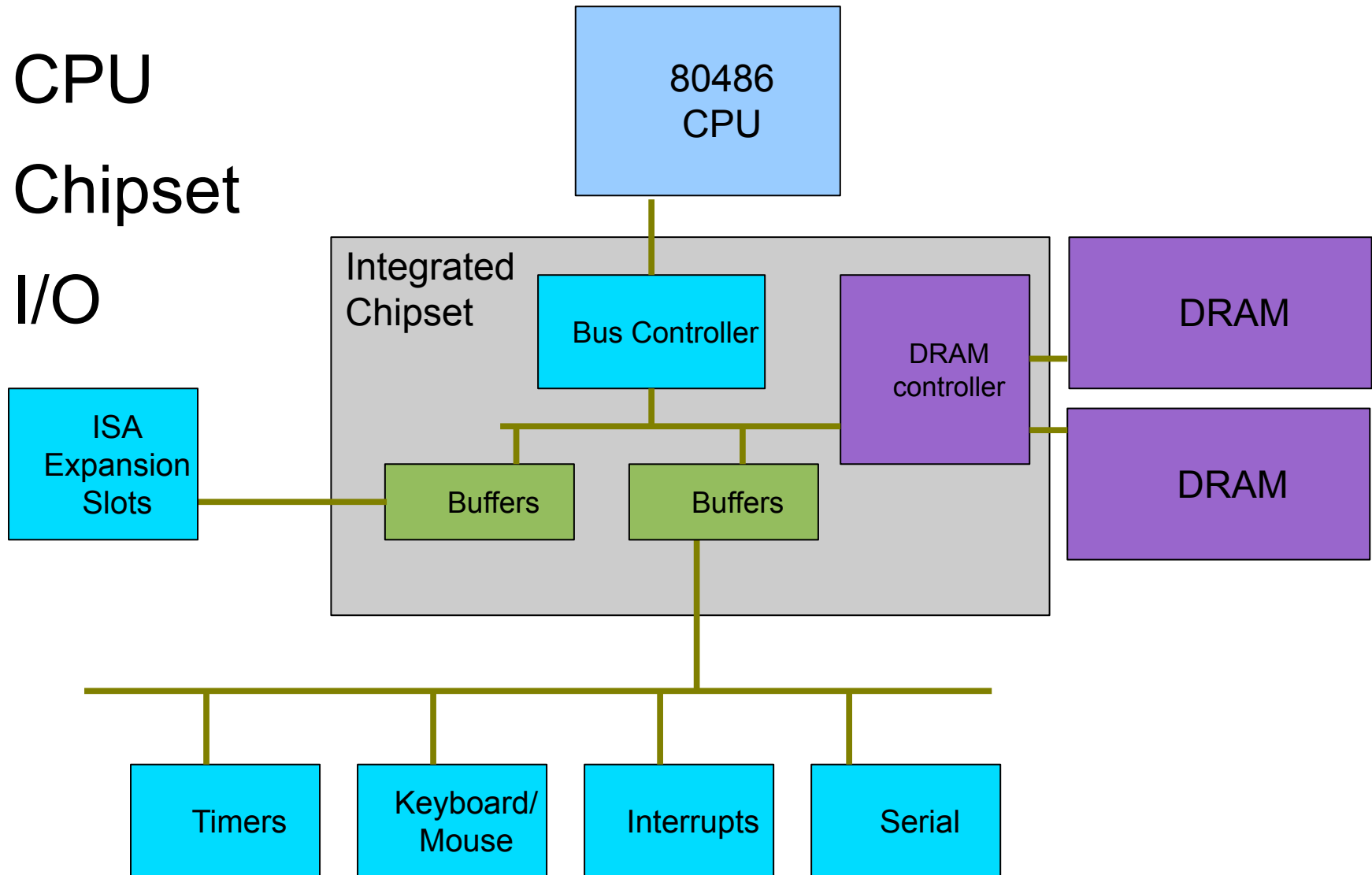
Early PCs

- CPU
- I/O bus



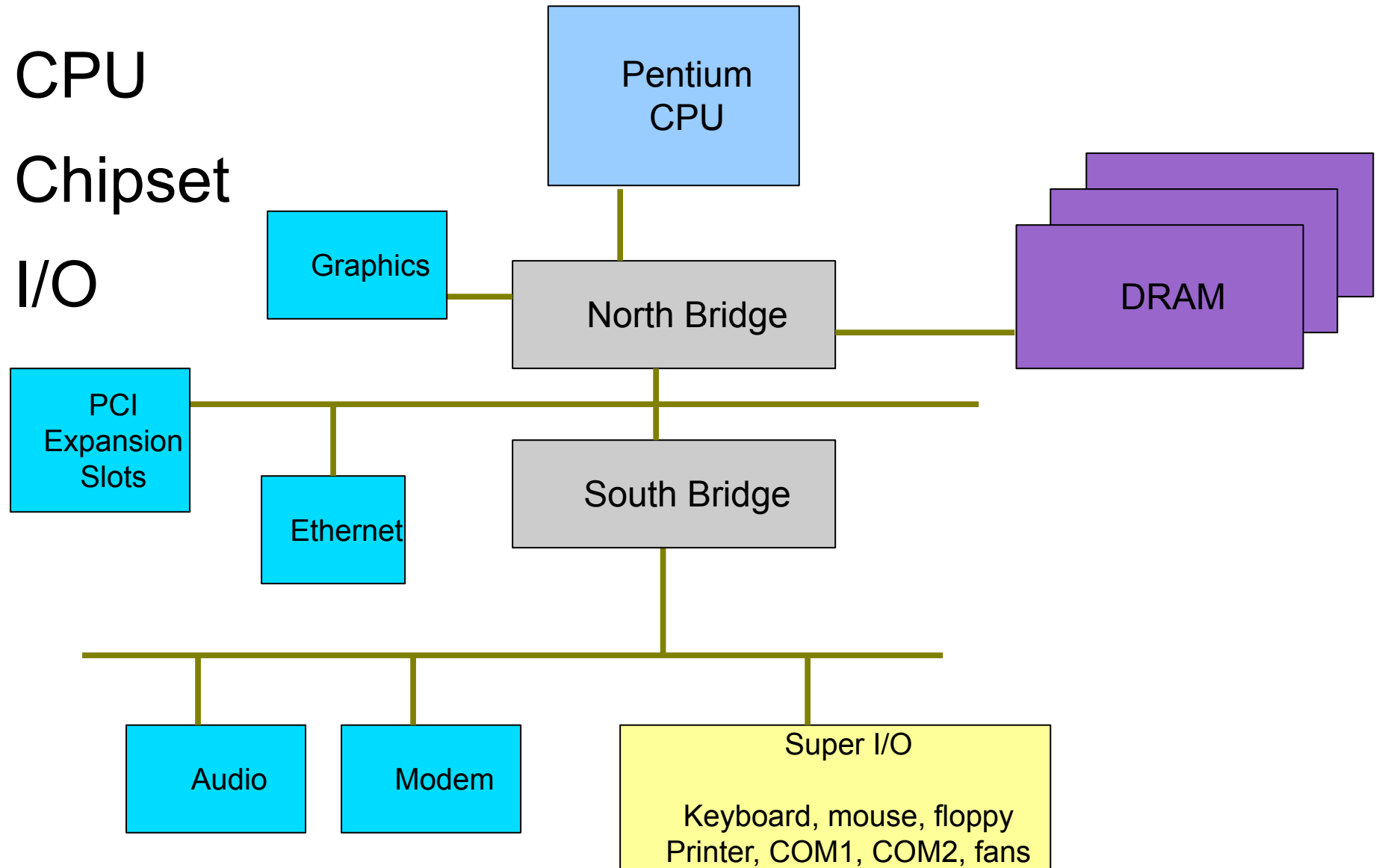
Later PCs

