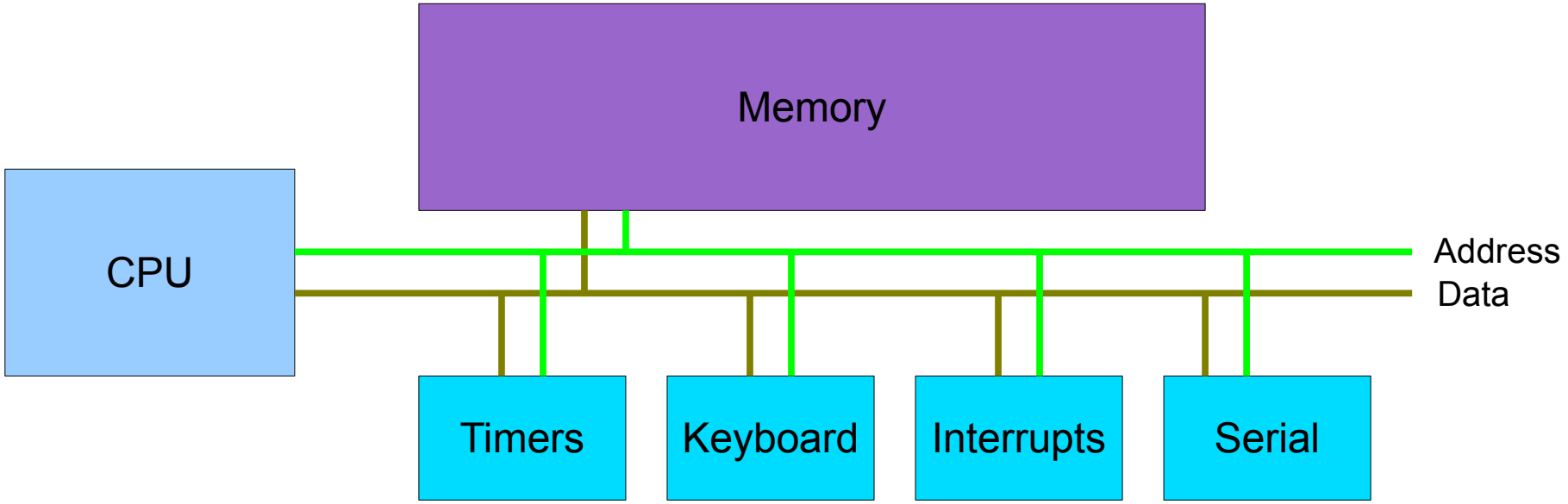
PCI Drivers

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

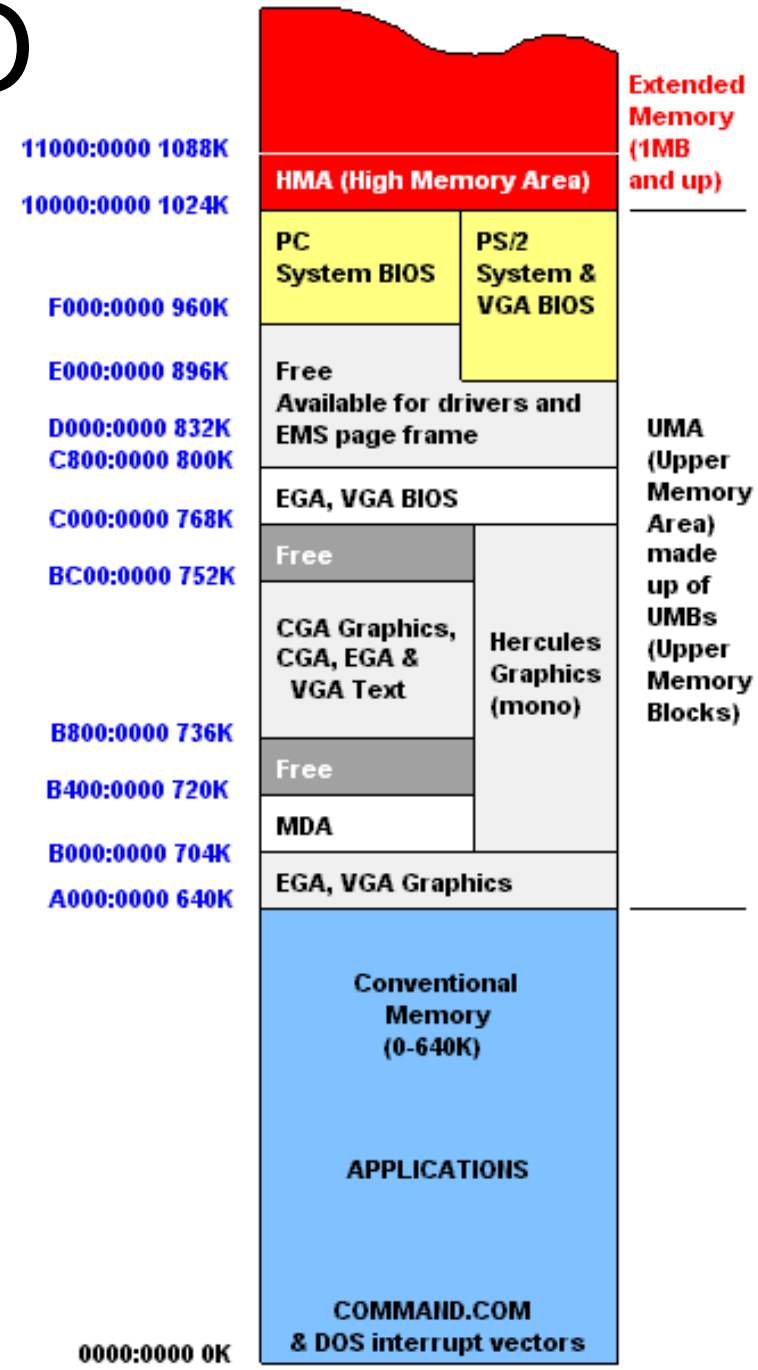
```
#define VIDEO_BASE  0x800000
#define MAX_X       1024
#define MAX_Y       1024

