Memory

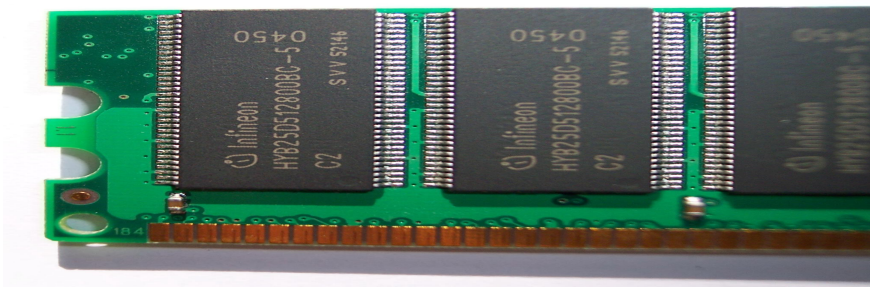
ECE 373

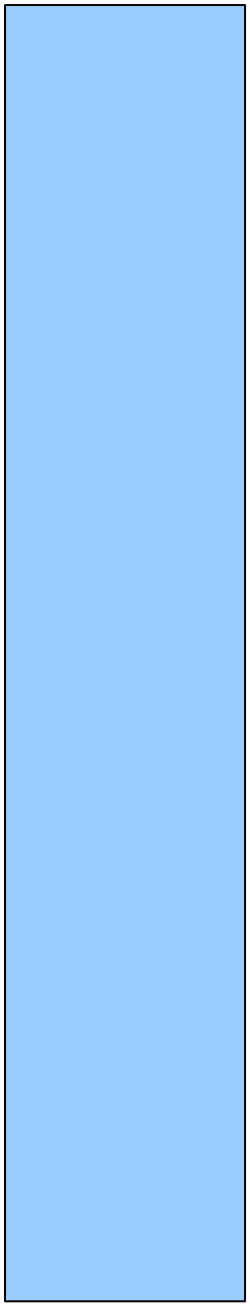
Prelims

- Questions on lab or reading assignments, class?

Linux memory basics

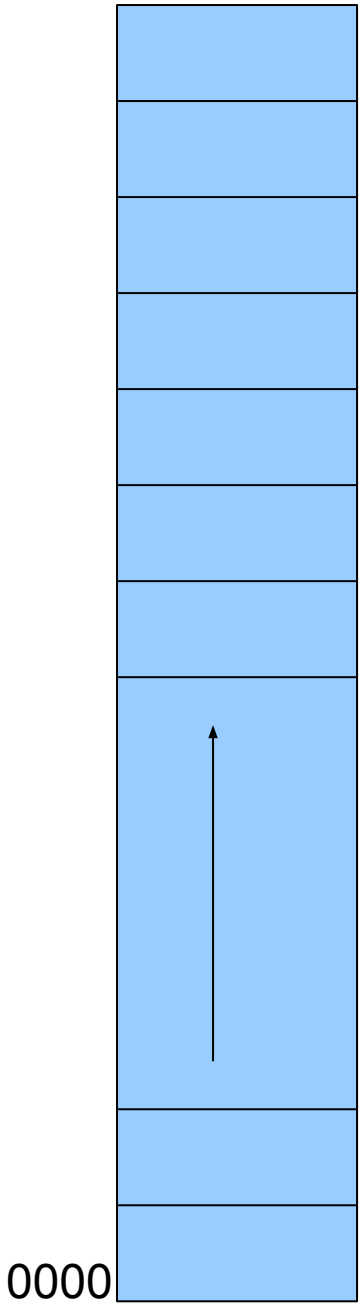
- Linux partitions memory into various chunks
- Physical, virtual, kernel logical, bus, kernel virtual
- How memory is partitioned dependent on:
  - Host architecture
  - Kernel configuration
  - Physical layout of chips





Physical addresses

- Addresses the CPU uses between itself and RAM
- Systems we use (x86-64 / AMD64) use 64-bit addresses
- This space is all of internal RAM (the big pool)



