Microprocessors, Lecture 2:

PC buses and Interfaces
Introduction

- The anatomy of a modern personal computer (PC)
- Common PC buses and interfaces
Motherboard
Motherboard

- In personal computers, a *motherboard* is the central printed circuit board (PCB) used to connect many of the system components.
- All busses external to the CPU are on the motherboard.
- The motherboard includes connector sockets for the CPU and many I/O peripherals.
Motherboard

- Connects all the components of a computer together
- Supplies power to (and allows data to flow among) all components
- A series of different slots which cables and cards fit into
- All parts are compatible with the motherboard else the machine will not work
- In particular, the motherboard must be matched to the CPU, especially in the bus speed
Motherboard Components

- The first IBM PC motherboard had only a processor and card slots
- Users plugged components like floppy drive controllers and memory into the slots
- Today, motherboards typically boast a wide variety of built-in features
  - On-chip storage and memory controllers, sound, network adaptor, modem, …..
Motherboard Components

- Some functionalities are added by expansion cards
  - Modem, sound, TV, Ethernet, graphics, ….
Common Motherboard Components

- Processor socket: where processor is plugged in
- BIOS: Basic Input/Output System, a chip that controls most basic operations
- PCI and PCI-express slots: Peripheral Component Interconnect, for external devices
- AGP slot: Accelerated Graphics Port, dedicated port for video card
- SATA and IDE connectors: attachments for hard drives, by serial plug (SATA) or parallel ribbon (IDE)
- Clock
- Memory slots
- Northbridge and Southbridge: chipset that connect the processor to everything else
- Logic and connectors to control USB, PS2, serial port, parallel port, Ethernet LAN, audio
- ….
Motherboard Components - 10 years ago

- BIOS Chip
- CMOS Battery
- AGP Expansion Slot
- LPT 1 Printer Port
- USB Port
- PS/2 Mouse & Ps/2 Keyboard Connector
- ATX Power Connector
- CPU Socket 370
- DIMM Memory Sockets
- PCI Expansion Slots
- Chipset
- Floppy Drive Controller
- Floppy Drive Controller
- ChipSet
Modern Motherboard Components
Very old motherboard components- grand-motherboard!
Form Factor
Motherboard Form Factors

- Determines motherboard size, features
  - Dimensions, power supply type, location of mounting holes, number of ports on the back panel
- Ensure that parts are interchangeable across vendors and generations
- Compatibility with power supplies, cases, expansion cards, ...
Motherboard Form Factors

- Most popular form factors:
  - ATX, MicroATX, FlexATX, BTX, NLX
- AT is the oldest form factor introduced by IBM in the 80s
- ATX and ATX-mini are the current popular standards
  - By Intel since 1997
  - The latest update to the ATX standard was released in 2007

ATX: 305 × 244 mm
ATX-mini: 244 × 244 mm
Motherboard Form Factors

ATX motherboard

AT motherboard
CPU Sockets
Processor Sockets

- Where the CPU is inserted on the motherboard
- Provides mechanical and electrical connections between a CPU and motherboard
- Allows the CPU to be replaced without soldering
Processor Socket Types

- Based on the CPU package type: PGA and LGA
- Pin grid array (PGA)
  - Pins aligned in uniform rows around socket
- Land grid array (LGA)
  - Uses lands rather than pins
  - The pins on the socket rather than the CPU
Processor Sockets

- Zero Insertion Force (ZIF) sockets are used to keep chips
  - Side lever lifts processor up and out of the socket

- A covering plate is also used to keep LGA chips
Standard Sockets

- Several standard sockets
  - Each compatible with a family or several families of processors
  - Based on the CPU dimensions and power, ground, and IO pins
- LGA 775 (Socket T) is the Intel desktop CPU socket for Pentium 4 and Core 2 Due processors
- LGA 1156 (Socket H) is the Intel desktop CPU socket for Core i7 processors
Standard Sockets

