Computer Architecture

Hardware

INFO 2603
Platform Technologies

Week 2

Computer Architecture

Computer architecture refers to the overall design of the physical parts of a computer.

It examines:

- what the main parts are;
- how they are physically connected to each other; and
- how they work together;

The physical parts of a computer are connected to each other by the motherboard

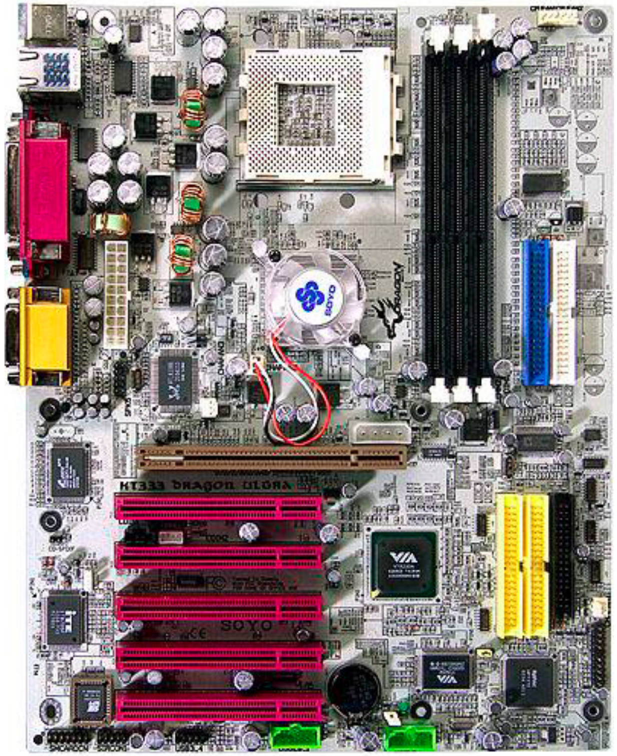

Fig. 1 A motherboard

Operating System

An Operating System is the layer of software that manages a computer’s resources for its users and their applications. It abstracts the use of these resources using a clean, simple, standardised interface