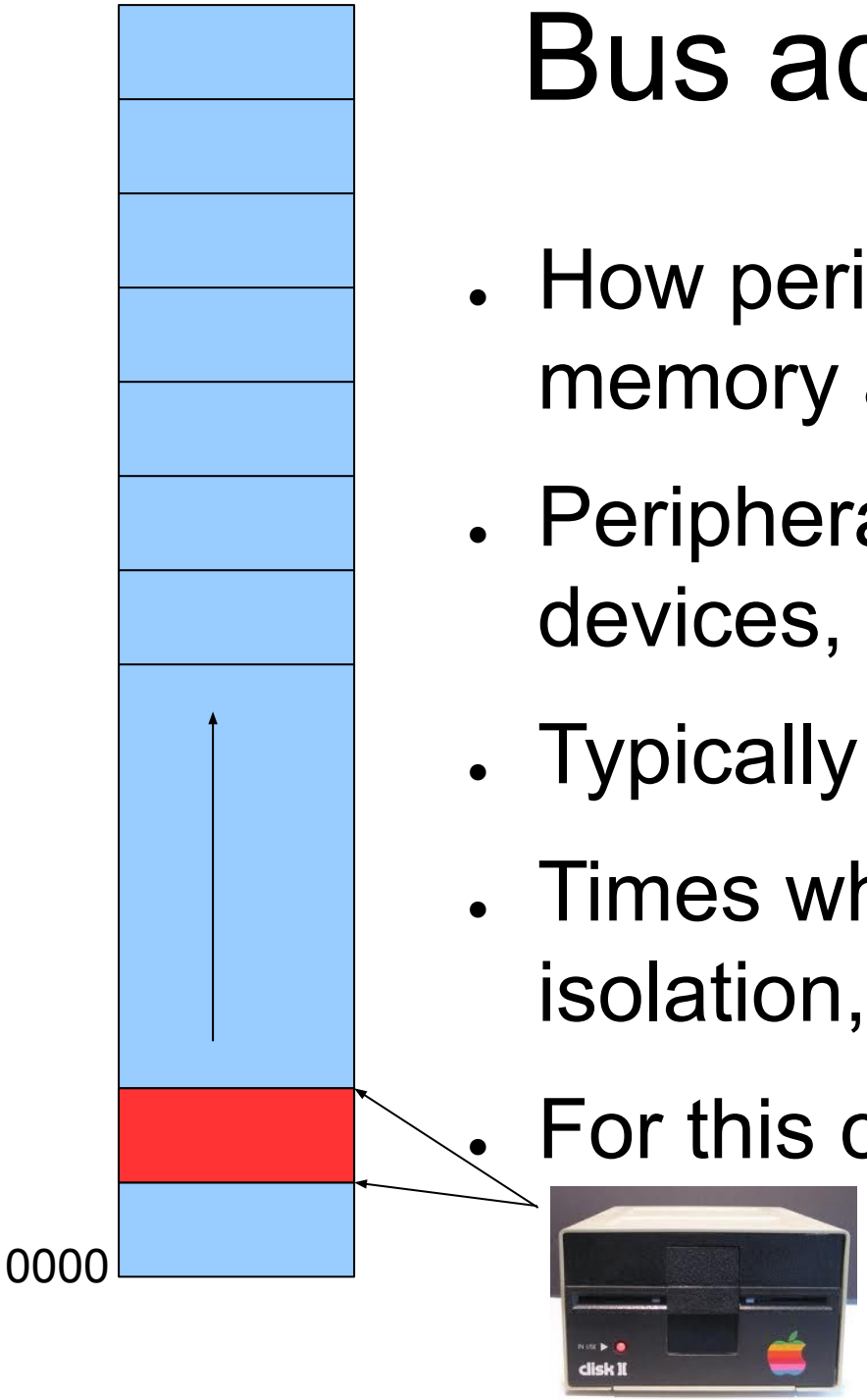
Pages

- Physical memory cut up into pages
- Sizes vary between architectures
  - 4KB is common, some use 1MB
  - Linux defines PAGE_SIZE in asm/page.h
- Address = Page offset and page number
  - (page_num * PAGE_SIZE) + offset
- Tracked in kernel page tables
- TLB lookups

