Hardware Overview

Dave Eckhardt
de0u@andrew.cmu.edu

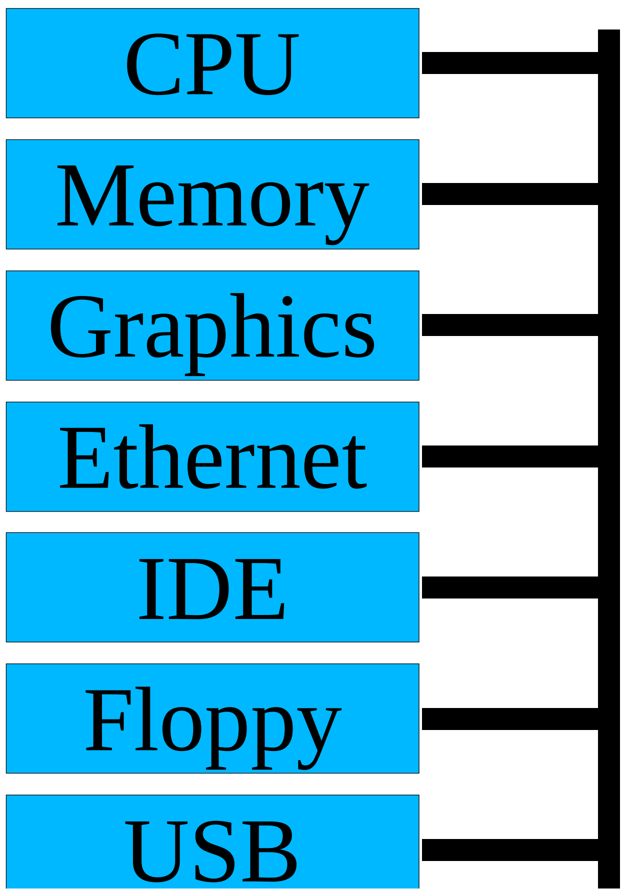
Synchronization

- Today's class
  - Not exactly Chapter 2 or 13
- Friday's class
  - Project 1 talk (probably relevant to you)
- Being registered is good
  - Disk space, access control lists, etc.