- CPU
- Chipset
- I/O



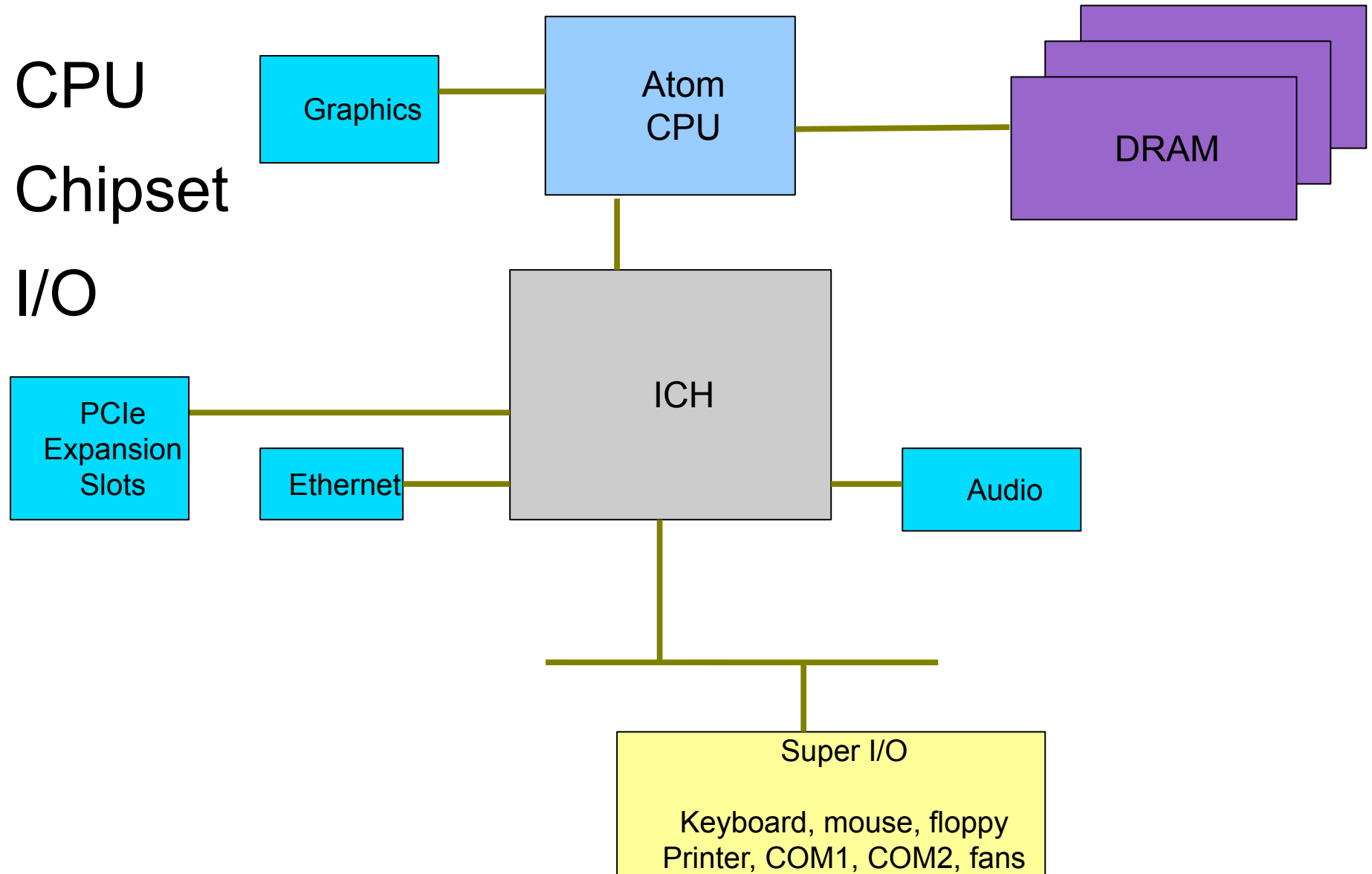
Later PCs

- CPU
- Chipset
- I/O



