

Programme: Diploma in Computer Hardware Engineering

Semester: 4

Course: 4131 (Rev 15), Computer System Hardware

Module: 1 (Part 1 of 2)

Syllabus Contents of Module 1

Motherboard- Form factors-Components of Motherboard- Bus Architecture- Chipsets- Expansion Slots- Memory slots and Cache- CPU and Processor socket- BIOS and POST- CMOS and CMOS Battery- Purpose and characteristics of Processors- Characteristics of Memory- types of memory- different types of DRAM- varieties of RAM- Memory packaging

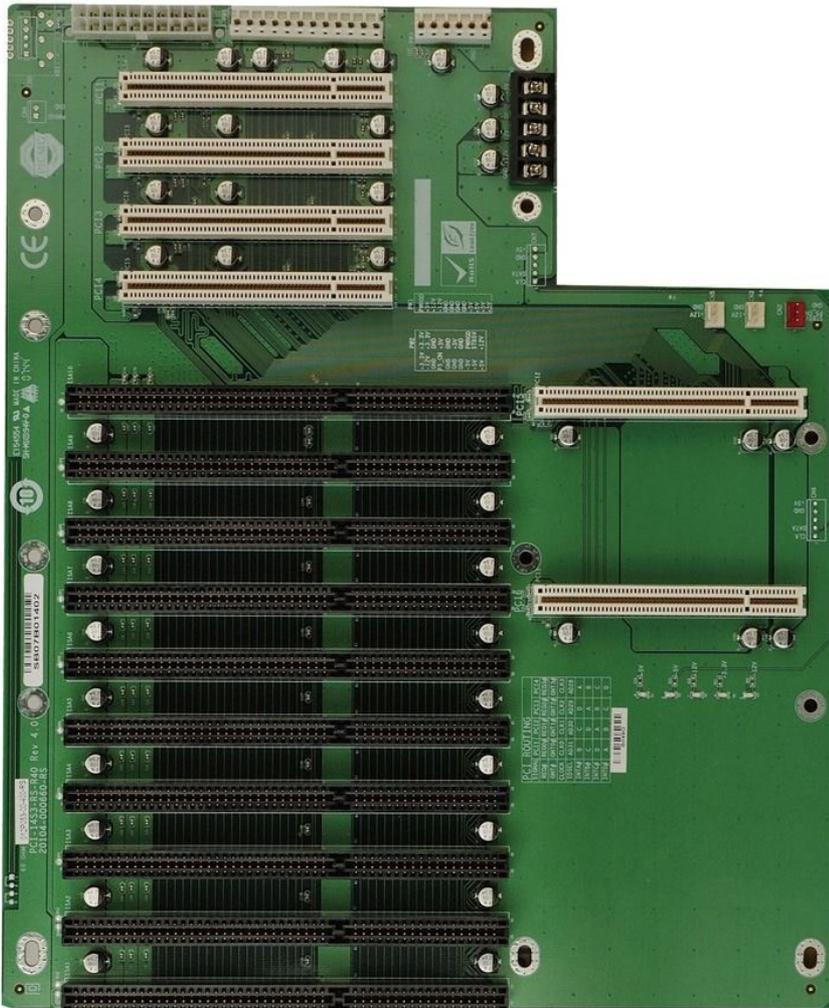
Courtesy:

CompTIA A+ Study Guide by Sybex

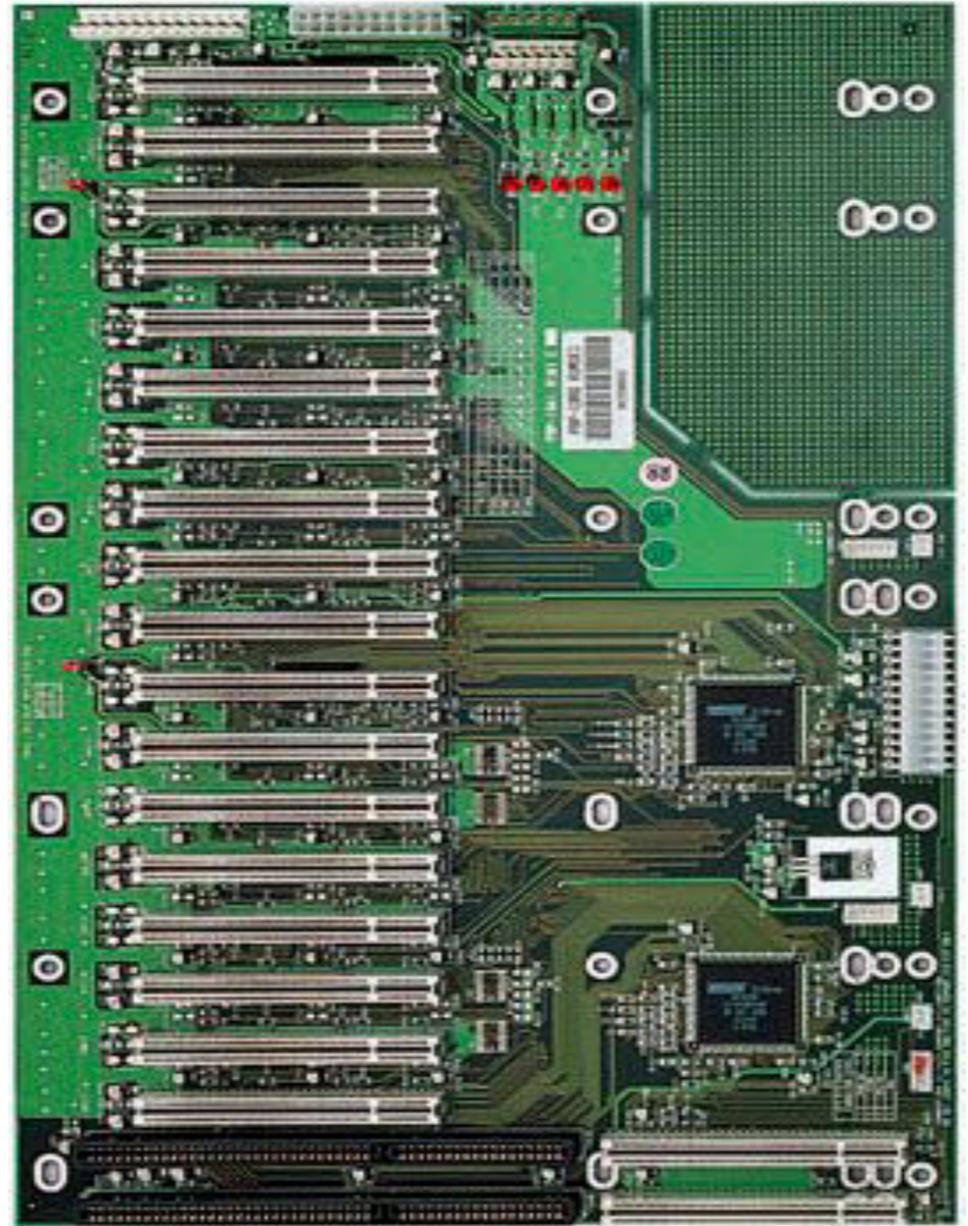
Various Websites

Motherboard:

- A large printed circuit board; every component is directly or indirectly connected.
- Connects all the computer components together.
- Also called system board and mainboard.
- Spine of the computer.
- Some are **backplane** style; ie boards containing expansion slots and communication paths between them.
 - Passive backplane: only expansion slots and communication paths, no computing circuitry
 - Active backplane: in addition to the slots, logical circuits that performs computing functions.