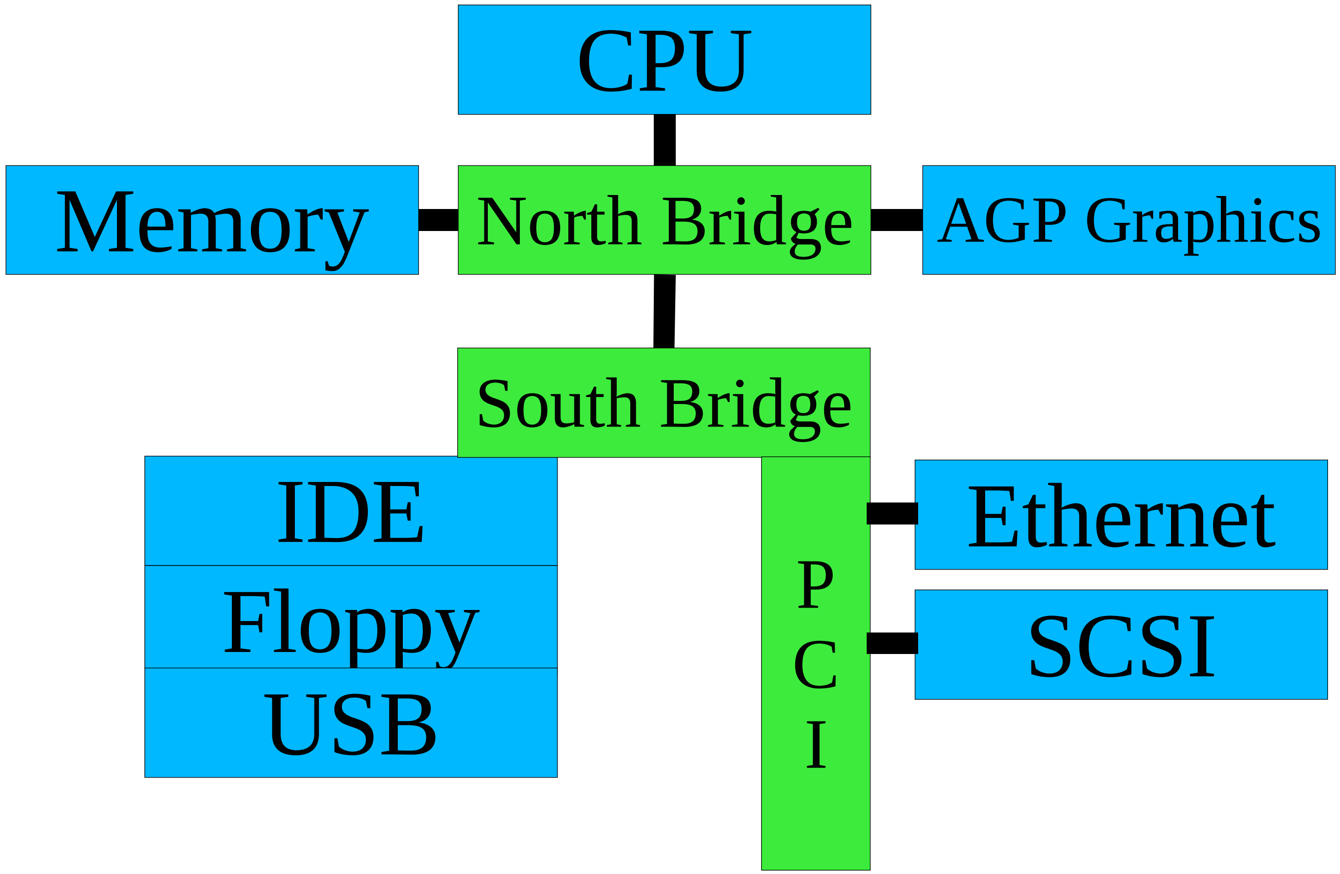
Outline

- Computer parts
- CPU State
- Fairy tales about system calls
- CPU context switch (intro)
- Interrupt handlers
- Interrupt masking

Inside The Box - Historical/Logical



Inside The Box - Really



CPU State

- User registers (on Planet Intel)
  - General purpose - %eax, %ebx, %ecx, %edx
  - Stack Pointer - %esp
  - Frame Pointer - %ebp
  - Mysterious String Registers - %esi, %edi

CPU State

- ***Non-user*** registers, aka...
- Processor status register(s)
  - User process / Kernel process
  - Interrupts on / off
  - Virtual memory on / off
  - Memory model
    - small, medium, large, purple, dinosaur

CPU State

- Floating Point Number registers
  - Logically part of “User registers”
  - Sometimes special instead
    - Some machines don't have floating point
    - Some processes don't use floating point

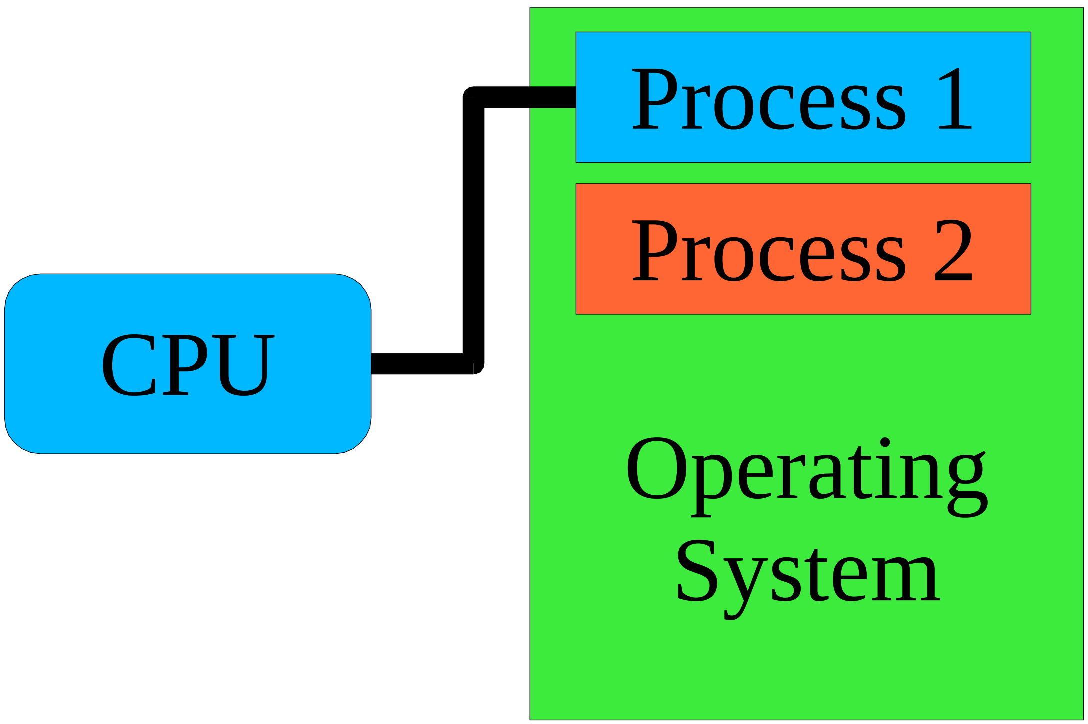
Story time!