- LGA 775 (Socket T) for Pentium 4 and Core 2 Due
- LGA 1366 (Socket H) for Core i7
- AM2 for modern AMD processors (Athlon, Opteron, Phenom)
  - 940 pin, PGA
PCB Bus tracks near a Pentium 4
## Sockets for Intel processors

<table>
<thead>
<tr>
<th>Intel Socket Names</th>
<th>Used by Processor Family</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>LGA1366 or Socket B</td>
<td>Core i7</td>
<td>▶️ 1366 pins that touch pads on the processor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▶️ Works with DDR3 memory</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▶️ Expected to replace LGA771 and LGA775 sockets</td>
</tr>
<tr>
<td>LGA771 or Socket J</td>
<td>Core 2 Extreme</td>
<td>▶️ 771 pins that touch pads on the processor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▶️ Used on high-end workstations and low-end servers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▶️ Works with DDR2 memory on boards that have two processor sockets</td>
</tr>
<tr>
<td>LGA775 or Socket T</td>
<td>Core 2 Extreme</td>
<td>▶️ 775 lands or pads</td>
</tr>
<tr>
<td></td>
<td>Core 2 Quad</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Core 2 Duo</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pentium Dual-Core</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pentium Extreme Edition</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pentium D</td>
<td></td>
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<tr>
<td></td>
<td>Pentium</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pentium 4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Many Celeron processors</td>
<td></td>
</tr>
<tr>
<td>Socket 478</td>
<td>Pentium 4</td>
<td>▶️ 478 holes for pins</td>
</tr>
<tr>
<td></td>
<td>Celeron processors</td>
<td>▶️ Uses a dense micro PGA (mPGA)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▶️ No longer sold</td>
</tr>
<tr>
<td>Socket 423</td>
<td>Pentium 4</td>
<td>▶️ 423 holes for pins</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▶️ 39 x 39 SPGA grid</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▶️ No longer sold</td>
</tr>
</tbody>
</table>
## Sockets for AMD processors

<table>
<thead>
<tr>
<th>AMD Socket</th>
<th>Used by Processor Family</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM3 or AMD3</td>
<td>Phenom II</td>
<td>- 938 holes for pins (PGA)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Works with DDR3 memory</td>
</tr>
<tr>
<td>AM2+ or AMD2+</td>
<td>Phenom II, Phenom, and Athlon</td>
<td>- 940 holes for pins (PGA)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Works with DDR2 memory</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Faster than AM2</td>
</tr>
<tr>
<td>AM2 or AMD2</td>
<td>Athlon and Sempron</td>
<td>- 940 holes for pins (PGA)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Works with DDR2 memory</td>
</tr>
<tr>
<td>Socket 754</td>
<td>Athlon and Sempron</td>
<td>- 754 holes for pins (PGA)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Works with DDR memory</td>
</tr>
<tr>
<td>Socket 940</td>
<td>Athlon</td>
<td>- 940 holes for pins (PGA)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Works with DDR memory</td>
</tr>
<tr>
<td>Socket 939</td>
<td>Athlon and Sempron</td>
<td>- 939 holes for pins (PGA)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Works with DDR memory</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- No longer sold</td>
</tr>
<tr>
<td>Socket A</td>
<td>Athlon, Sempron, and Duron</td>
<td>- 462 holes for pins (PGA)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Works with DDR memory</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Rarely sold today</td>
</tr>
</tbody>
</table>
Functional View
The Simple Top Level Model

Logically speaking, the computer has one bus used to allow all components to communicate.