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

Memory Mapped I/O

- Example: IBM PC

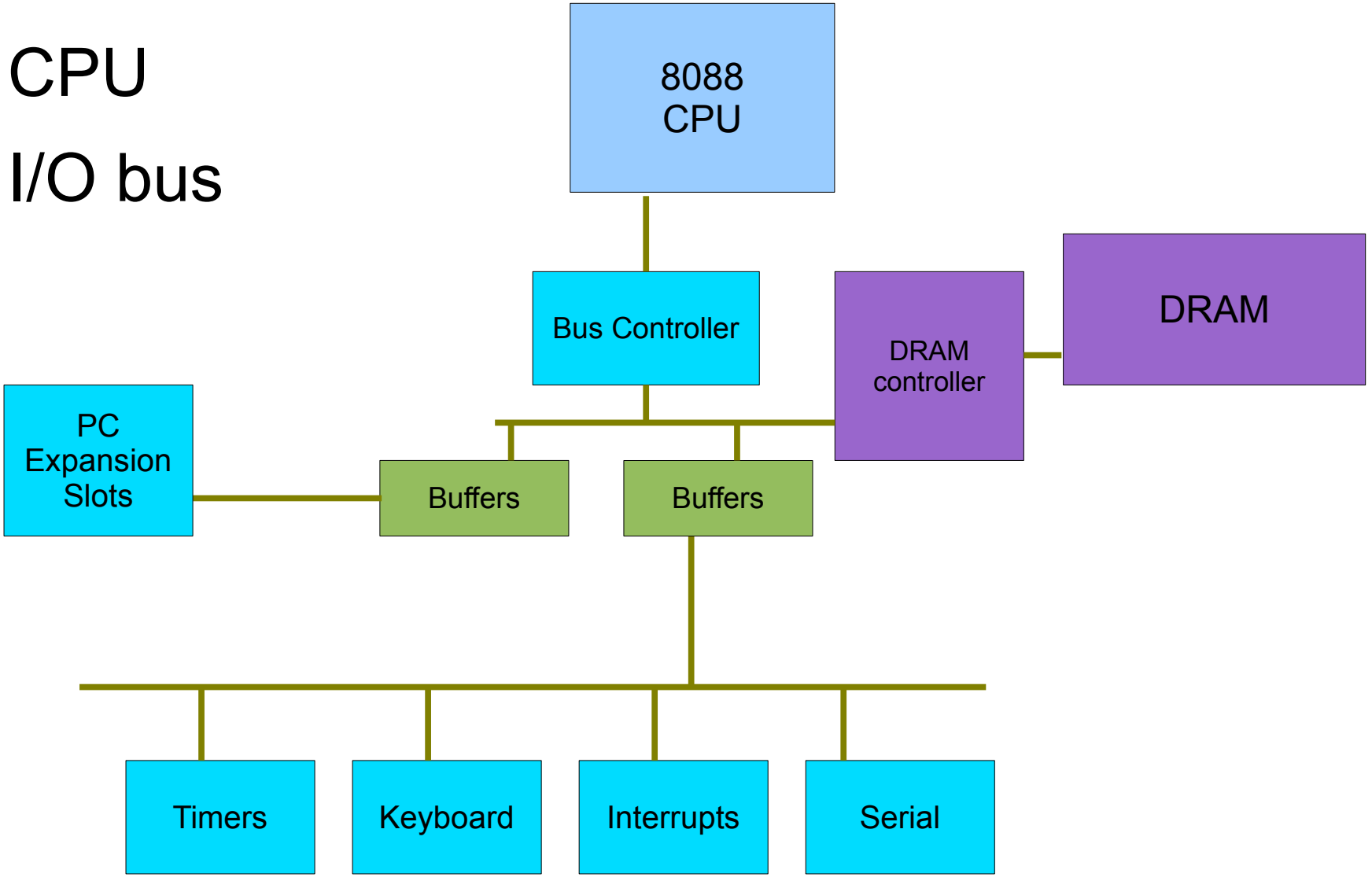
  Messy!

  - 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...



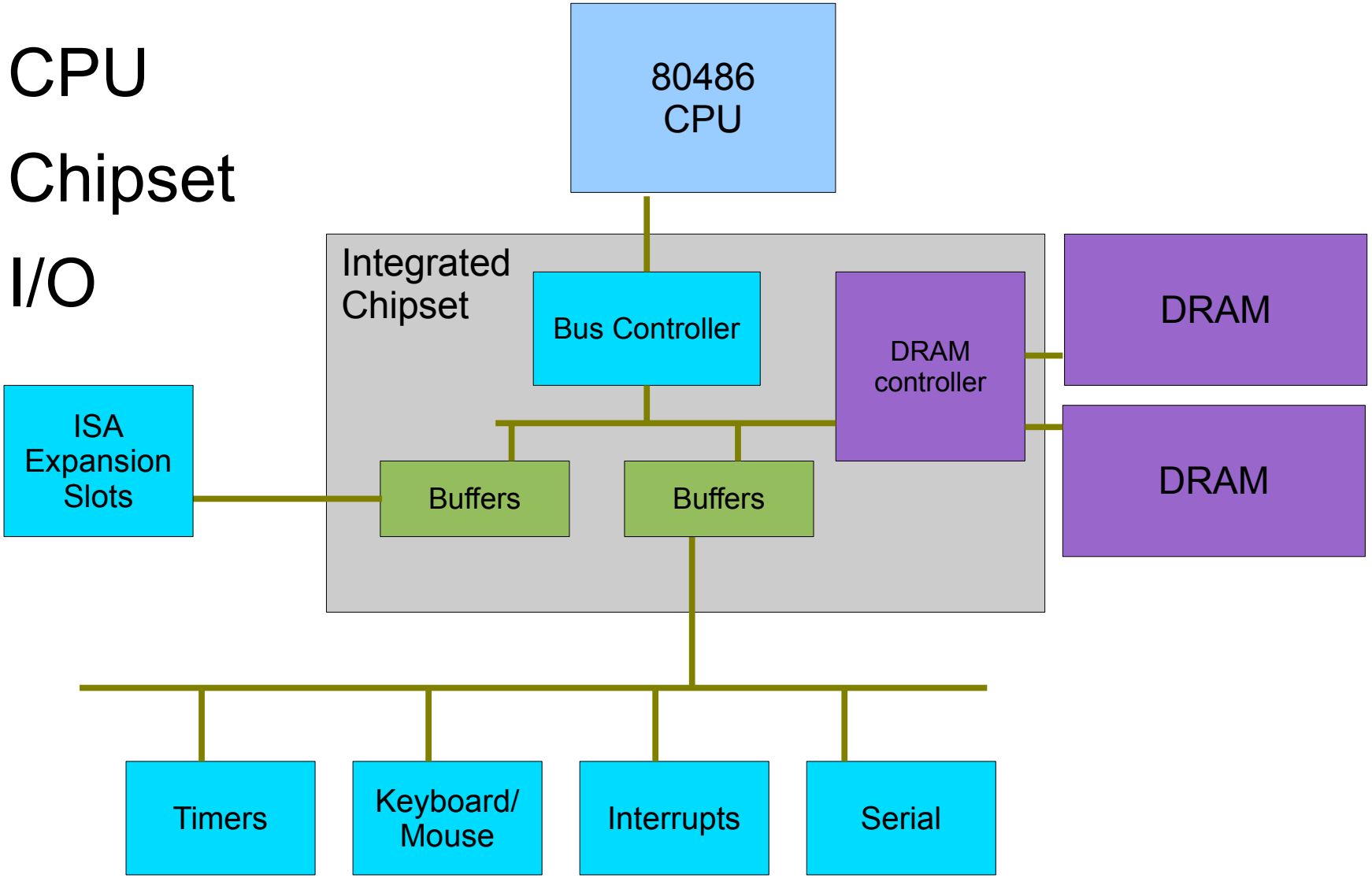