Passive Backplane



Active Backplane

Motherboard form factor:

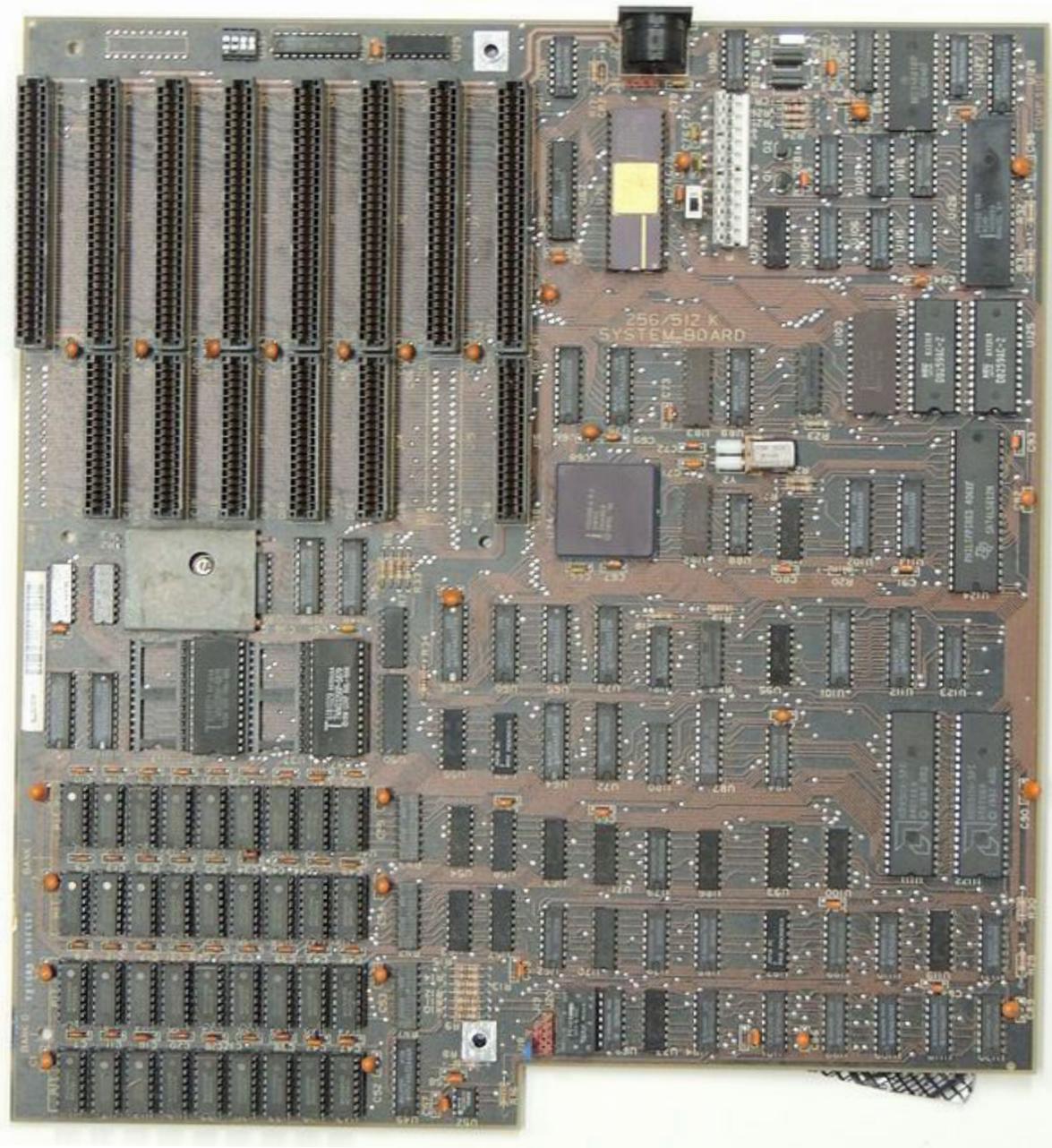
- A motherboard is specified by its **form factor**.
- It defines
 - Style
 - Dimension
 - Power Supply Type
 - Location of Mounting Holes
 - Layout of Components (such as Slots, Sockets)
 - Number of Ports on the Back Panel, etc.
- Different form factors are AT, Baby AT, LPX, NLX, ATX, MicroATX, FlexATX, BTX, etc.