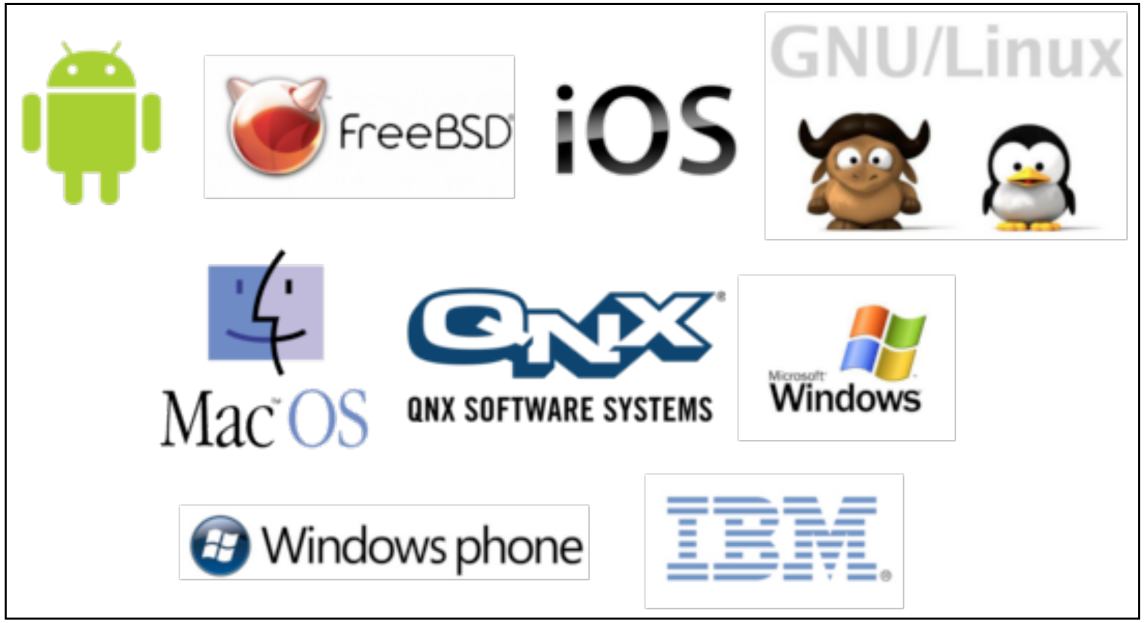

Fig. 2 Examples of Operating Systems

Research each of these Operating Systems: platform, OS-family, usage

Operating System

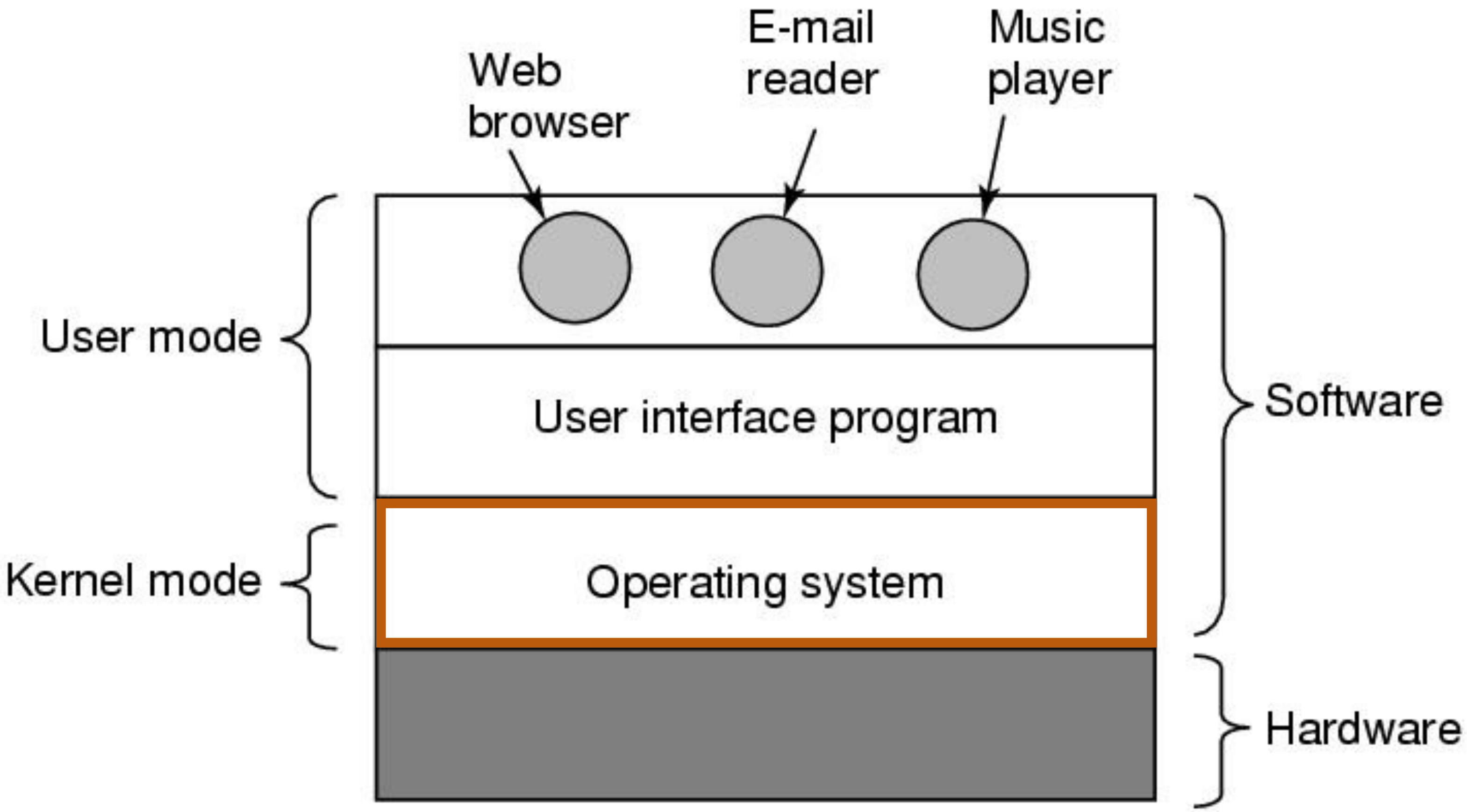

Fig. 3 Operating System Relative to Hardware and Software Layers

Computer Architecture Map

Main components controlled by the operating system:

- CPU: Central Processing Unit
  - ✦ Computer Brain
  - ✦ Performs calculations
- RAM: Random Access Memory
  - ✦ System memory
- Graphics
  - ✦ Video Card
- Input/Output Buses
  - ✦ Connect I/O devices to the motherboard