Early PCs

- CPU
- I/O bus



Later PCs

- CPU
- Chipset
- I/O



Later PCs

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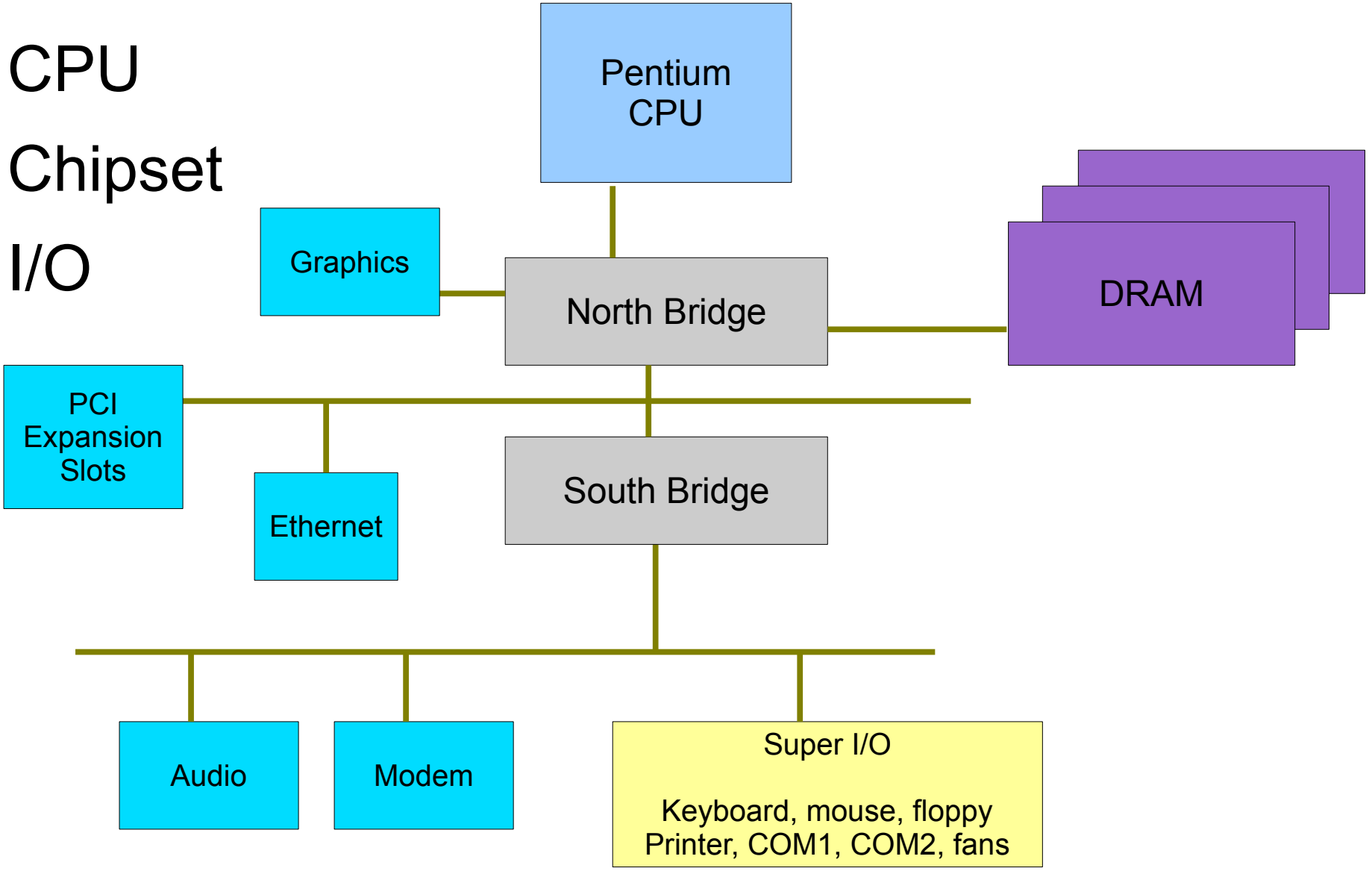
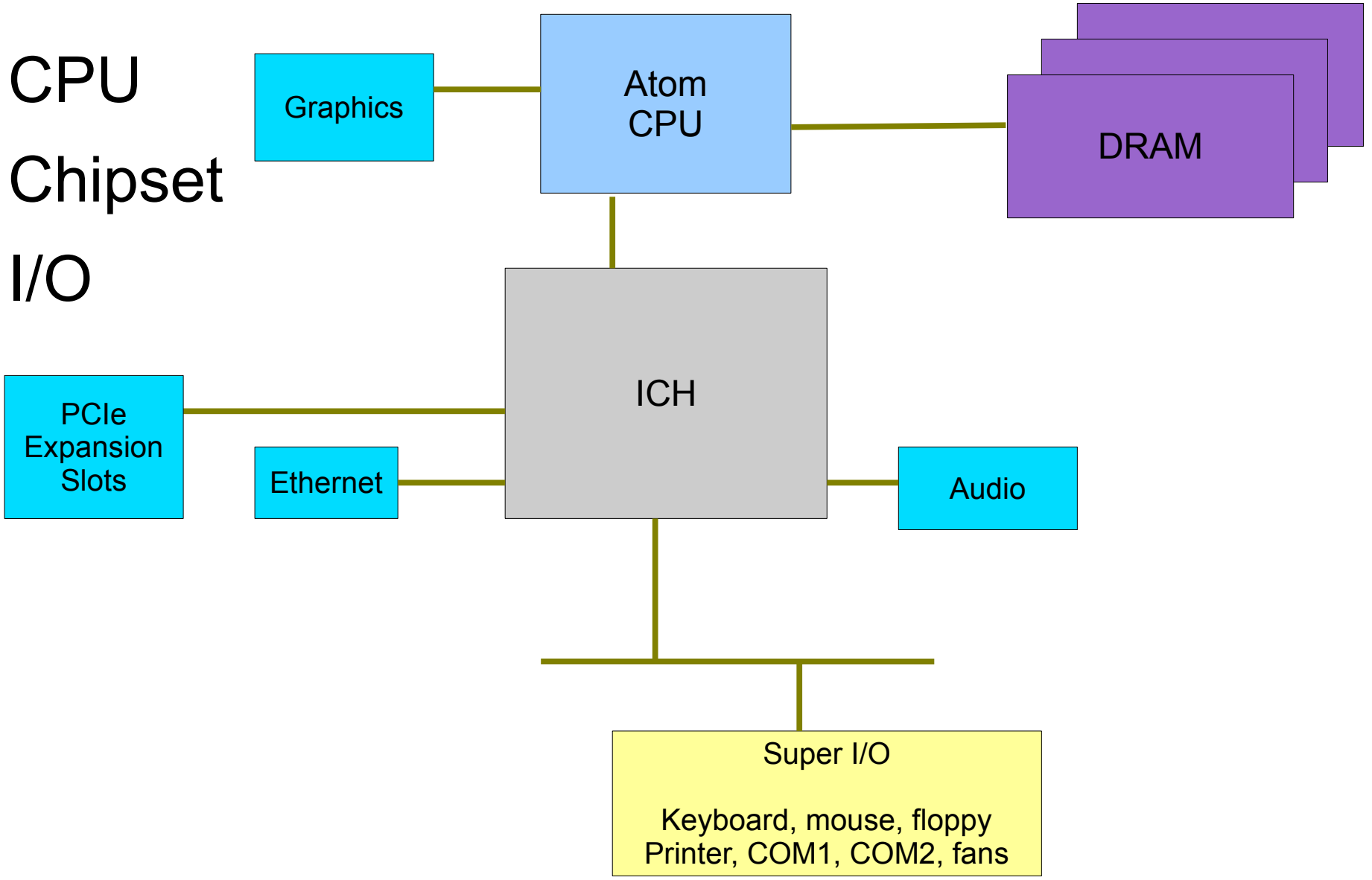
- I/O



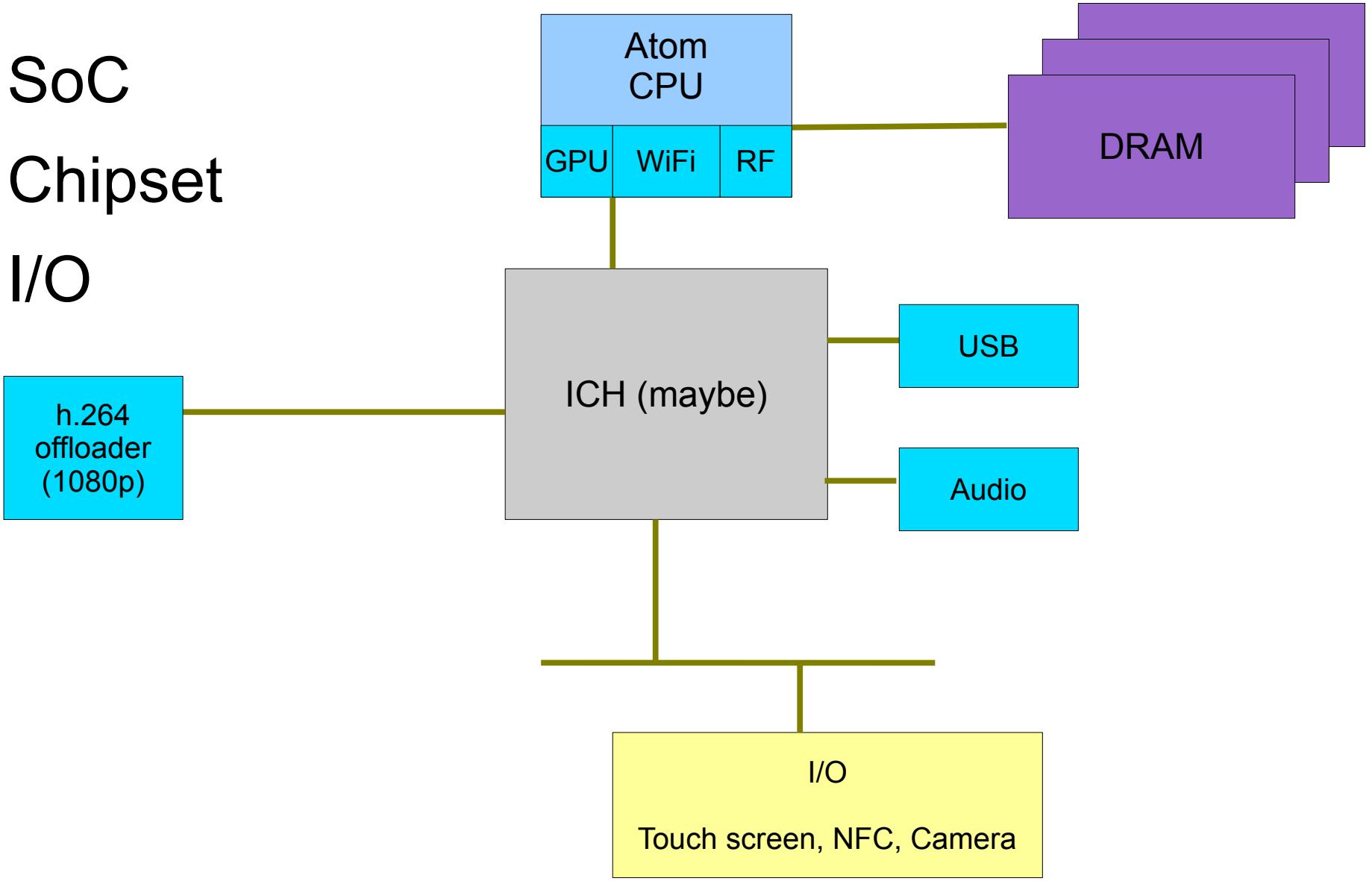