- Time for some fairy tales
  - The getpid() story (shortest legal fairy tale)
  - The read() story (toddler version)
  - The read() story (grade-school version)

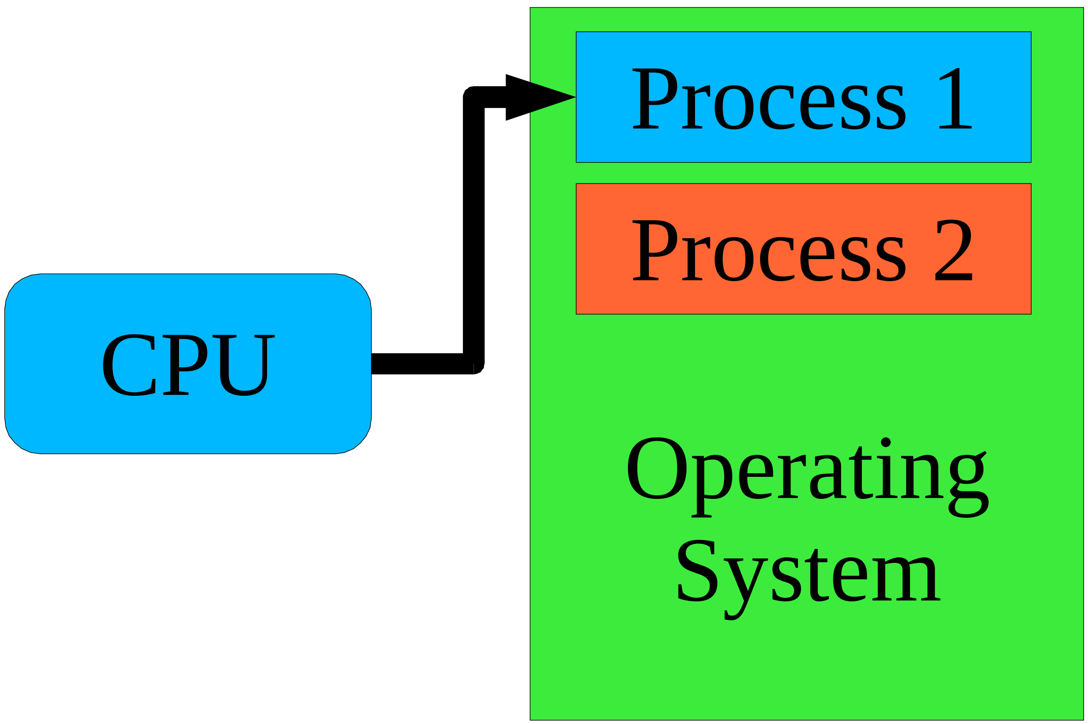
The Story of getpid()

- User process is computing
  - User process calls getpid() library routine
  - Library routine executes TRAP(314159)
- The world changes
  - Some registers dumped into memory somewhere
  - Some registers loaded from memory somewhere
    - (else)
- The processor has ***entered kernel mode***