Computer Hardware Review

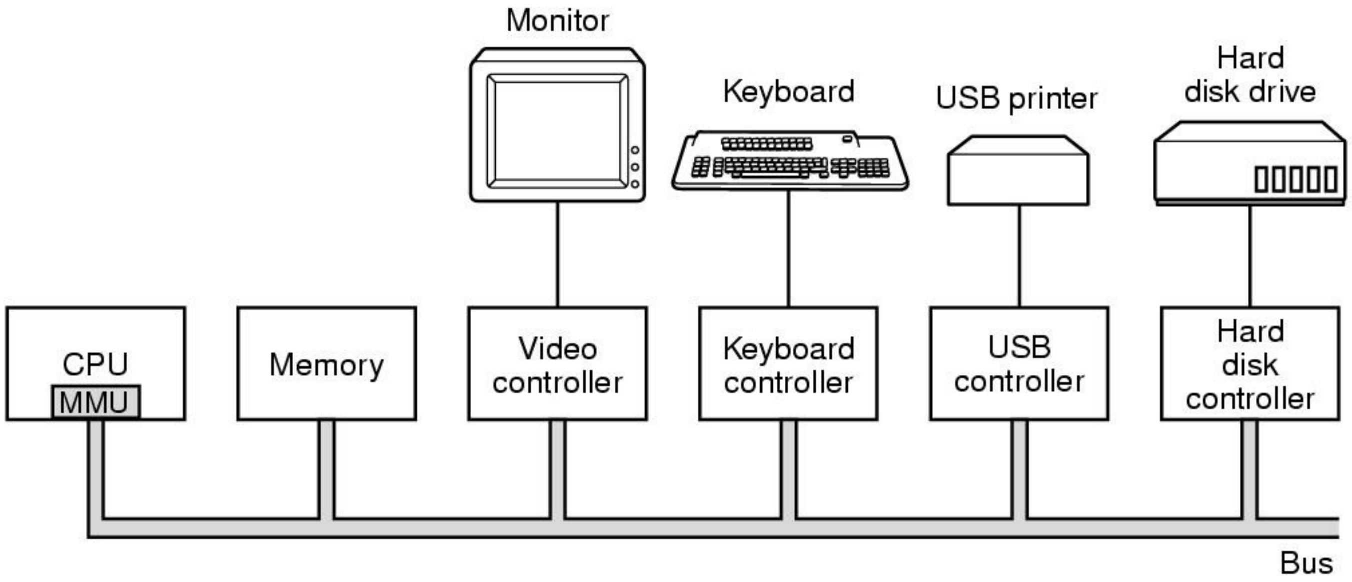

Figure 4. Some of the components of a simple personal computer.

Tanenbaum, Modern Operating Systems 3 e, (c) 2008 Prentice-Hall, Inc. All rights reserved. 0-13-6006639

Bus

A bus is a communication pathway connecting two or more devices. A key characteristic of a bus is that it is a shared transmission medium.

Multiple devices connect to the bus, but only one can successfully transmit a signal at a time.

A bus consists of multiple communication pathways or lines. Each line transmits a binary signal: 0 or 1. An 8-bit unit of data can be transmitted over 8 bus lines (parallel, simultaneous transmission).

System Bus

A system bus connects major computer components (processor, memory, I/O). The most common interconnection structures are based on the use of one or more system buses.

A system bus consists of typically 50 -100 separate lines. Each line is assigned a particular meaning or function.

Three major functional groups for classifying lines are:

- Data lines
- Address lines
- Control lines

Data Lines and Data Bus

The data lines provide a path for moving data between system modules and are collectively called the Data Bus.

The data bus consists of 8,16, or 32 separate lines. The number of lines refer to the width of the data bus.

The data bus consists of are internal and external data buses.

- Internal data bus: connects the internal components of the CPU (registers, ALU etc) to the data I/O pins
- External data bus: connects the data I/O pins of the CPU to the memory and I/O devices (e.g. printer, monitor)

The width of the internal data bus is used to classify a microprocessor (e.g. 8-bit, 16-bit, 32-bit, 64-bit microprocessors)

Address Lines and Address Bus

The address lines are used to designate the source or destination of the data on the data bus. Collectively these lines are called the Address Bus.

The address lines are also used to address I/O ports.