(Mostly) Current PCs

- CPU
- Chipset
- I/O

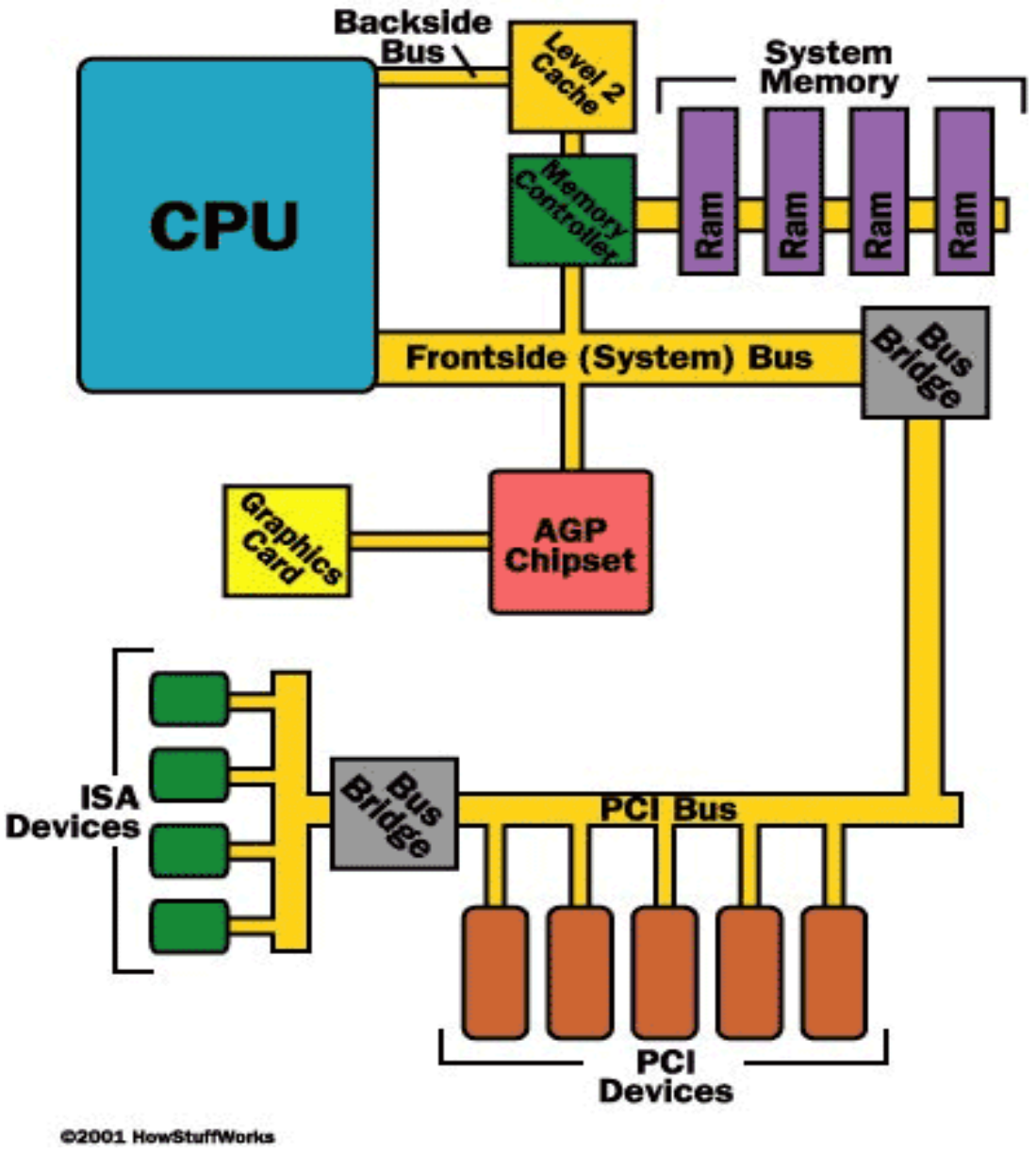


Current “PCs“

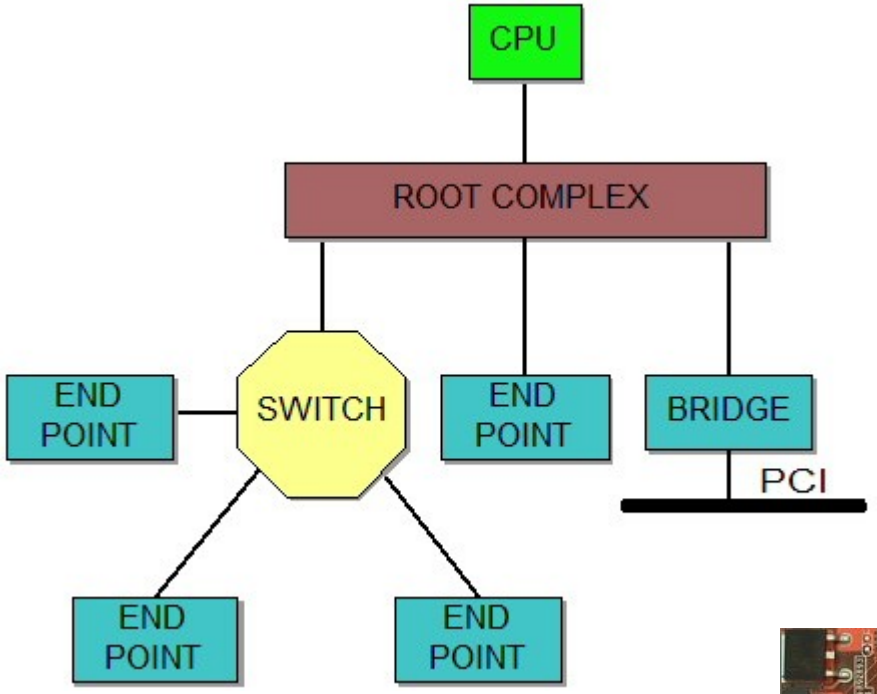
- SoC
- Chipset
- I/O

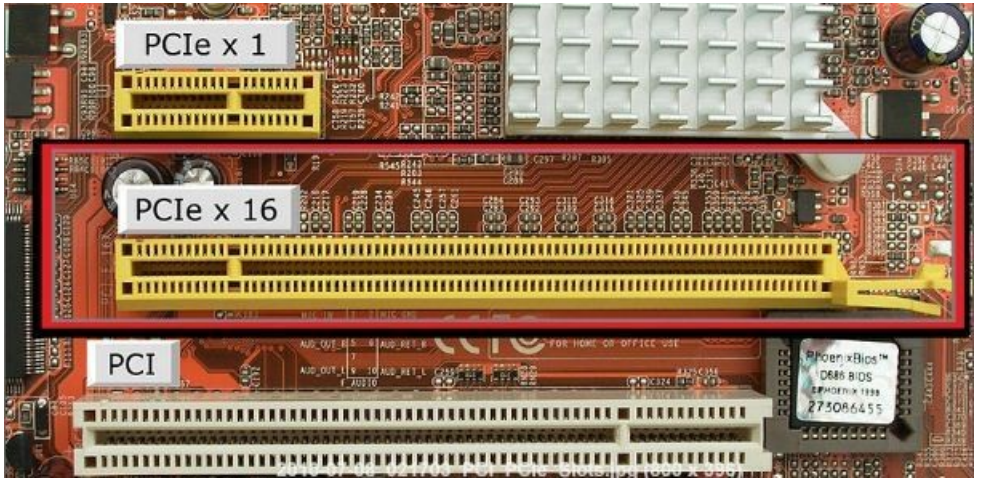


PCI at a glance