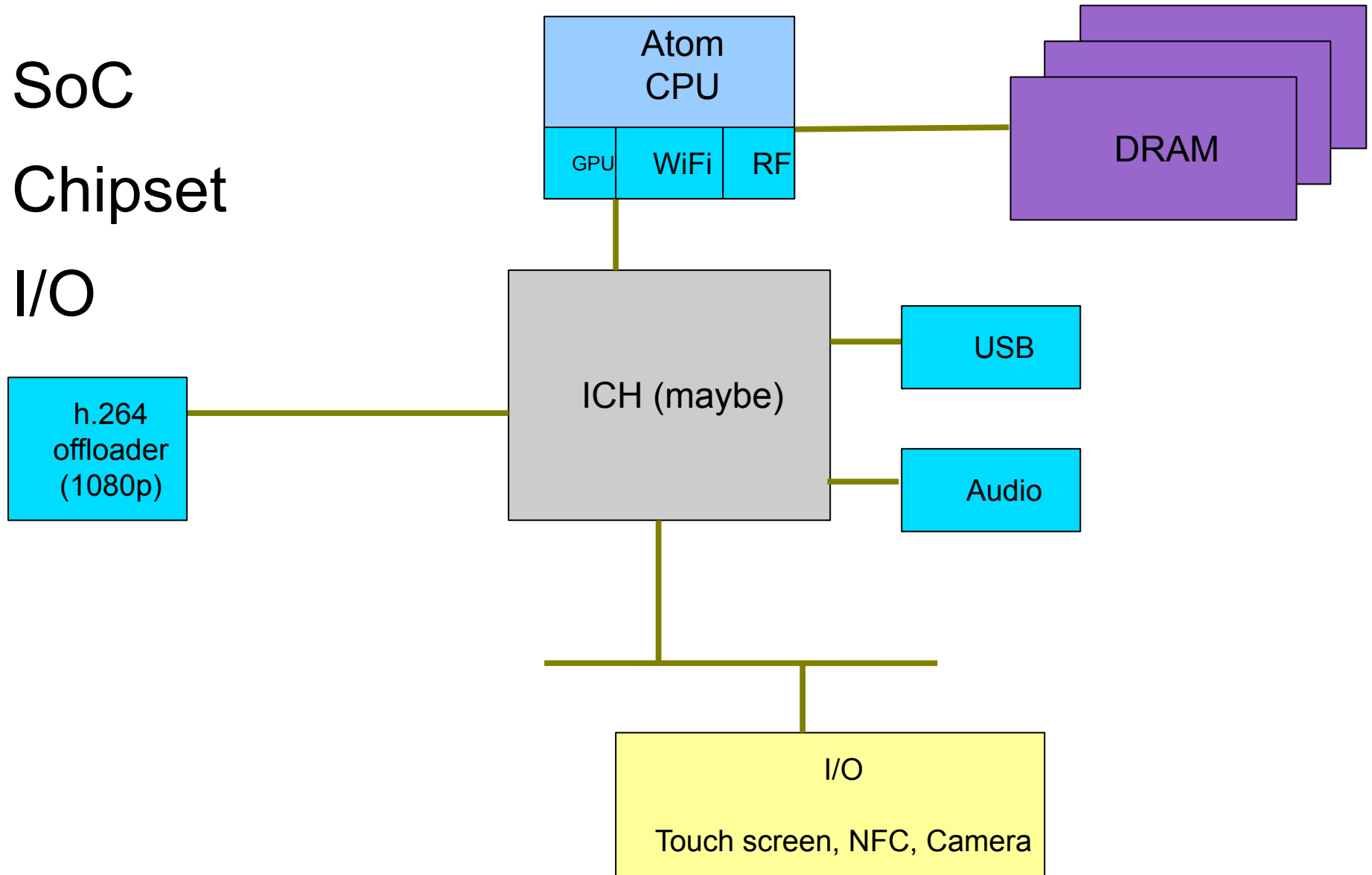
(Mostly) Current PCs

- CPU
- Chipset
- I/O

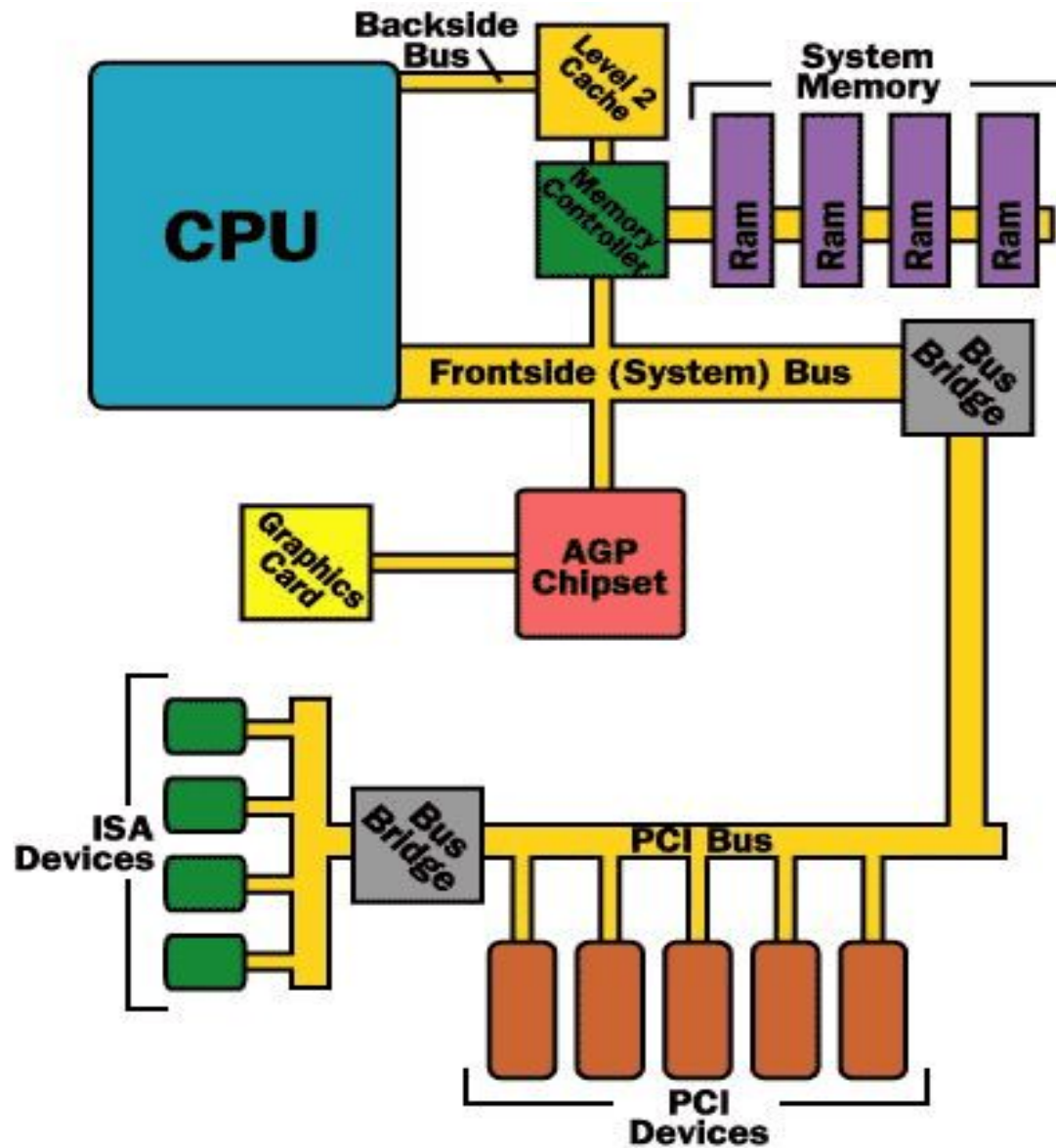