Memory addresses are put on the address line for reading data from memory

The width of the address bus determines the maximum possible memory capacity of the system. For example, a system with a 32-bit address bus can address 2^{32} (4,294,967,296) memory locations. If each memory location holds one byte, the addressable memory space is 4 GB.

Control Lines and Control Bus

The control lines are used to control the access to and the use of data and address lines which are shared by all components. Collectively these lines are called the Control Bus.

Control signals transmit timing and command information between system modules.

Timing signals indicate the validity of data and address information.

Command signals specify operations to be performed.

Control Lines

Examples of typical control lines:

- Memory write: causes data on the bus to be written into the addressed location
- Memory read: causes data from the addressed location to be placed on the bus
- I/O write: causes data on the bus to be output to the addressed I/O port
- I/O read: causes data from the addressed I/O port to be placed to the bus
- Clock: used to synchronise operations

Control Lines

Examples of typical control lines:

- Transfer ACK: indicates that data has been accepted or placed on the bus

- Bus request: indicates that a module needs to gain control of the bus

- Bus grant: indicates that a requesting module had been granted control of the bus

- Interrupt request: indicates that an interrupt is pending

- Interrupt ACK: acknowledges that the pending interrupt has been recognised

Physical System Bus

The system bus is actually a number of parallel electrical conductors.

The bus extends across all of the system components, each of which taps into some or all of the bus lines.

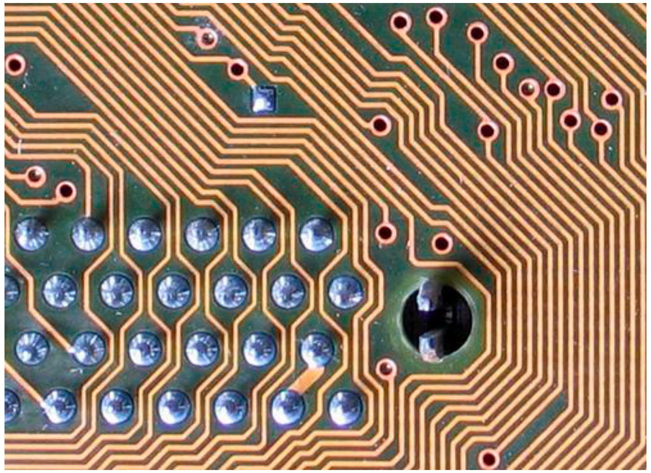

Fig. 5 Conductors

Circuits or pathways conduct electricity and are called "traces."

The electrical pathways or conductors are made up of two different parts. The first part is the lines themselves and they are called "traces." The second part is called a "land" or "pad." A land is a conductive surface providing a place on which to attach various components.

Physical System Bus

Major system components occupy a board which plugs into the bus at specific slots.

A small computer may be acquired and expanded later (more memory, more I/O) by adding more boards.

Components can be easily removed and replaced if a failure occurs.