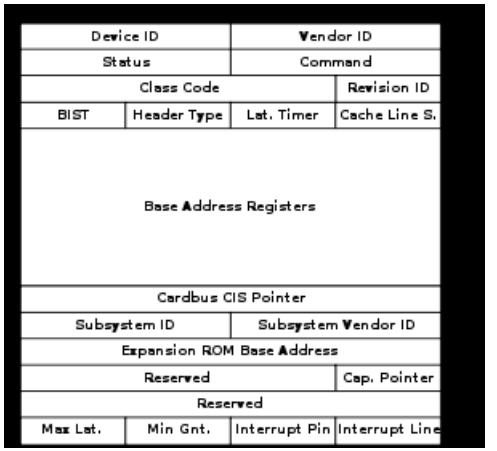
PCI Express (PCIe)





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



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

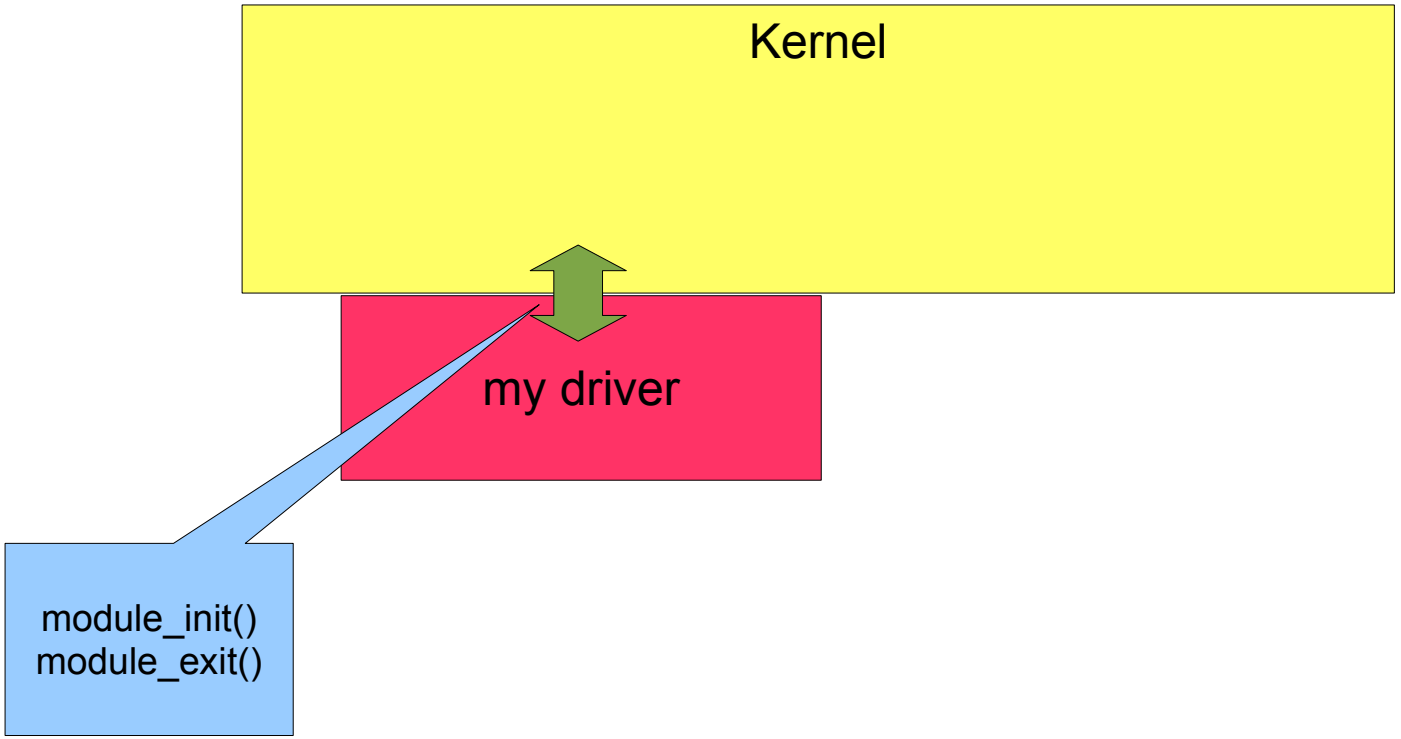
The driver

