Interrupt

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Summary of last lectures

- Tools: building, exploring, and debugging Linux kernel
- Core kernel infrastructure
  - syscall, module, kernel data structures
- Process management & scheduling

Today: “interrupt”

- A mechanism to implement abstraction and multiplexing
- Interrupt: asking for a service to the kernel
  - by software (e.g., `int`) or by hardware (e.g., keyboard)
- Interrupt handling in Linux
  - top half + bottom half

Exceptions and Interrupts

- Synchronous interrupts (called exceptions)
  - produced by the CPU while executing instructions
    - non-maskable interrupt (NMI)
- asynchronous interrupts (called interrupts)
  - issued by other hardware devices (e.g., HDD, NIC, etc.)
    - normal and maskable interrupts

Three kinds of Exceptions

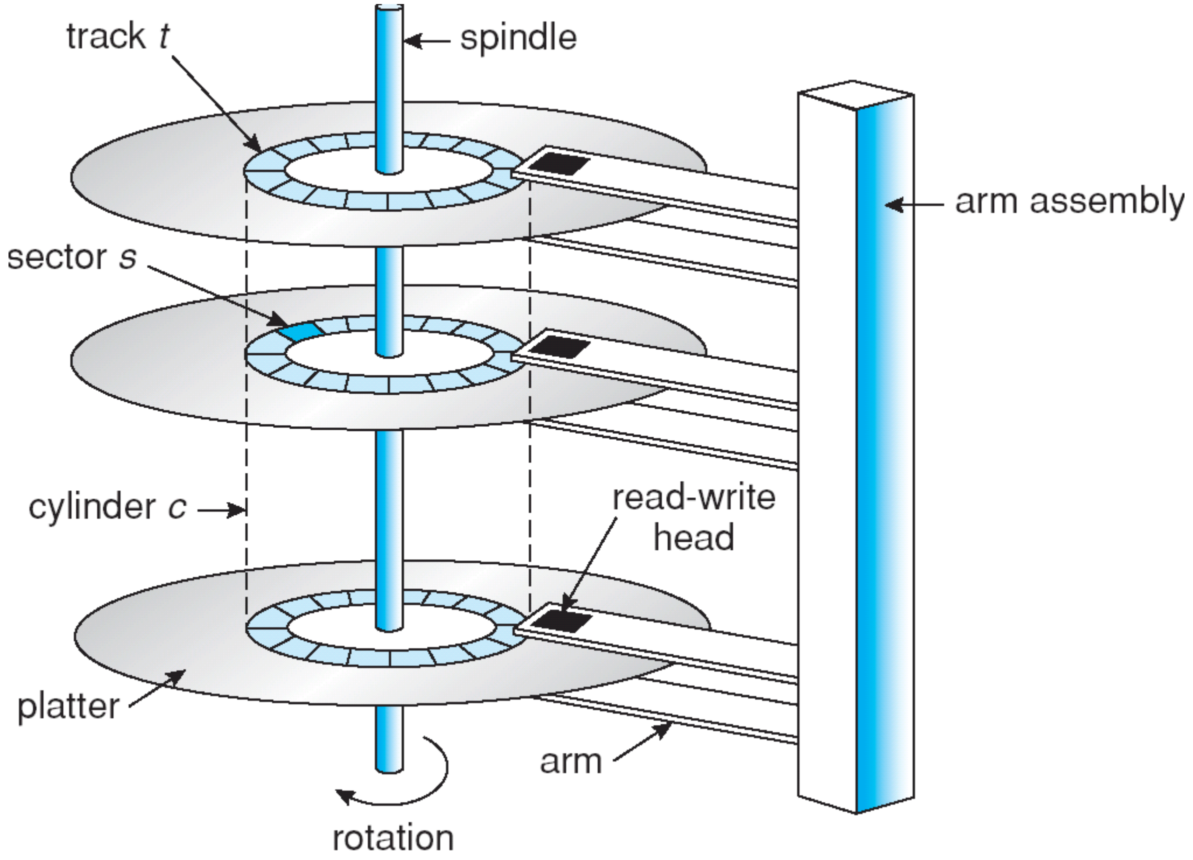
- Faults: Can be corrected. The program may continue as if nothing happened (e.g., page faults).
- Traps: Reported after the execution of a trapping instruction.
  - invalid memory access, devision by zero
  - switch to the kernel mode in response to a system call
  - programmed execeptions: e.g., int 0x03 (breakpoint)
  - If the kernel code does cause a trap, it immediately panics.
- Aborts: Some severe unrecoverable error.

Exceptions

#	Description	Type
0	Divide-by-zero Error	Fault
1	Debug	Fault/Trap
2	Non-maskable Interrupt	Interrupt
3	Breakpoint	Trap
8	Double Fault	Abort
13	General Protection Fault	Fault
14	Page Fault	Fault
…	…	…

Yeah! New hard disk drive!