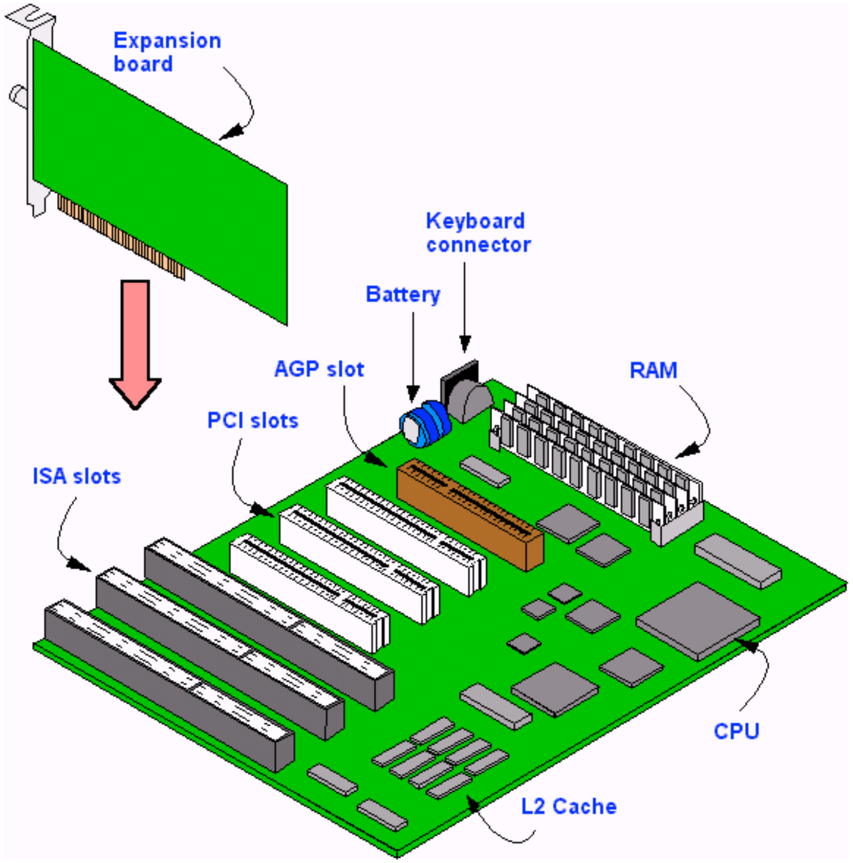

Fig. 6 Physical Realisation of Bus Architecture

Buses

Some industry standards of bus interfaces

- ISA: Industry Standard Architecture
- PCI: Peripheral Component Interconnect
- IDE: Integrated Drive Electronics
- SCSI: small computer-systems interface
- USB: Universal Serial Bus
- ATA: AT Attachment
- SATA: Serial ATA