AT Form Factor (also referred to as Full AT or full-size AT):

- AT – Advanced Technology
- First came in 1984 in IBM's Personal Computer AT
- First front-side power switch
- Had 5-pin DIN connector for keyboard. (DIN: Deutsches Institut für Normung)
- The Full AT is 12" wide x 13.8" deep and only fits into a full size AT tower case.

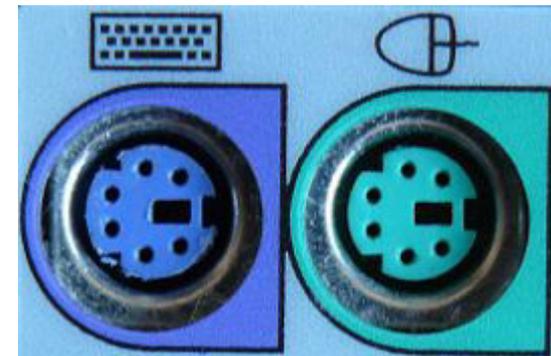
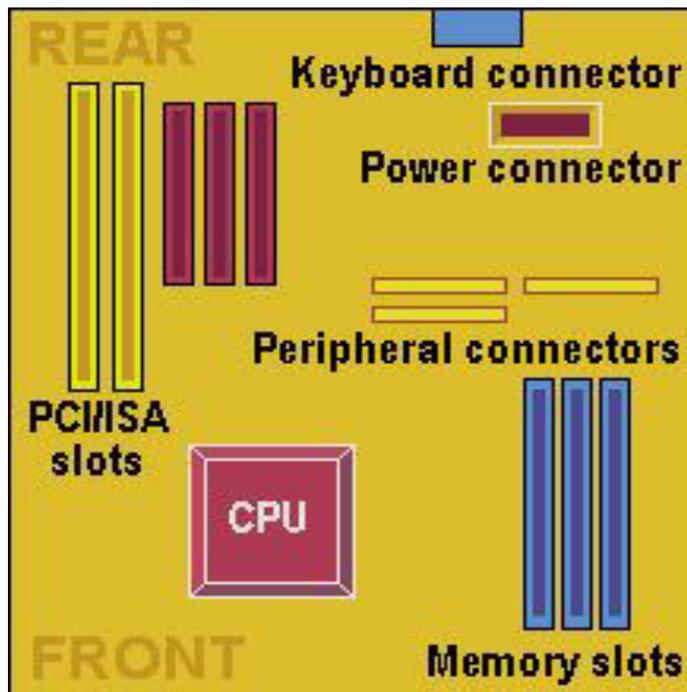