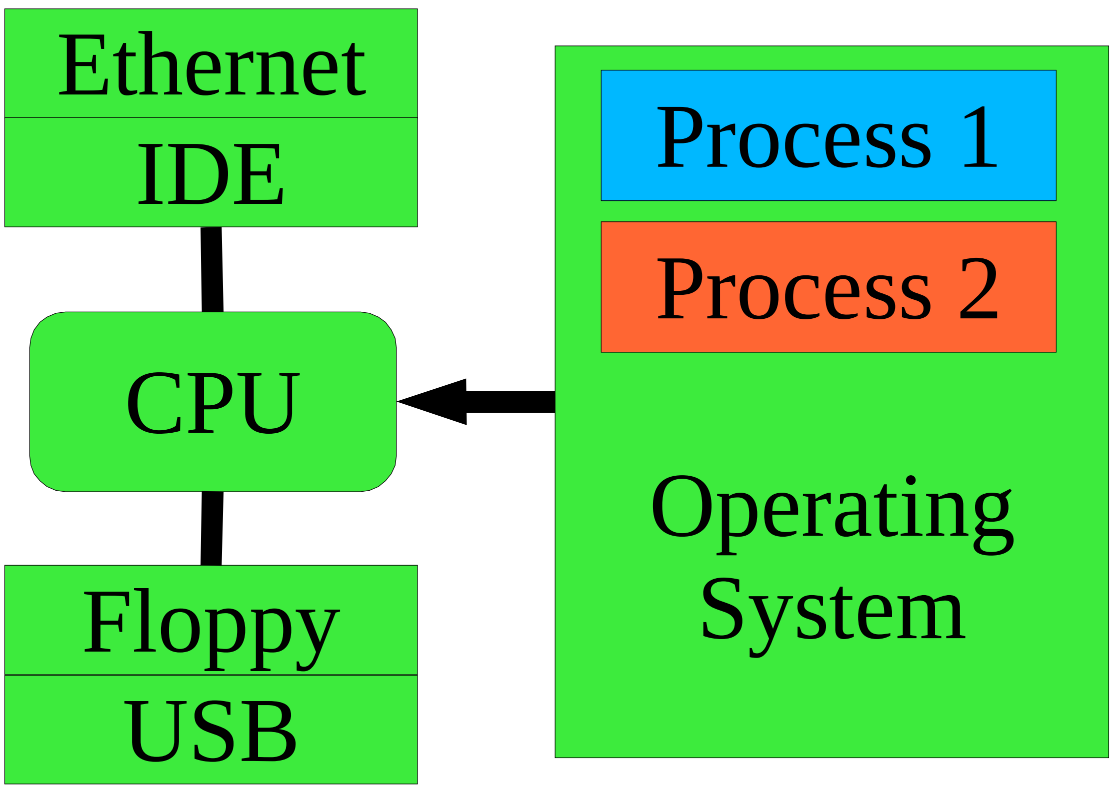
User Mode



Entering Kernel Mode



Entering Kernel Mode



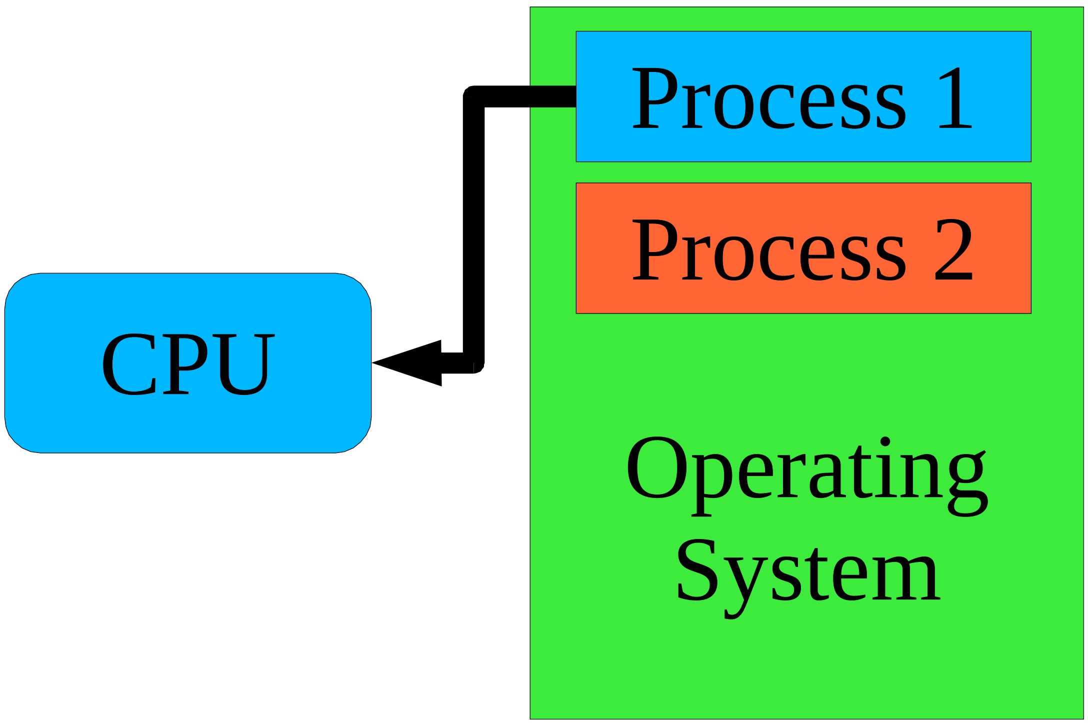
The Kernel Runtime Environment

- Language runtimes differ
  - ML: no stack, “nothing but heap”
  - C: stack-based
- Processor is mostly agnostic
- Trap handler builds kernel runtime environment
  - Switches to correct stack
  - Turns on virtual memory
  - Flushes caches

The Story of getpid()

- Process in kernel mode
  - u.u_reg[R_EAX] = u.u_pid;
- Return from interrupt
  - Processor state restored to user mode
    - (modulo %eax)
- User process returns to computing
  - Library routine returns %eax as value of getpid()

Returning to User Mode



A Story About read()

- User process is computing

```
count = read(0, buf, sizeof (buf));
```

- User process “goes to sleep”
- Operating system issues disk read
- Time passes
- Operating system copies data
- User process wakes up

Another Story About read()

- P1: read()
  - Trap to kernel mode
- Kernel: issue disk read
- Kernel: switch to P2
  - Return from interrupt - but to P2, not P1!
- P2: compute 1/3 of Mandelbrot set

Another Story About read()

- Disk: done!
  - Interrupt to kernel mode
- Kernel: switch to P1
  - Return from interrupt - but to P1, not P2!

What do you need for P1?

- Single-process “operating system”
- Only one C runtime environment
  - One memory address space, one stack
- Process based on polling

```
while(1)
  if (time_to_move(paddle))
    move_paddle();
  if ((c = getchar()) != NONE)
    process_char(c);
```

What do you need for P1?

- Keyboard interrupt handler
  - Turns key up/down events into characters
  - Makes characters available to getchar()
    - [not its real name]
- Timer interrupt handler
  - Updates “now” when countdown timer fires