Bus Configuration

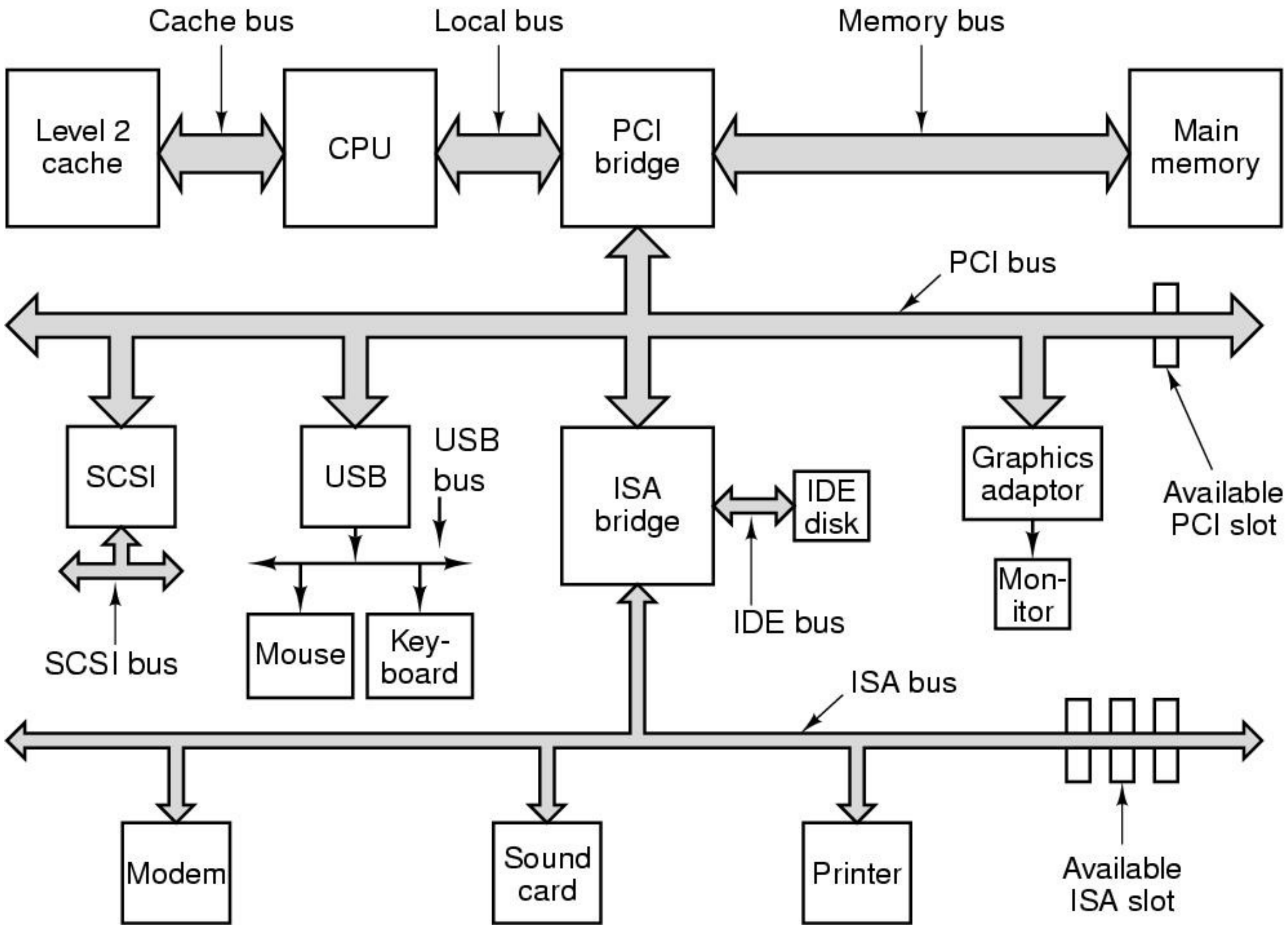

Figure 7. The structure of a large Pentium system

ISA - Industry Standard Architecture

ISA Bus

- This was the industry standard in the 1980s and early 1990s.
- It is now used to provide support for older and slower devices.
- Common devices connected to the ISA bus might include an older modem, a joystick, a mouse, or a printer (using the older, wide-style printer port).

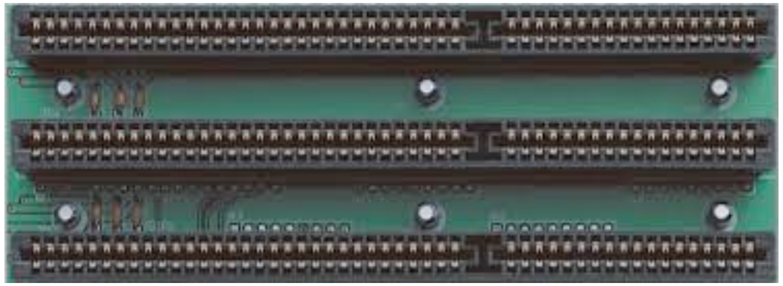

Figure 8. ISA slots

PCI – Peripheral Component Interconnect

PCI Bus

- This is for newer and faster devices than ISA.
- You can think of this like a wider road, with a faster speed limit!
- Some common devices connected to the PCI bus include your network card, EIDE devices (hard disk, CD/DVD drive, etc).

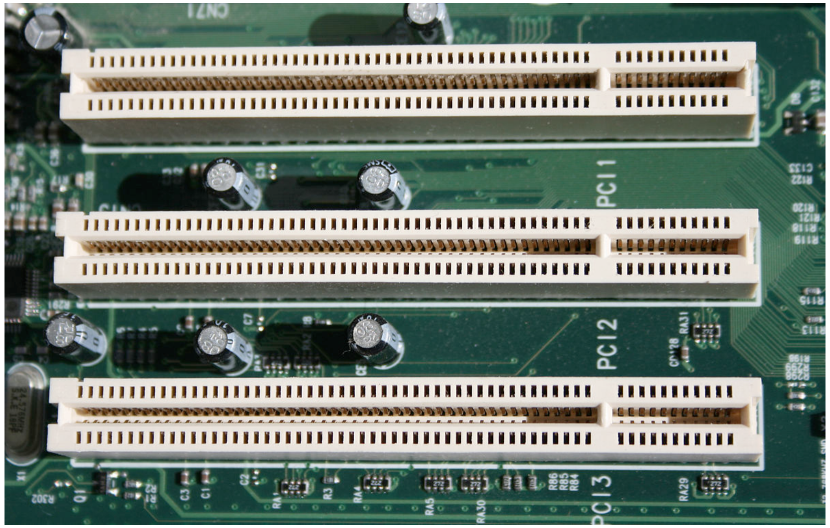

Figure 9. PCI slots

USB – Universal Serial Bus

USB – Universal Serial Bus

- Many new devices can connect to your computer using a USB port.
- Examples include webcams, MP3 players, printers, PDAs, etc.