Original IBM AT motherboard



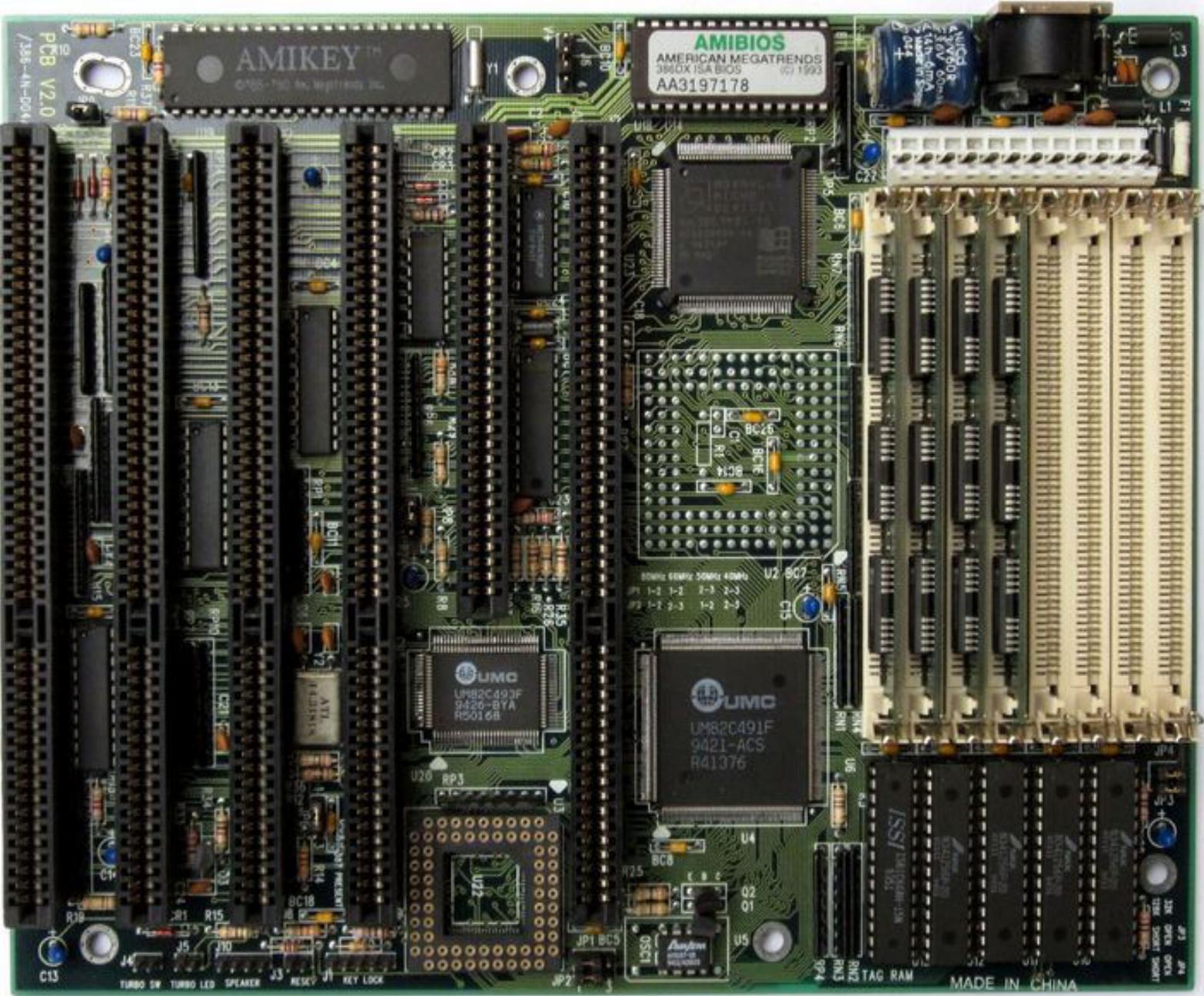
Baby AT Form Factor:

- Smaller type AT (9 in X 10 in), fits into the AT tower case.
- Popular than AT, existed a decade until ATX came.
- Only one type connector: 5-pin DIN or a 6-pin mini-DIN for keyboard.
 - 6-pin mini-DIN connector is also called PS/2 connector (IBM Personal System 2)
- Some baby AT motherboards have one more PS/2 connector for mouse.
- All other connectors are mounted on the system case and are attached to the motherboard via cables.
- Processor relocated to the front of the motherboard.