- Console driver
  - Put/scroll characters/strings on screen

Interrupt Vector Table

- How does CPU handle ***this*** interrupt?
  - Disk interrupt -> disk driver
  - Mouse interrupt -> mouse driver
- Need to know
  - Where to dump registers
    - often: property of current process, not of interrupt
  - New register values to load into CPU
    - key: new program counter, new status register

Interrupt Vector Table

- Table lookup
  - Interrupt controller says: this is interrupt source #3
- CPU knows table base pointer, table entry size
- Spew, slurp, off we go

Race Conditions

```
if (device_idle)
  start_device(request);
else
  enqueue(request);
```

Race Conditions

aaaaaa

User process	*Interrupt handler*
`if (device_idle)`	
	`INTERRUPT`
	`...`
	`device_idle = 1;`
	`RETURN FROM INTERRUPT`
`enqueue(request)`	

Interrupt masking

- Atomic actions
  - Block device interrupt while checking and enqueueing
  - Or use a lock-free data structure
    - [left as an exercise for the reader]
- Avoid blocking ***all*** interrupts
  - [not a big issue for 15-410]
- Avoid blocking too long
  - Part of Project 3 grading criteria

Timer – Behavior

- Count something
    - CPU cycles, bus cycles, microseconds
- When you hit a limit, generate an interrupt
- Reload counter (don't wait for software to do it)

Timer – Why?

- Why interrupt a perfectly good execution?
- Avoid CPU hogs

```
for (;;) ;
```

- Maintain accurate time of day
  - Battery-backed calendar counts only seconds (poorly)
- Dual-purpose interrupt
  - ++ticks_since_boot;
  - force process switch (probably)

Closing

- Welcome to the machine
  - For P1
    - Keyboard
    - Clock
    - Screen
    - Memory (a little)
- Browse Intel document introductions?
- ***Start choosing a partner for P2***