

Lecture 6: Interrupts

CSC 469H1F
Fall 2006
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Topics

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

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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

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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

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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

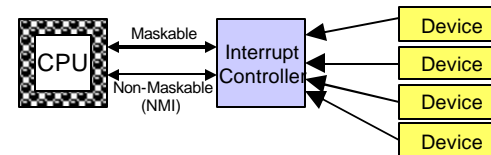
"Polling is like picking up your phone every few seconds to see if you have a call. ..."

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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



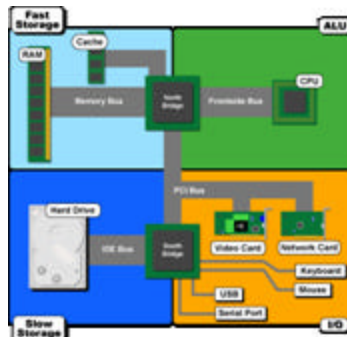
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Intel 430HX Motherboard

- 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)



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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

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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

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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?

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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

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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

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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)

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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)

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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

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