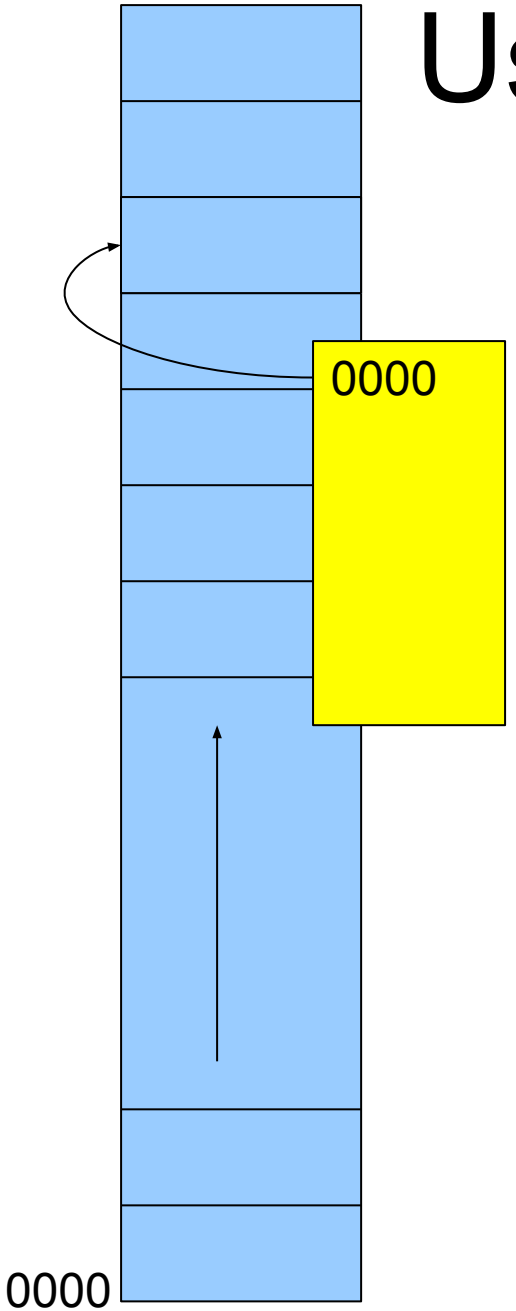
Pages in Linux

- Pages maintain reference count
  - `alloc_page()` gets a page, increments refcnt
  - `free_page()` returns a page, decrements refcnt
  - page returned to free list when `refcnt == 0`
  - Most drivers use higher level `kmalloc/kfree`
- Free lists maintained by memory manager in the kernel