- 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



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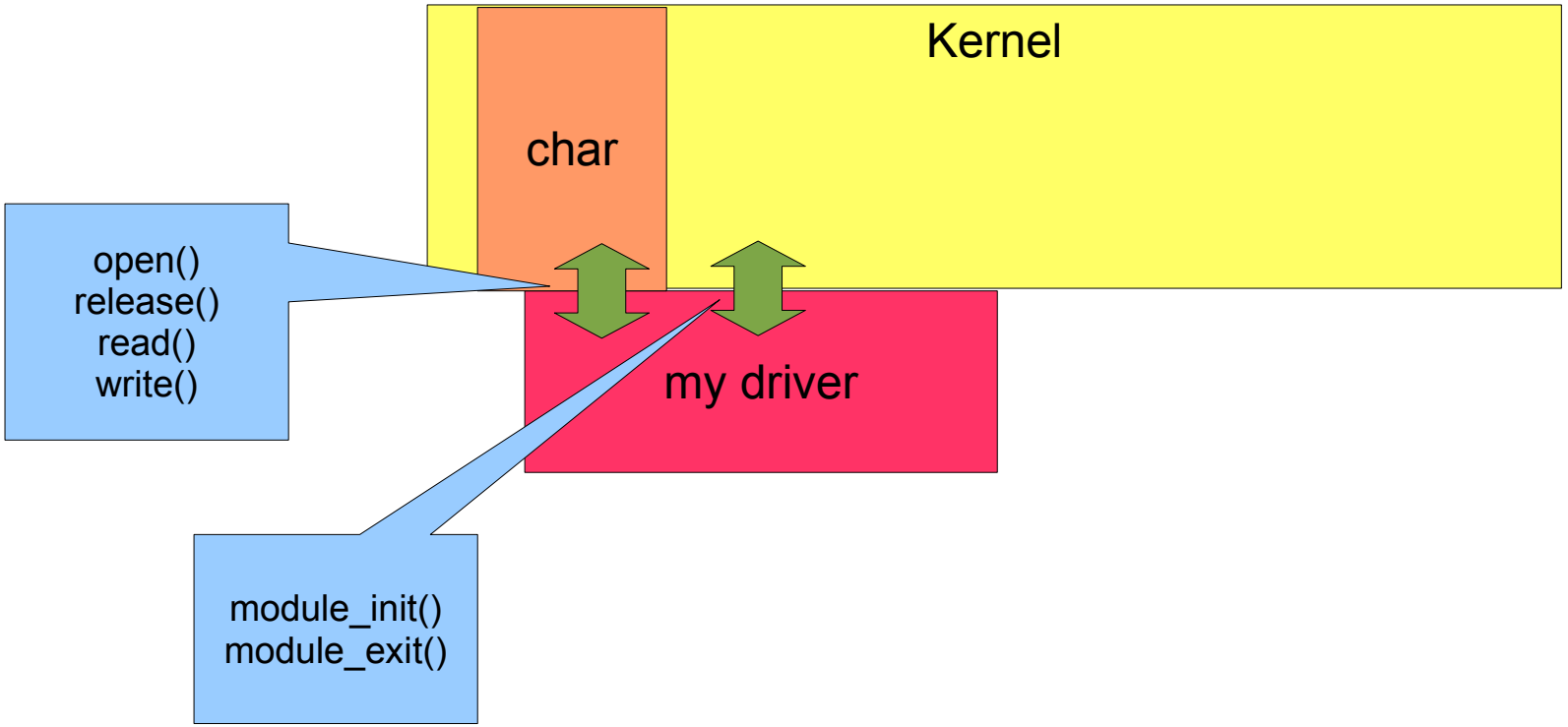
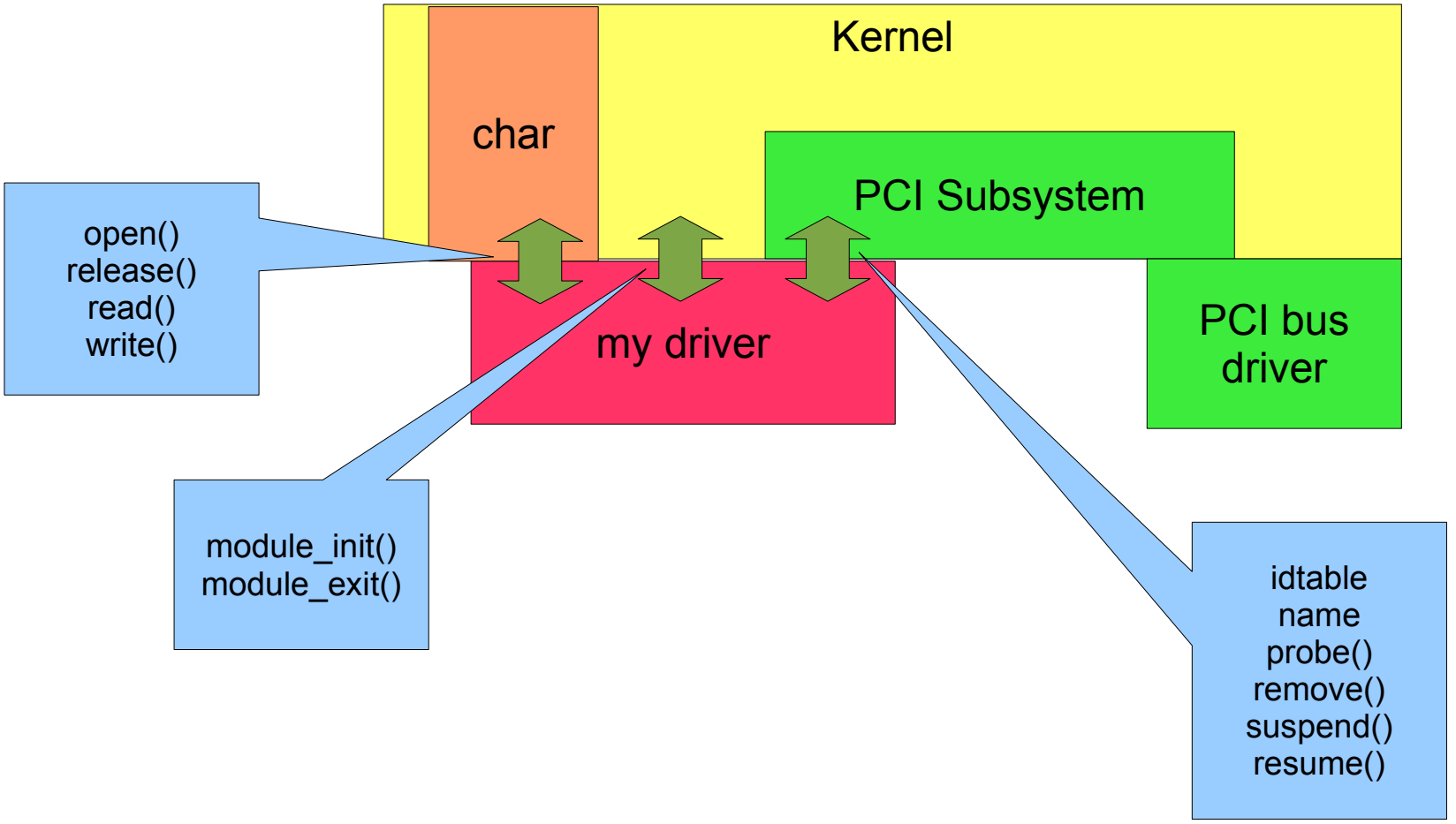


Driver callback hook-age



Example code