Current “PCs”

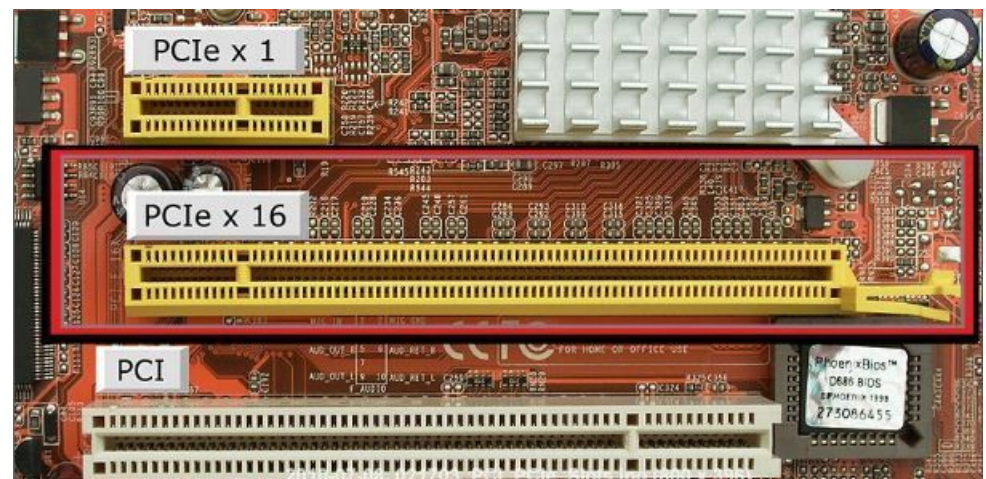
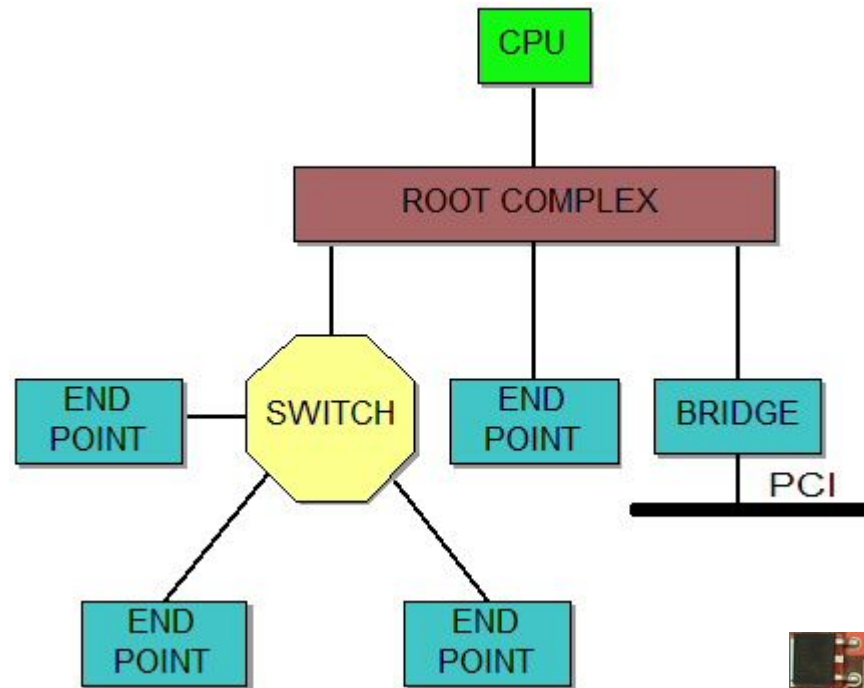
- SoC
- Chipset
- I/O