HDD architecture



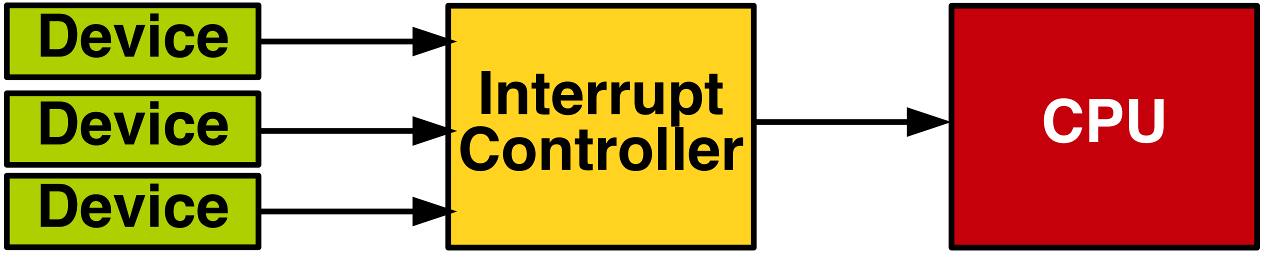
How fast is my new HDD?

- HDD access time = seek time + rotational latency
- Seek time
  - The time to move the disk head to the track that contains data
  - Average seek time: 4 ~ 10 msec
- Rotational latency
  - The delay for the rotation of the disk to bring the required disk sector under the read-write mechanism
  - 7200 RPM: 4.16 msec
- **Access time of your new HDD: about 10 msec**

Interrupt

- **Compared the the CPU, devices are slow to respond (e.g., 10 msec)**
    - The kernel must be free to go and handle other work, dealing with the hardware only after that hardware has completed its work
- **How to know the completion of a hardware operation**
    - **Polling:** the kernel periodically checks the status of hardware
    - **Interrupt:** the hardware signals its completion to the processor
- Interrupt examples
    - Completion of disk read
    - Key press on a keyboard, network packet arrival

Interrupt controller



- Interrupts are electrical signals multiplexed by the interrupt controller
  - Sent on a specific pin of the CPU
- Once an interrupt is received, a dedicated function is executed
  - **Interrupt handler**
- The kernel/user space can be interrupted at (nearly) any time to process an interrupt

Advanced PIC (APIC, I/O APIC)

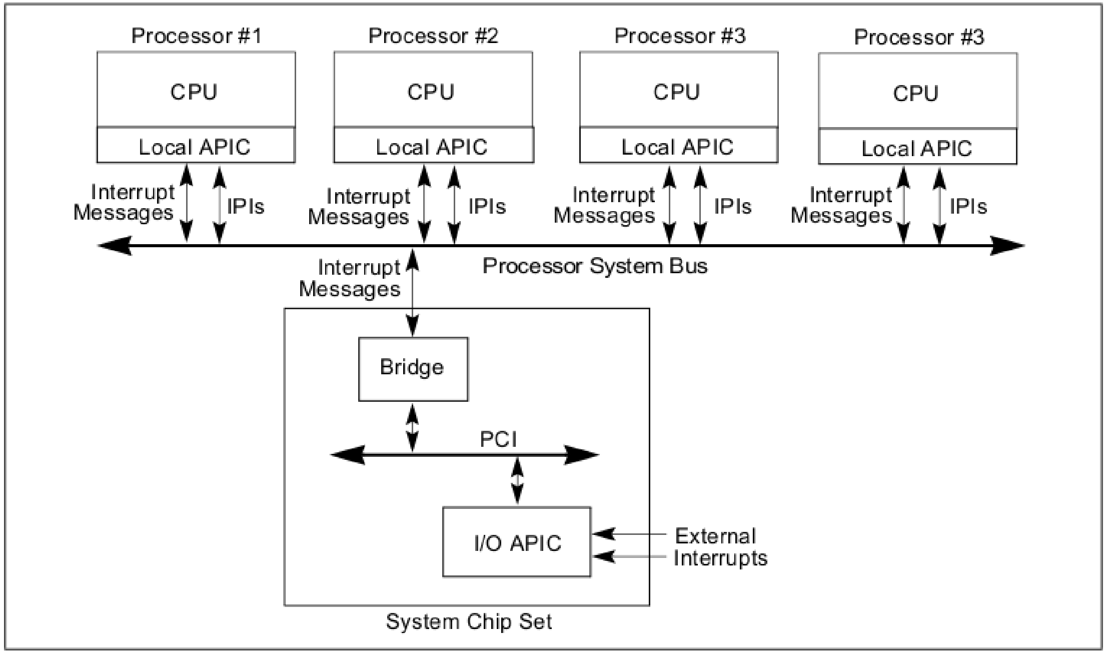
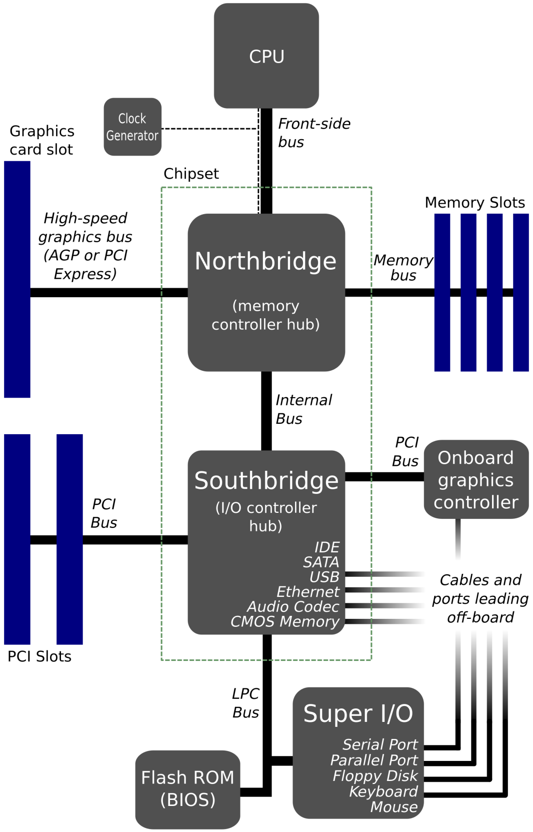


