Lecture 6: Interrupts

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Topics

- What is an interrupt?
- How do operating systems handle interrupts?
  - FreeBSD example
  - Linux in tutorial

Interrupts

Defn: an event external to the currently executing process that causes a change in the normal flow of instruction execution; usually generated by hardware devices external to the CPU

- From "Design and Implementation of the FreeBSD Operating System", Glossary

- Key point is that interrupts are asynchronous w.r.t. current process
  - Typically indicate that some device needs service

Why Interrupts?

- People like connecting devices
  - A computer is much more than the CPU
    - Keyboard, mouse, screen, disk drives
    - Scanner, printer, sound card, camera, etc.
- These devices occasionally need CPU service
  - But we can't predict when
- External events typically occur on a macroscopic timescale
  - we want to keep the CPU busy between events

☞Need a way for CPU to find out devices need attention

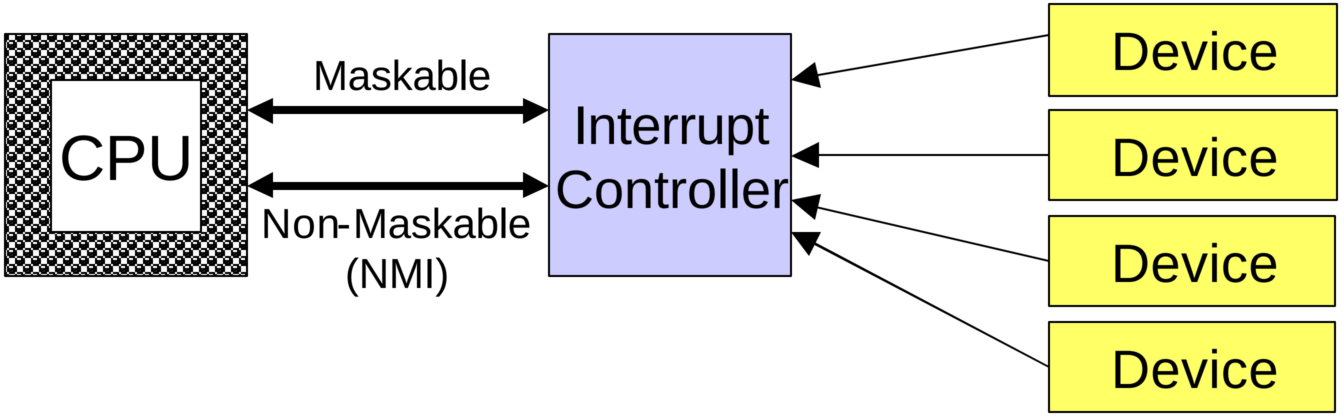
Possible Solution: Polling

- CPU periodically checks each device to see if it needs service
  - ✘ takes CPU time even when no requests pending
  - ✘ overhead may be reduced at expense of response time
  - ✓ can be efficient if events arrive rapidly

"Polling is like picking up your phone every few seconds to see if you have a call. …"

Alternative: Interrupts

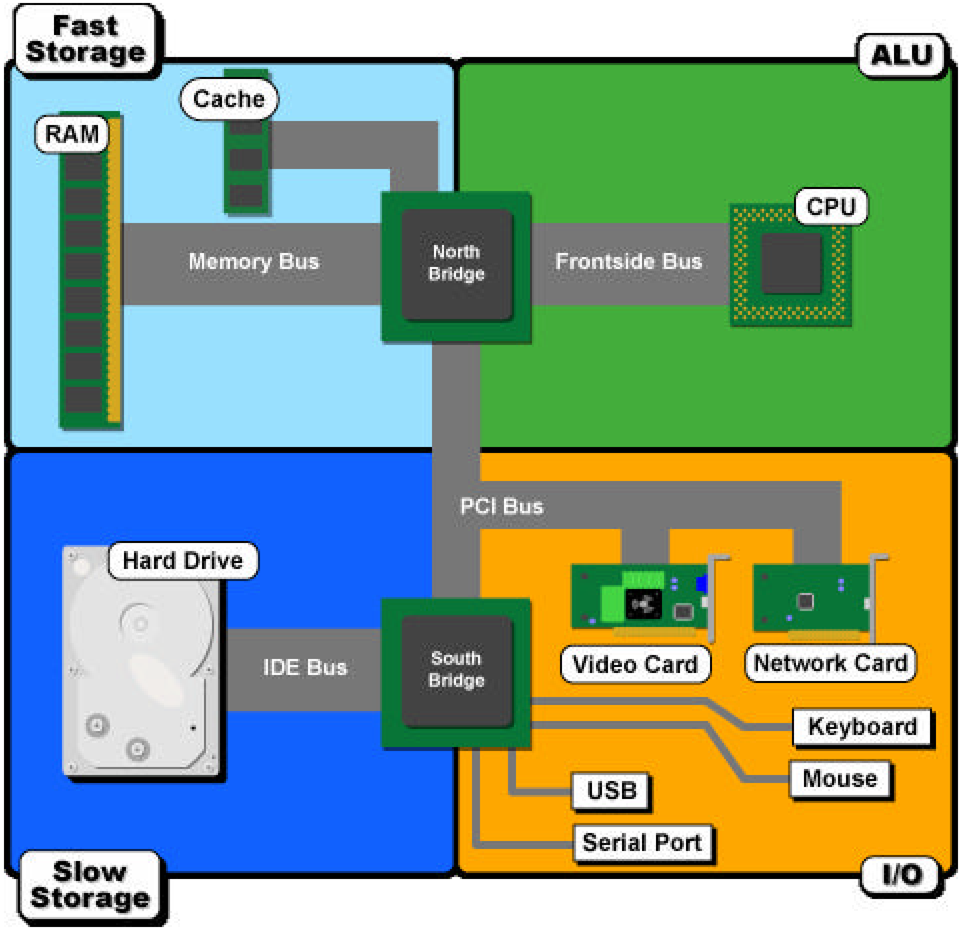
- Give each device a wire (interrupt line) that it can use to signal the processor
  - When interrupt signaled, processor executes a routine called an interrupt handler to deal with the interrupt
  - No overhead when no requests pending