PCI at a glance



PCI Express (PCIe)



PCI devices

- Plug into PCI bus to get power and comm link

- https://en.wikipedia.org/wiki/PCI_Express

- Well defined initial data interface

- Data block starts with vendor & device ID

- e.g. 0x8086 0x100f => Intel 82545EM

- ... and capabilities

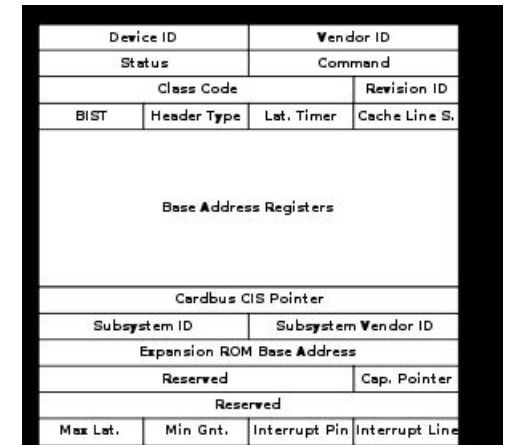
- MSIX, Power Management, IRQs, speed, memory

- ... and memory address for "registers"

- https://en.wikipedia.org/wiki/PCI_configuration_space

- Internal register set maps into kernel memory

- Data and config registers
 - Trigger (doorbell) registers



The diagram illustrates the layout of the PCI configuration space, which is a 256-byte block of memory. It is divided into several fields, each with a specific size and function. The fields are as follows:

Device ID		Vendor ID	
Status		Command	
Class Code		Revision ID	
BIST	Header Type	Lat. Timer	Cache Line S.
Base Address Registers			
Cardbus CIS Pointer			
Subsystem ID		Subsystem Vendor ID	
Expansion ROM Base Address			
Reserved		Cap. Pointer	
Reserved			
Max Lat.	Min Gnt.	Interrupt Pin	Interrupt Line

PCI lifecycle

- The OS

- scans PCI bus for devices
- queries found device for config block
- finds deviceID in PCI driver table
- loads driver and calls `probe()`
- calls `remove()` to unload device & driver

- The driver

- inits device and maps it into memory
- registers interrupt handlers
- waits to service interrupts and OS requests
- stops device, releases memory