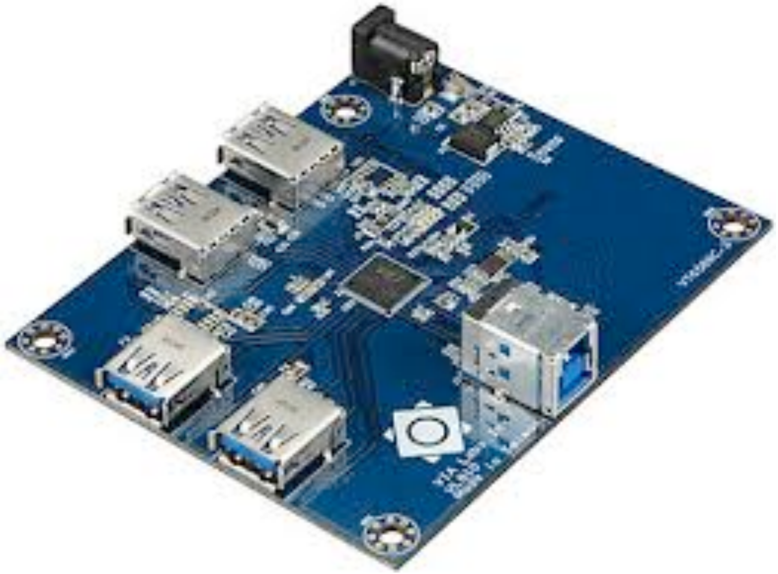

Figure 9. USB slots

Expansion Buses

- These are “slots” on the motherboard
  - ISA – Industry Standard Architecture (outdated)
  - PCI – Personal Component Interconnect (outdated)
  - EISA – Extended ISA (outdated)
    - SIMM – Single Inline Memory Module (plugs into slot)
    - DIMM – Dual Inline Memory Module (plugs into slot)
  - MCA – Micro-Channel Architecture (outdated)
  - AGP – Accelerated Graphics Port (outdated)
  - VESA – Video Electronics Standards Association (outdated)
  - PCMCIA – Personal Computer Memory Card International Association (outdated)
  - PCI-e – PCI express (Current)
  - HT – Hypertransport (Current)

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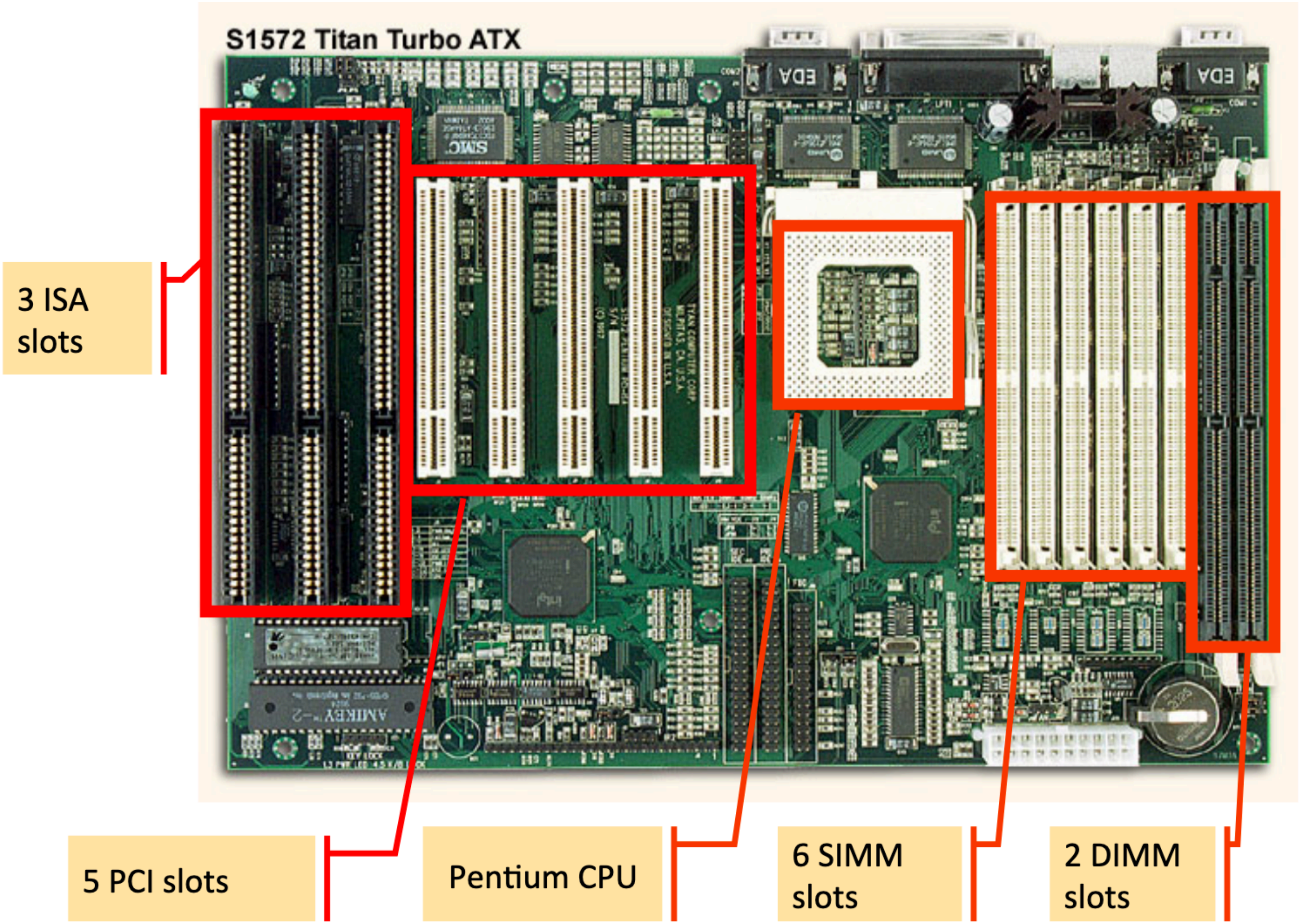