Figure 10-2. Local APICs and I/O APIC When Intel Xeon Processors Are Used in Multiple-Processor Systems

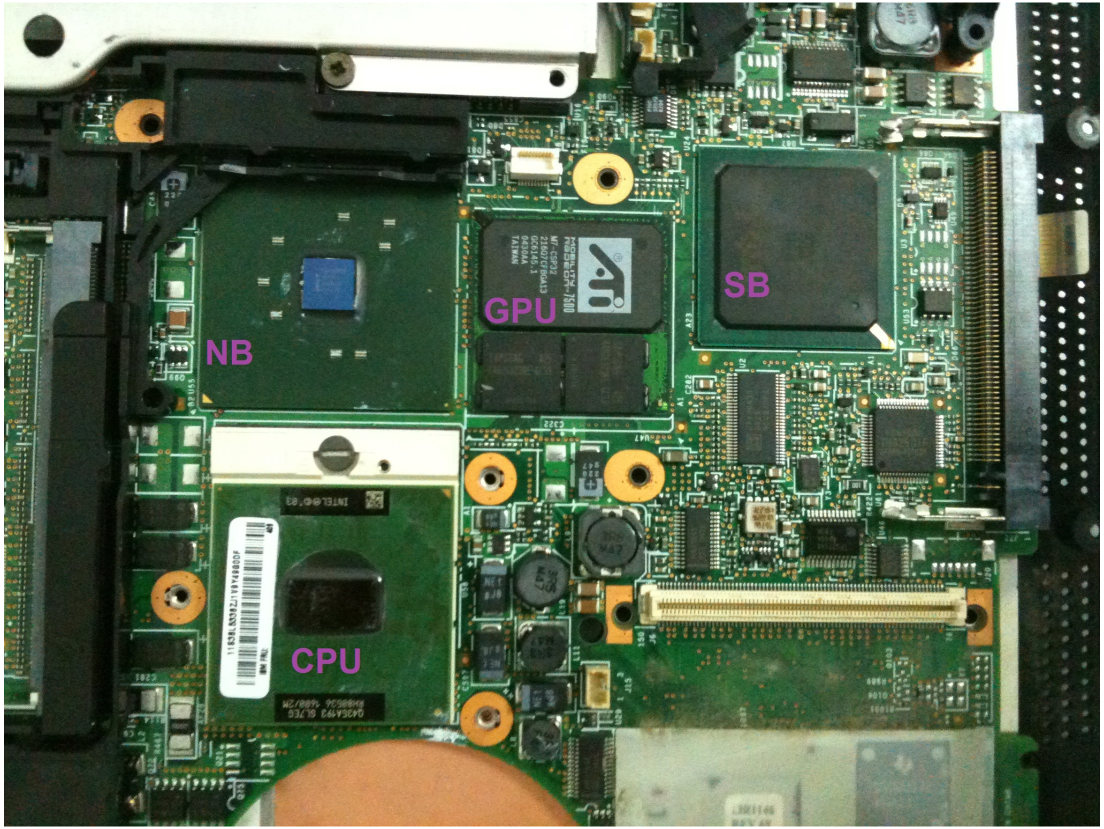
Advanced PIC (APIC, I/O APIC)