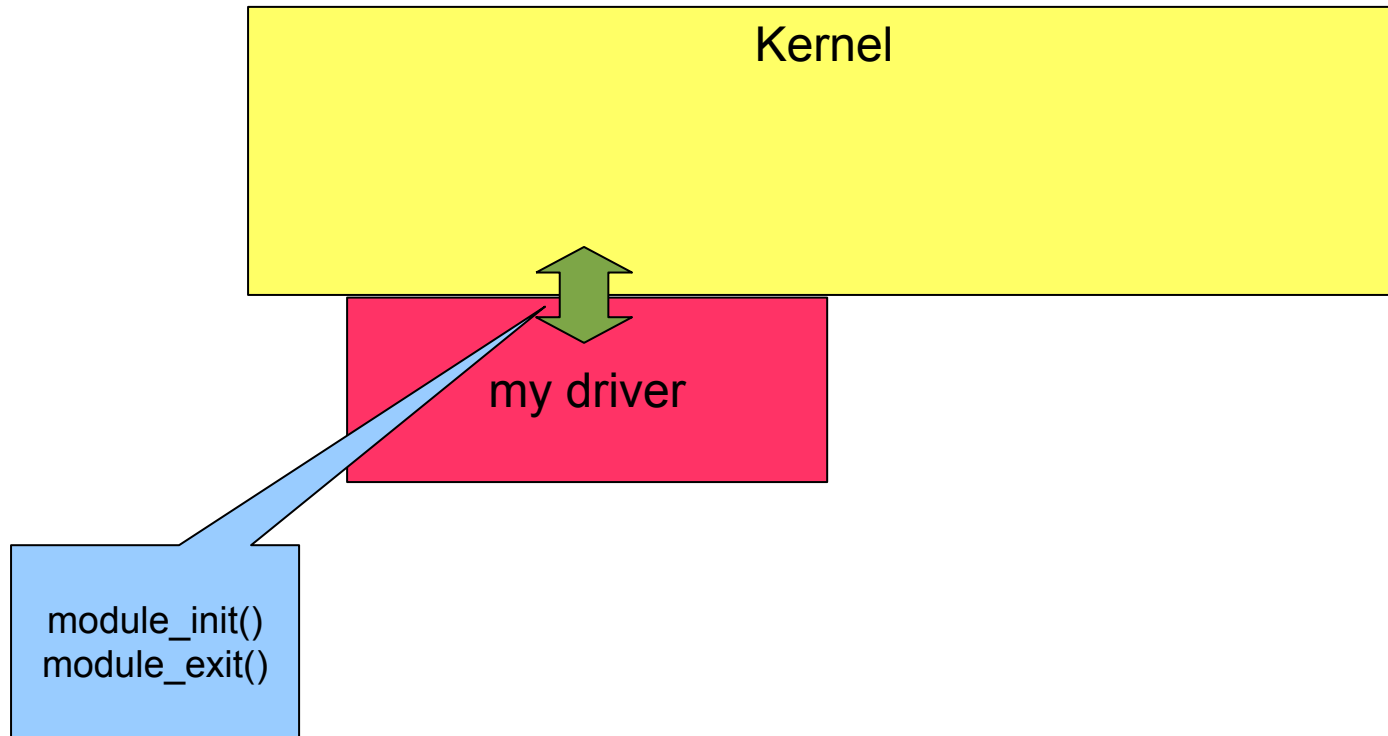


PCI access in Linux

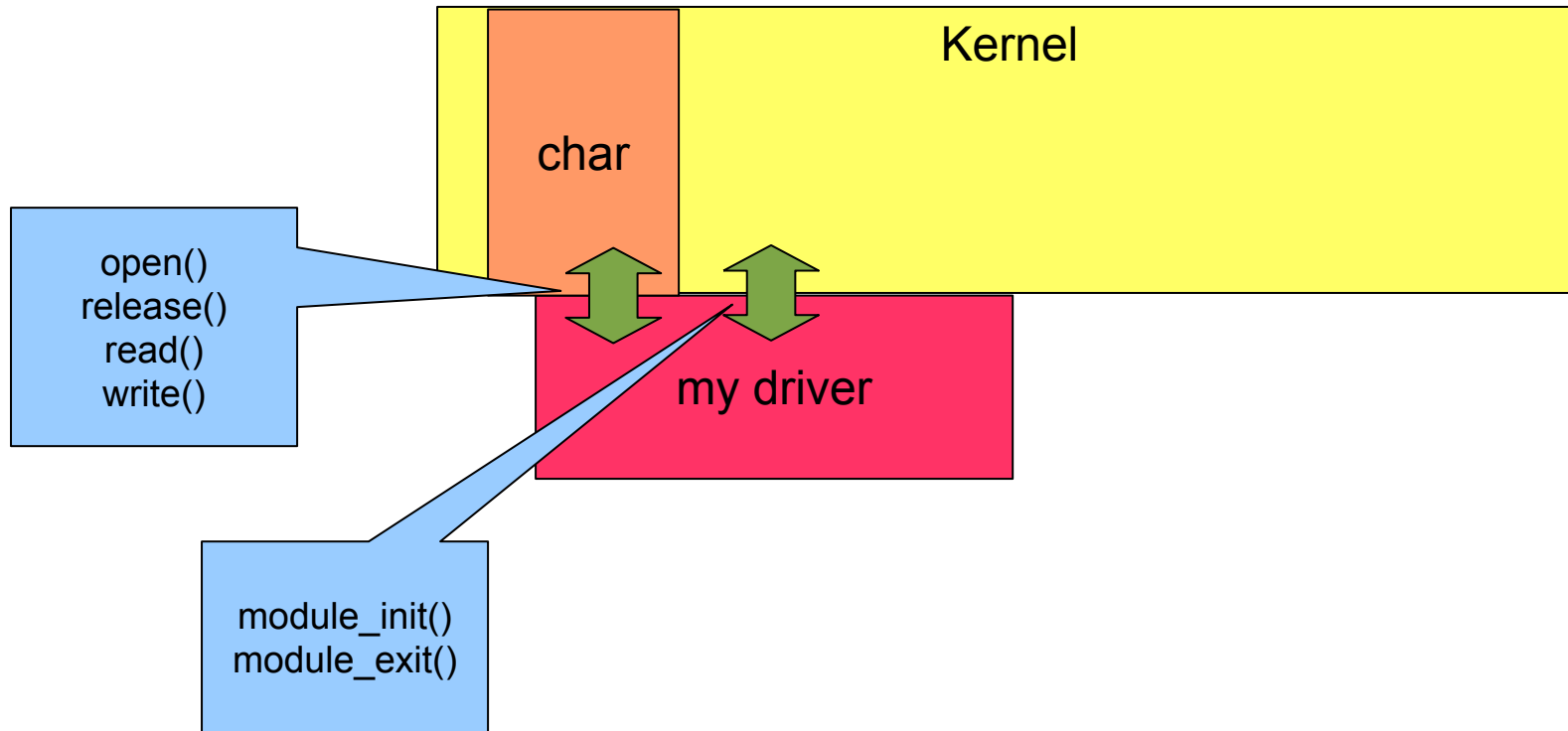
- New structure for PCI devices:
 - `struct pci_driver`
- Needed to hook into PCI subsystem
- Init and exit the same, but have another step to device initialization: `probe()`
 - Various fields for probe: `name`, `id_table`, `probe`, `remove`, `suspend`, `resume`, etc.
- Still use same `init_module()` and `exit_module()` **access**