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Disk Interfaces

- Examples
  - ATA – AT Attachment (named after IBM PC-AT) (outdated)
  - IDE – Integrated Drive Electronics (same as ATA) (outdated)
  - Enhanced IDE (outdated)
    - Encompasses several older standards (ST-506/ST-412, IDE, ESDI, ATA-2, ATA-3, ATA-4)
  - Floppy disk (outdated)
  - SCSI – Small Computer Systems Interface (servers) (Current)
  - ESDI – Enhanced Small Device Interface (mid-80s, obsolete) (outdated)
  - PCMCIA (outdated)
  - SATA – serial ATA (Current)
  - Ethernet (used for network drives) (Current)

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External Buses

- Examples
  - Parallel – sometimes called LPT (“line printer”) (outdated)
  - Serial – typically RS232C (sometimes RS422) (outdated)
  - PS/2 – for keyboards and mice (outdated)
  - USB – Universal Serial Bus (current)
  - IrDA – Infrared Device Attachment (specialized)
  - FireWire – very high speed, developed by IEEE (outdated)

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Communications Buses

- For connecting systems to systems
- Parallel/LPT (outdated)
  - special purpose, e.g., using special software (*Laplink*) to transfer data between systems
- Serial/RS232C (outdated)
  - To connect a system to a voice-grade modem
- Ethernet (current)
  - To connect a system to a high-speed network

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Chips, Cores and Processors

A chip refers to the physical integrated circuit (IC) on a computer. A chip in the context of computing technology may refer to an execution unit that can be single-core or multi-core.

A core comprises a logical execution unit containing an L1 cache and functional units. A multi-core chip may have several cores e.g. dual-core means 2 cores. Cores are able to independently execute programs.

A processor could describe either a single execution core or a single physical multi-core chip. The context of use will define the meaning of the term.

Machine Instructions

The operation of the CPU is determined by the instructions its executes, referred to as machine instructions or computer instructions.

The collection of different instructions that the CPU can execute is referred to as the CPU's instruction set.

Instruction Types

Instructions can be categorised as follows:

- Data processing: Arithmetic and logic instructions
- Data storage: Memory instructions
- Data movement: I/O instructions
- Control: Test and branch instructions

Instruction Representation

A high level language expresses operations in a concise algebraic form, using variables.

```
x = x + y;
```

A machine language expresses operations in a basic form using movement of data to or from registers.

```
1. Load register with contents of memory location 513
2. Add contents of memory location 514 to the register
3. Store the contents of the register in memory location 513
```

Instruction Set

Each instruction must contain the information required by the CPU for execution.

The main elements that an instruction must define are:

- Operation code : the operation to be performed (e.g. ADD)
- Source operand reference: the inputs for the operation
- Result operand reference: the results that may be produced
- Next instruction reference: location of next instruction

Required Reading

- Unit 1: Computer Architecture Review: http://cp2060.pbworks.com/f/Operating+System+Fundamentals.pdf

- 32 bit vs 64 bit: https://www.digitaltrends.com/computing/32-bit-vs-64-bit-operating-systems/

- Busses and Interfaces: https://web.njit.edu/~rlopes/Mod7.1.pdf

- AMD Ryzen: https://www.digitaltrends.com/computing/amd-launches-second-generation-ryzen-threadripper-cpu/