Bus addresses



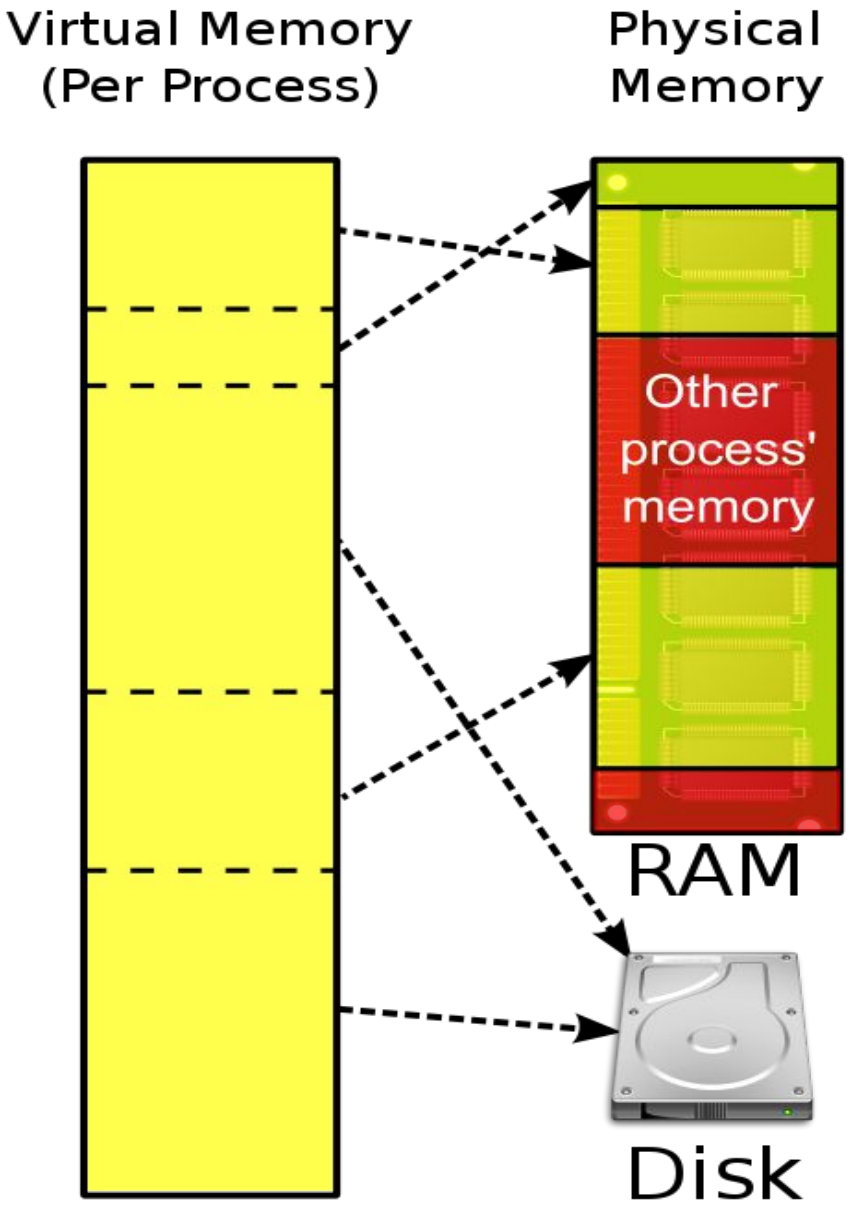
- How peripherals communicate with memory and CPU
- Peripherals include PCI bus, serial devices, etc.
- Typically same as physical address
- Times when they differ is bus isolation, or an IOMMU is used
- For this class, bus = physical