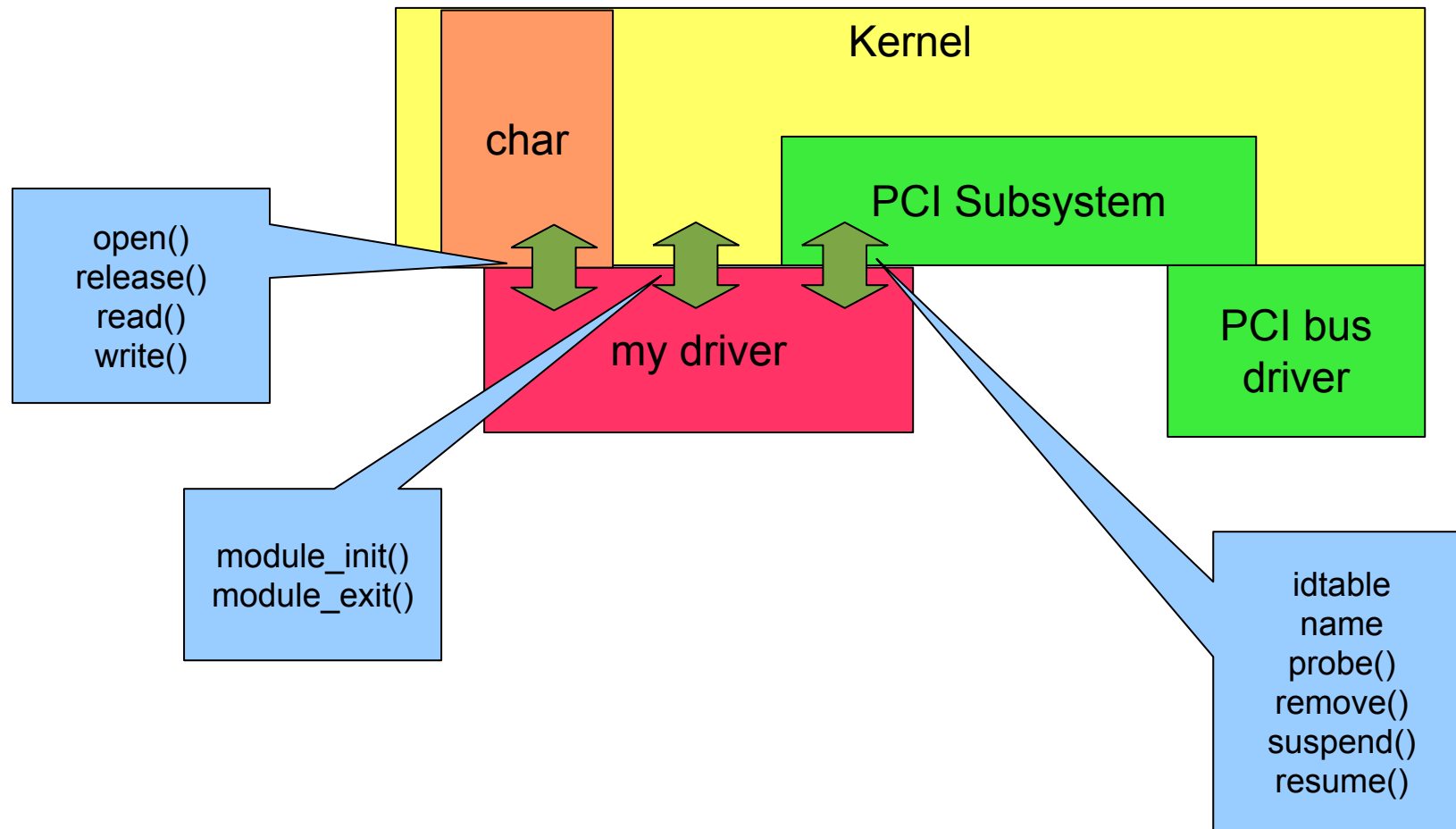
Driver callback hook-age



Driver callback hook-age



Driver callback hook-age



Example code

- Let's look at e1000e driver (PCI Express gigabit Ethernet driver)
- See how PCI driver hooks up to kernel
- <https://elixir.bootlin.com/linux/latest/source/drivers/net/ethernet/intel/e1000e/netdev.c>

The BAR



The BAR

- BAR is a Base Address Register
- Offset on devices to access device registers, resides in PCI "space"
- # lspci -s <bus:[slot:fn](#)> -vv