- Let's look at e1000e driver (PCI Express gigabit Ethernet driver)
- See how PCI driver hooks up to kernel
- http://lxr.free-electrons.com/source/drivers/net/ethernet/intel/e1000e/netdev.c

The BAR

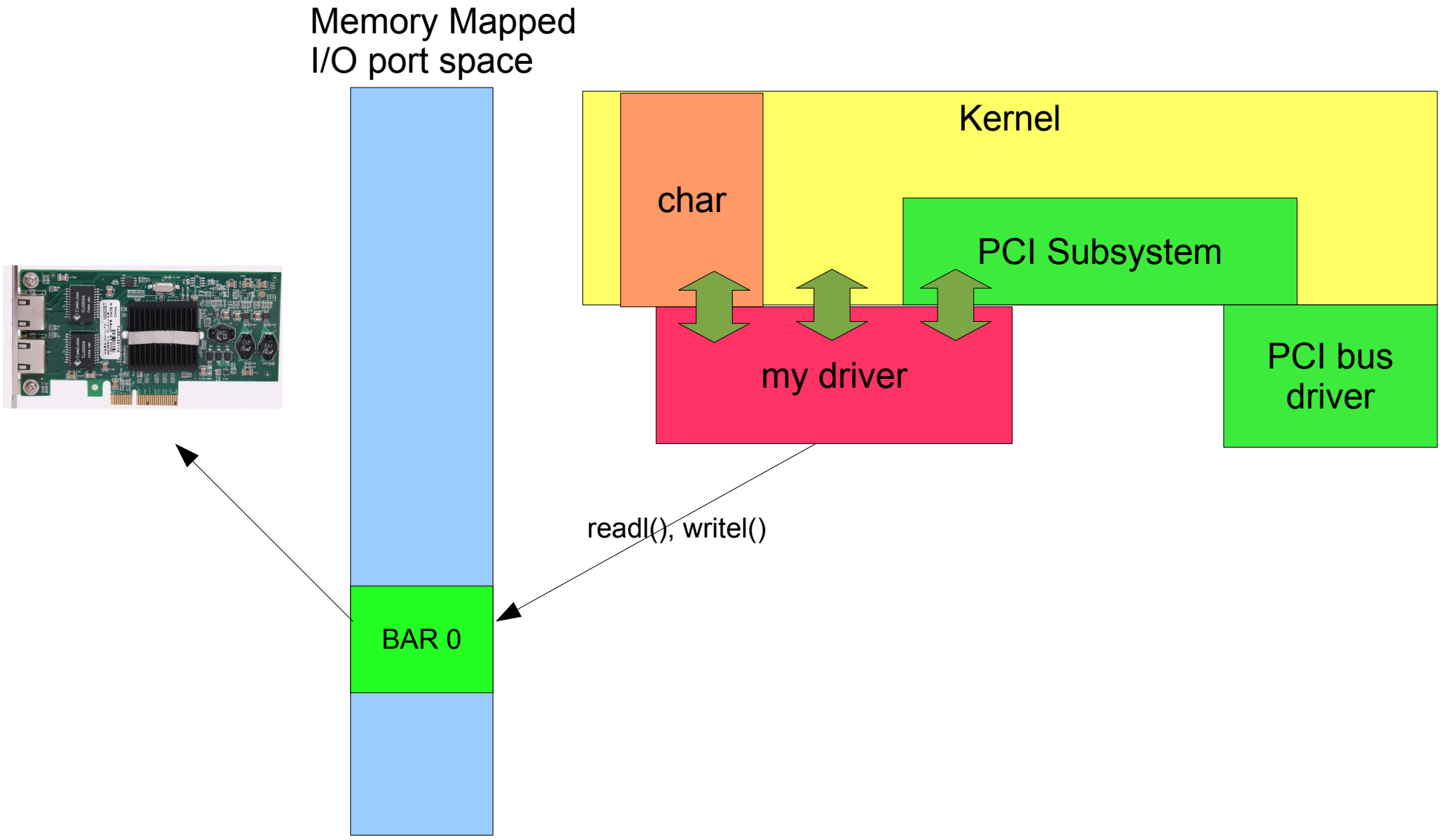
The BAR

- 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() / iowrite32() and ioread32()
- We just mapped the BAR for access...

Driver to HW mappage



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
- Unmap and unregister BARs
- Unregister PCI driver