Early designs, such as the PDP-11, had only one bus. For these slow machines, it worked well.
Realistic Organizations

- The design on the previous slide is logically correct, but it will not work!
- It is too slow. Problem: A single system level bus cannot handle the load
  - Modern applications demand fast video; this requires a fast bus to the video chip.
  - The memory system is always a performance bottleneck. We need a dedicated memory bus in order to allow acceptable performance
I/O Devices sorted by bandwidth

10 B/s  100 B/s  1kB/s  10 kB/s  100 kB/s  1 MB/s  100 MB/s  10 GB/s

Keyboard  Mouse  Joystick  Audio  Scanner  HDD  Video  CD Rom  TV Camera

10 B/s  100 B/s  1kB/s  10 kB/s  100 kB/s  1 MB/s  100 MB/s  10 GB/s
Fast and very fast Components

- Hard Disk
- Memory
- Video Card
- CPU
Slow Components
Modern designs

- Define 2 buses: one for high-speed devices and one for low-speed
  - Fast components are connected to Northbridge
  - Slow components are connected to Southbridge
- The combination of the North and Southbridge in a computer is called the chipset.
Northbridge

- Also known as MCH – Memory Controller Hub
- Bridges connection from CPU to RAM and Video Bus (AGP/PCI-X)
- Connects to South Bridge
- In some instances the Northbridge and Southbridge functions were combined
  - Nvidia GeForce 320M in the 2009/2010 Macbook
Southbridge

- Also known as ICH – I/O Controller Hub
- Bridge connection from Northbridge to slower devices like USB devices, PCI, IDE(SATA/PATA), BIOS, onboard sound and more
Organization
Organization
Front-side Bus

- Front-side bus (FSB): Connects CPU to the Northbridge
  - FSB is a major selling point for motherboards in the market today
- Back-side bus: connects the CPU to the cache
  - If the cache is on-board
Further hierarchy

Very Fast

Fast

Slow
Three Layer Buses

Further hierarchy:

- In some implementations very low-speed devices are connected to the Southbridge via another bridge: SuperIO
Main components of Intel Chipset: Pentium 4

- Northbridge:
  - DDR memory
  - Graphics
- Southbridge: I/O
  - PCI bus
  - Disk controllers
  - USB controllers
  - Audio
  - Serial I/O
  - Interrupt controller
  - Timers
Very Modern System Configuration

- In modern CPUs (Intel Core i7, AMD Phenom,…) the memory controller is integrated into the CPU
- Memory is directly connected to the CPU
- Simpler Northbridge
Very Modern System Configuration

- **Platform Controller Hub**: Southbridge + the remaining parts of Northbridge that has not moved to CPU
Very Modern System Configuration

1. CPU Socket
2. CPU Fan
3. VRM
   a. Capacitors
   b. Chokes (SFC)
   c. MOSFET/sink
4. 12v CPU Power
5. RAM Slots
6. 24pin Power
7. Troubleshooting
8. Chipset
9. USB3 + SATA
10. Displays
    a. BIOS chips
    b. Segment Display (for POST)
11. Front I/O
    a. USB2.0
    b. 1394/FireWire
    c. Front Panel
    d. TPM header
    e. HD Audio
12. PCI-e
    a. PCI-e x1
    b. PCI-e x16/x8
    c. PLX / PEX Chip
13. Southwest Chips
    a. Network Chip
    b. Audio Chipset
    c. Oscillating Clock Crystals
14. CMOS battery
15. Rear I/O panel
PCI bus

- Peripheral Component Interconnect
- Introduced by Intel in 1993
- 32 or 64 bit
- Working at 33 and 66 MHz
- PCI-X works at 133 MHz
PCI-Express

- Replace the older PCI, PCI-X, and AGP bus standards
- High-speed serial connection
- A lane is a serial point-to-point communication channel between two PCI-e ports
- A link is composed of 1 or more lanes: 1, 2, 4, 8, 16, 32 lanes
- PCI-e 16x for VGA, 1x for slower devices
- Very high speed
  - PCI-e v1: 250 MB/3 per lane
  - PCI-e v2: 500 MB/s per lane
  - PCI-e v3: 1GB/s per lane

<table>
<thead>
<tr>
<th>PCI Express</th>
<th>×4</th>
<th>×16</th>
<th>×1</th>
<th>×16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional PCI</td>
<td>(32-bit)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Buses and Expansion Slots

- Peripheral Component Interconnect (PCI)
  - Improved several times
  - Categories
    - Conventional PCI, PCI-X, PCI Express