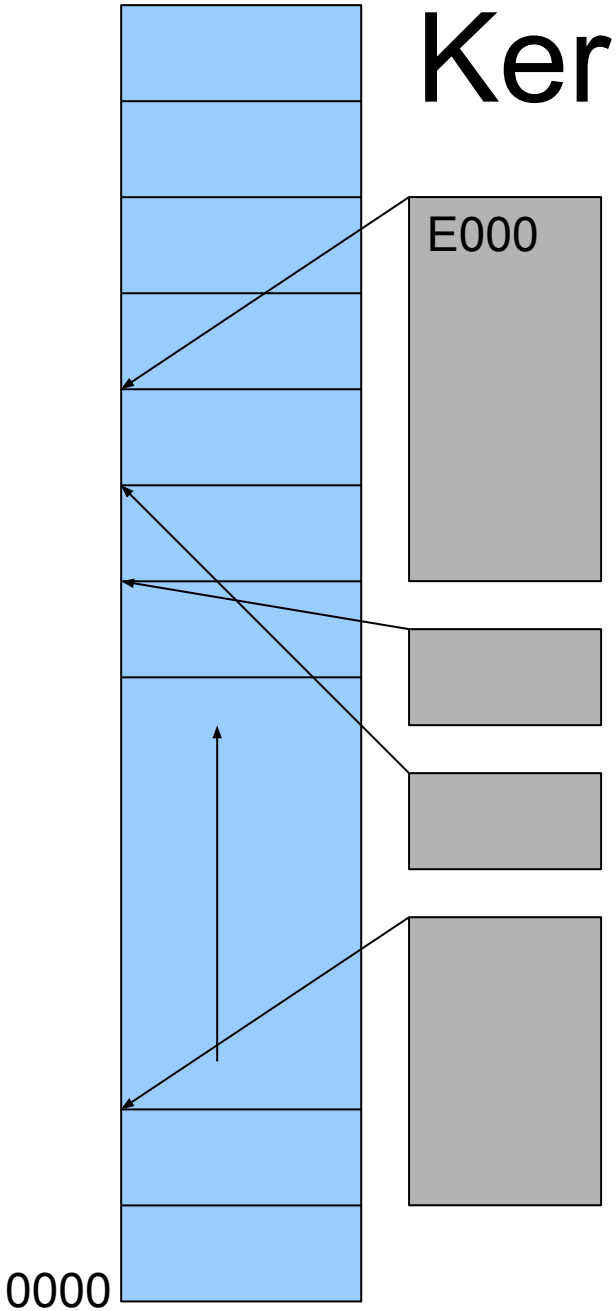
User virtual addresses

- Userspace applications always use virtual addresses
- Returned by things like `malloc()` and `new()`
- Virtual address space doesn't need to fit into actual amount of memory
- Processes get their own address space
- SIGSEGV when out-of-bounds

User virtual address layout



Kernel logical addresses



- All memory that kernel maps for kernel use
- Kernel memory that is returned by `kmalloc()`
- Not always physical address
- Mapped directly to physical address
- Typically at some constant offset from physical address
- Stored in things like `void *`

Kernel virtual addresses

- Still mapped to physical addresses (isn't everything?)
- Not guaranteed to be one-to-one mapping to physical address
- Memory returned from `vmalloc()`
- Cannot be pinned

Kernel virtual addresses

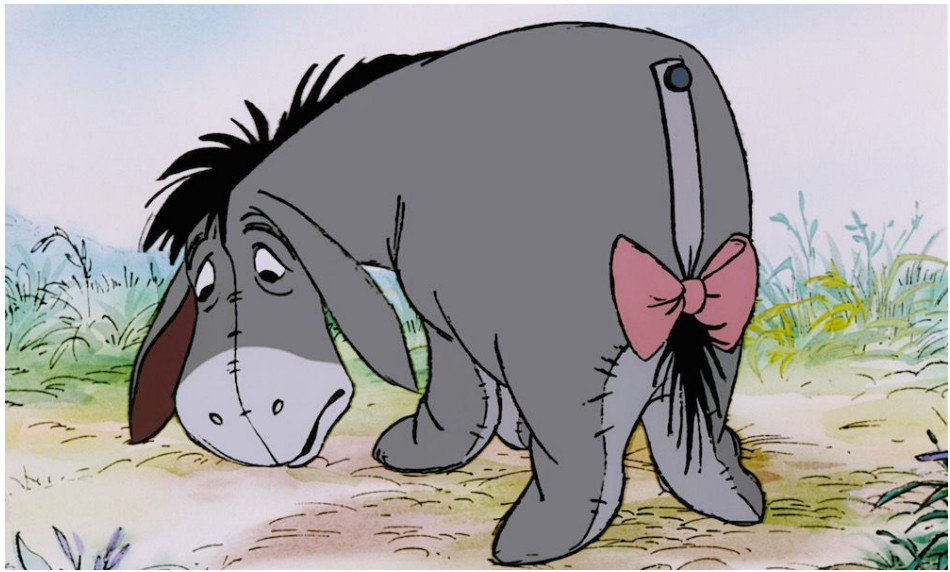
- Still mapped to physical addresses (isn't everything?)
- Not guaranteed to be one-to-one mapping to physical address
- Memory returned from vmalloc()
- Cannot be pinned
- Cannot be used for DMA or MMIO

The act of pinning

- Memory that cannot be swapped out
- Necessary for memory peripheral device or CPU needs

The act of pinning

- Memory that cannot be swapped out
- Necessary for memory peripheral device or CPU needs
- Page faults can be fatal...
- Only physical, bus, or kernel logical addresses can be pinned



virtual to physical (and back)

- Can derive physical address from virtual address
- Macros defined in `asm/page.h` to help
- `__pa()` - takes virtual, returns physical
- `__va()` - takes physical, returns virtual

So what?

- CPU uses physical
- Peripherals use bus
- Users use virtual
- Kernel and drivers use logical, virtual, and bus
  - When and why?