- I/O APIC
  - system chipset (or south bridge)
  - redistribute interrupts to local APICs
- Local APIC
  - inside a processor chip
  - has a timer, which raises timer interrupt
  - issues a IPI (inter-process interrupt)

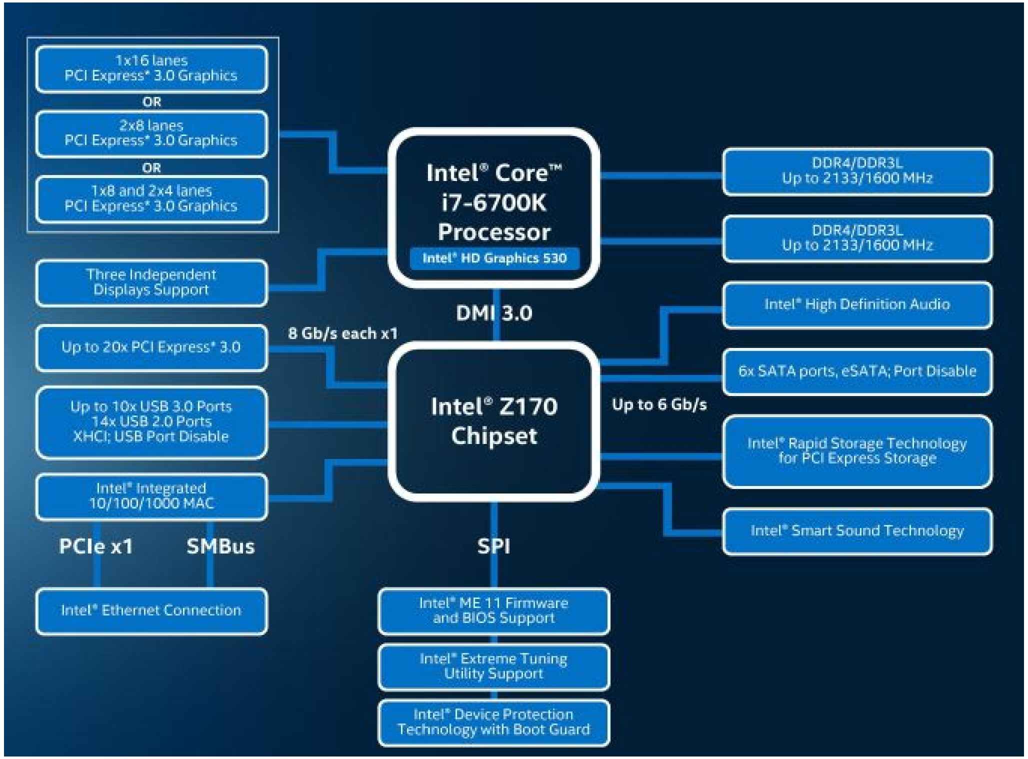
A bigger picture



A real motherboard (T42)



Intel Z170 chipset


1x16 lanes PCI Express* 3.0 Graphics
OR
2x8 lanes PCI Express* 3.0 Graphics
OR
1x8 and 2x4 lanes PCI Express* 3.0 Graphics
Three Independent Displays Support
Up to 20x PCI Express* 3.0
8 Gb/s each x1
Up to 10x USB 3.0 Ports 14x USB 2.0 Ports XHCI; USB Port Disable
Intel® Integrated 10/100/1000 MAC
PCIe x1
SMBus
Intel® Ethernet Connection
Intel® Core™ i7-6700K Processor
Intel® HD Graphics 530
DMI 3.0
Intel® Z170 Chipset
SPI
Intel® ME 11 Firmware and BIOS Support
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Intel® Device Protection Technology with Boot Guard
DDR4/DDR3L Up to 2133/1600 MHz
DDR4/DDR3L Up to 2133/1600 MHz
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6x SATA ports, eSATA; Port Disable
Up to 6 Gb/s
Intel® Rapid Storage Technology for PCI Express Storage
Intel® Smart Sound Technology

- Ref: The Intel 6th Gen Skylake Review

Interrupt request (IRQ)

- **Interrupt line** or **interrupt request (IRQ)**
  - device identifier
- E.g., 8259A interrupt lines
  - IRQ 0: system timer, IRQ 1: keyboard controller
  - IRQ 3, 4: serial port, IRQ 5: terminal
- Some interrupt lines can be shared among several devices
  - True for most modern devices (PCIe)

Next lecture

- Interrupt handler: top half
- Interrupt handler: bottom half