Intel 430HX Motherboard

- Programmable interrupt controller (PIC) part of the "Southbridge" chip
  - Commonly 8259A chip
  - 8 inputs, 1 output
  - Can be chained together
- Newer systems use "Advanced PIC" (APIC) for SMP support
  - Principle is the same

(image from The Ars Technica Motherboard Guide, Dec. 2005, Jon Hannibal Stokes)



Polling vs. Interrupts

"Polling is like picking up your phone every few seconds to see if you have a call. Interrupts are like waiting for the phone to ring."

- Interrupts win if processor has other work to do and event response time is not critical
- Polling can be better if processor has to respond to an event ASAP
  - May be used in device controller that contains dedicated secondary processor

Hardware Interrupt Handling

- Details are architecture dependent!
- Interrupt controller signals CPU that interrupt has occurred, passes interrupt number
  - Interrupts are assigned priorities to handle simultaneous interrupts
  - Lower priority interrupts may be disabled during service
- CPU senses (checks) interrupt request line after every instruction; if raised, then:
  - uses interrupt number to determine which handler to start
  - interrupt vector associates handlers with interrupts
- Basic program state saved (as for system call)
- CPU jumps to interrupt handler
- When interrupt done, program state reloaded and program resumes

Software Interrupt Handling

- Typically two parts to interrupt handling
  - The part that has to be done immediately
    - So that device can continue working
  - The part that should be deferred for later
    - So that we can respond to the device faster
    - So that we have a more convenient execution context
      - What does that mean?

Interrupt Context

- Execution of first part of interrupt handler "borrows" the context of whatever was interrupted
  - Interrupted process state is saved in process structure
  - Handler uses interrupted thread's kernel stack
    - Have to be very careful about stack-allocated data
  - Handler is not allowed to block
    - Has no process structure of its own to save state or allow rescheduling
    - Can't call functions that might block (like kmalloc)
- Handler needs to be kept fast and simple
  - Typically sets up work for second part, flags that second part needs to execute, and re-enables interrupt

Software Interrupts

- The deferred parts of interrupt handling are sometimes referred to as "software interrupts"
  - In Linux, they are referred to as "bottom halves"
  - The terminology here is inconsistent and confusing
- What things can be deferred?
  - Networking
    - time-critical work → copy packet off hardware, respond to hardware
    - Deferred work → process packet, pass to correct application
  - Timers
    - Time-critical → increment current time-of-day
    - Deferred → recalculate process priorities

FreeBSD 5.2 & up

- All hardware devices and other interrupt events have an associated kernel thread with suitable priority
- First part of interrupt handling just schedules proper thread to run
  - Interrupted thread is marked as needing reschedule
  - High-priority handler thread is then scheduled on "return from interrupt"
- Handlers have full context, separate stack
  - So they can block now, but they usually don't
- Handling is often still divided into two parts, second part is performed by a lower-priority software interrupt thread
- Some interrupts that have to be very fast still run entirely in interrupt context (e.g. clock interrupt handler)

Signals

- Software equivalent of hardware interrupts
- Allows process to respond to asynchronous external events
  - Process may specify its own signal handlers or may use OS default action
  - Defaults include
    - Ignoring the signal
    - Terminating all threads in the process (with or without a core dump)
    - Stopping all threads in the process
    - Resuming all threads in the process
- Provide a simple form of inter-process communication (IPC)

Basics

- Process structure has flags for possible signals and actions to take
- When signal is posted to process, signal pending flag is marked
- When process is next scheduled to run, pending signals are checked and appropriate action is taken
  - Signal delivery is not instantaneous