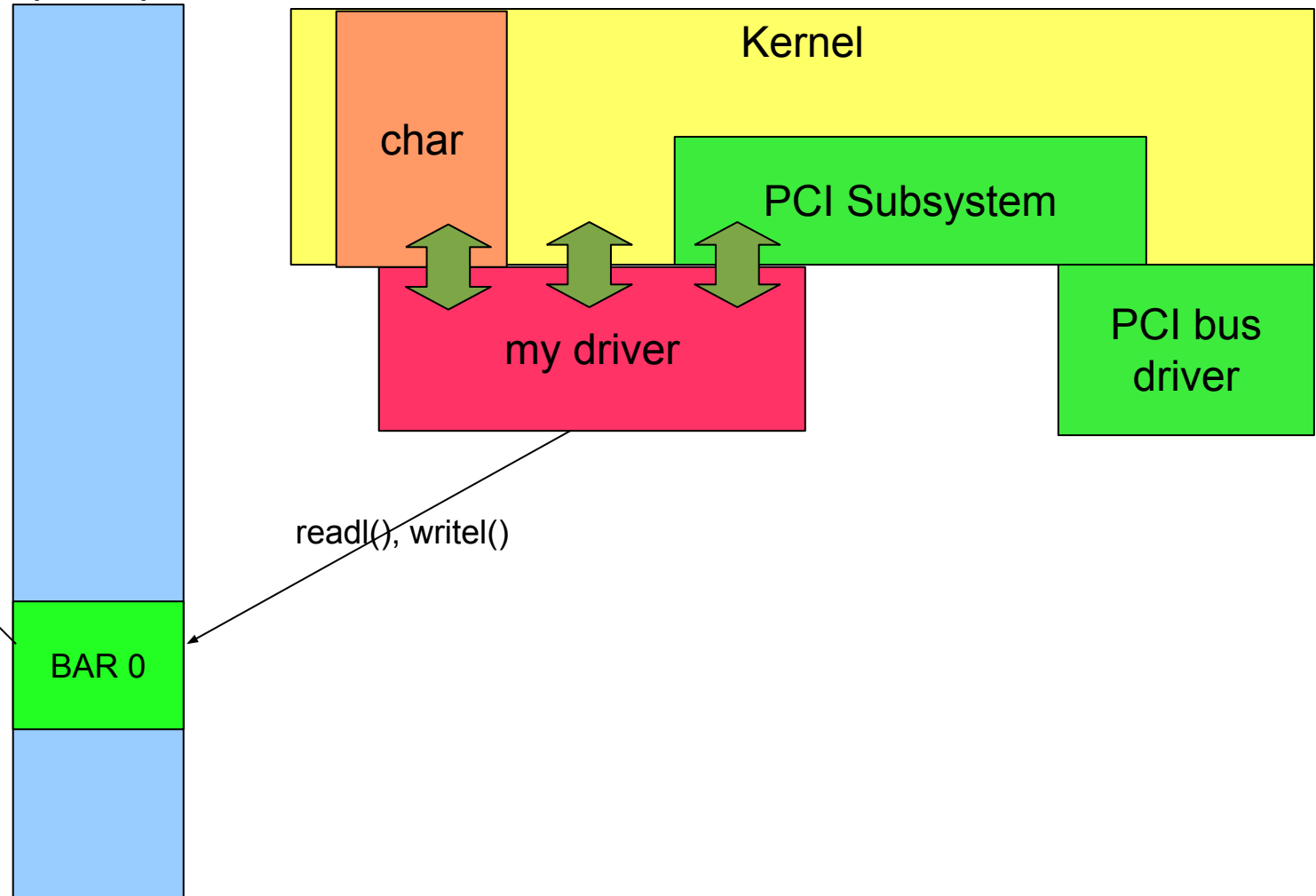
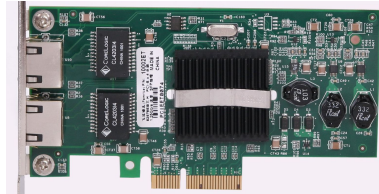


Accessing PCI regions

- `pci_request_selected_regions()` - Maps I/O BAR into `pci_device`
- `ioremap()` - Returns the physical address of the requested BAR
- At this point, PCI reads and writes can be issued to device:
 - `writel()` and `readl()`, or `iowrite32()` and `ioread32()`
- We just mapped the BAR for access...

Driver to HW mappage

Memory Mapped
I/O port space



Tearing down the PCI device

- As the device exits, must unregister device from PCI layer
- `iounmap()` and `pci_release_selected_regions()`
- Must be called from the "remove" function, not "exit_module"!
- `exit_module()` must unregister the `pci_device` struct from driver subsystem
- Look at the source...



Taking over a claimed device

- Drivers can drive many different devices
- Sometimes they suck at what they do on certain families of hardware
 - nouveau vs. nv on certain GeForce chipsets...
- What to do?
- Bind/unbind a device from a driver:
 - `echo 0:0:19.0 > /sys/module/e1000e/drivers/pci:e1000e/bind`
 - `echo 0:0:19.0 > /sys/module/e1000e/drivers/pci:e1000e/unbind`

Datasheets

- What device addresses (registers) are there
- What values to use in the registers
- What order to read/write to get things done

- Usually available on vendor websites

- Example...

- <http://www.intel.com/content/dam/doc/datasheet/82583v-gbe-controller-datasheet.pdf>

Wrap-up

- Know your memory types in Linux!
- PCI driver hookup, `pci_device` struct
- Probe entrypoint for PCI devices
- Map the BARs for access
- `writel()` and `readl()` for I/O access to device registers, or `iowrite32()` and `ioread32()`
- Unmap and unregister BARs
- Unregister PCI driver