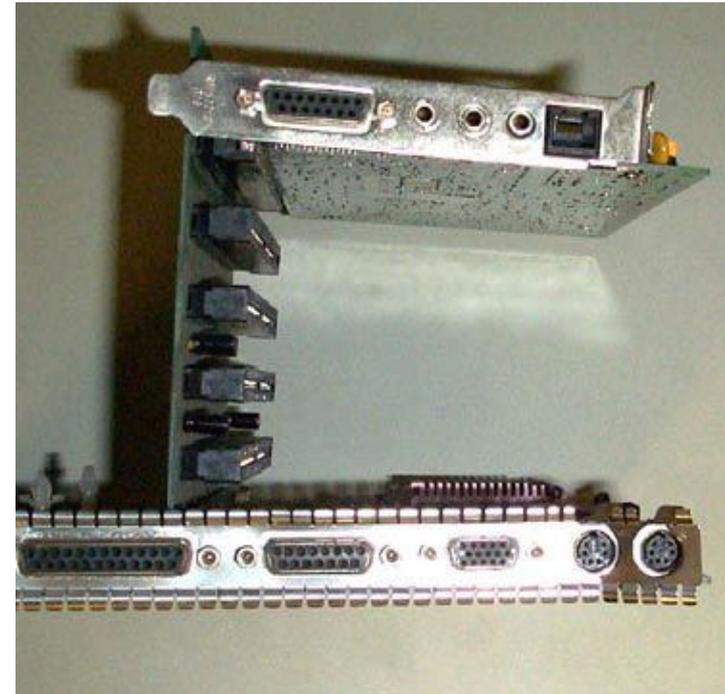
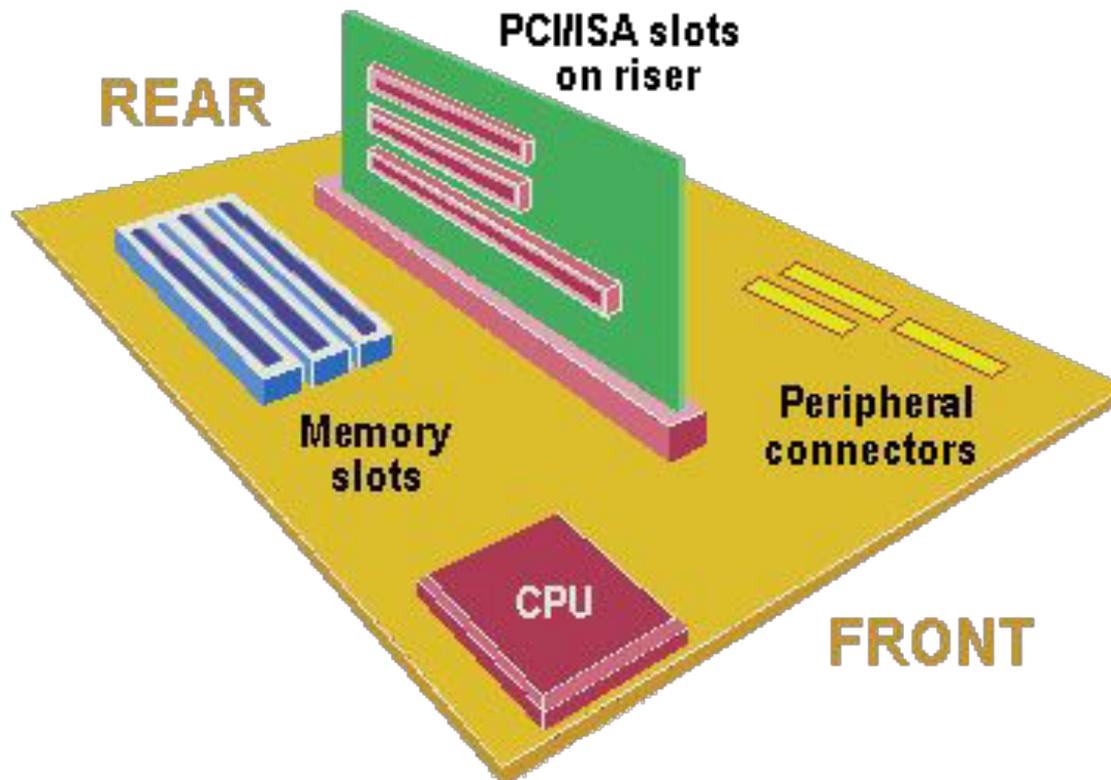
PS/2 connectors

Baby AT Form Factor:



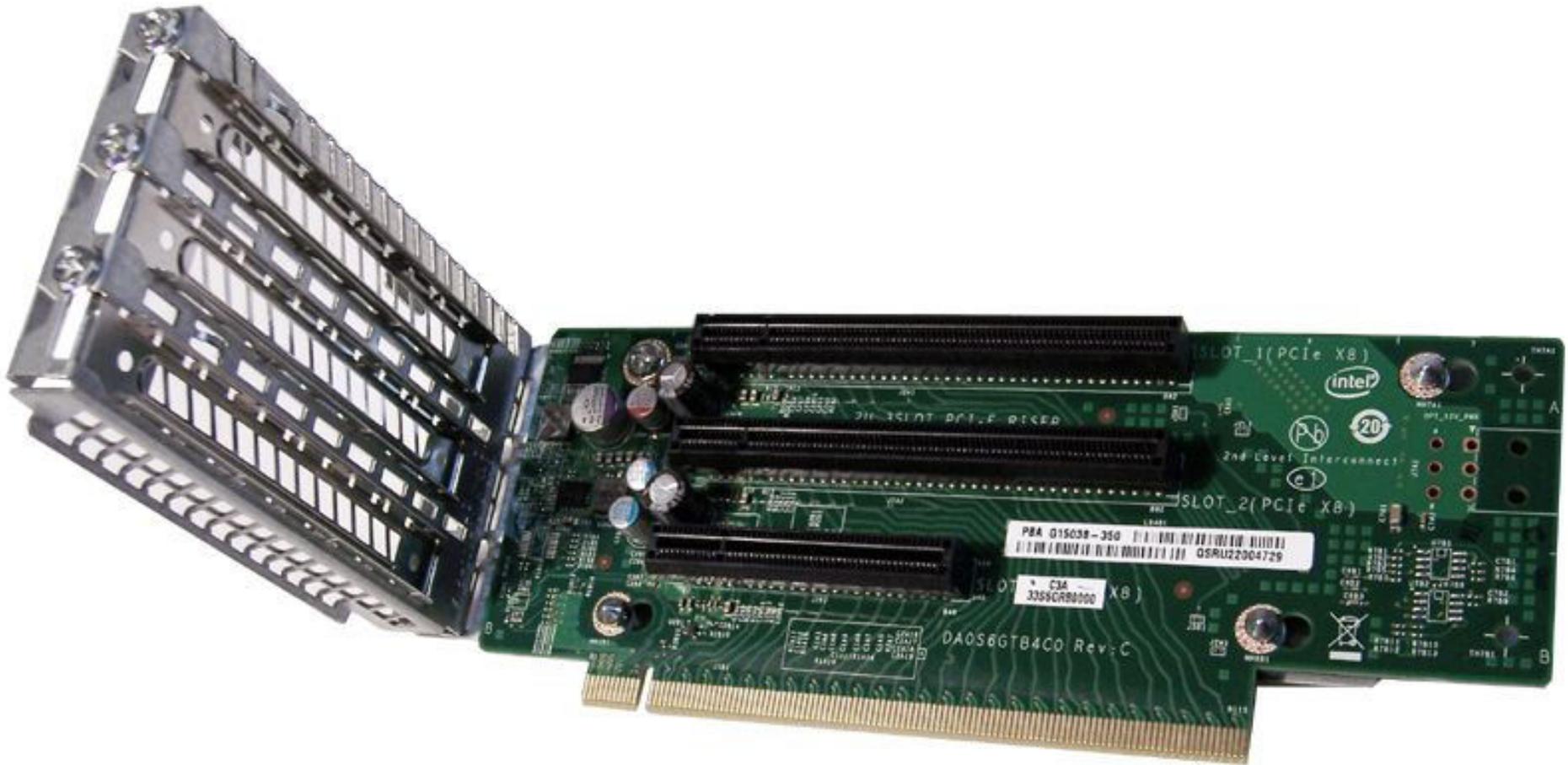
LPX (Low Profile Extension) and mini LPX:

- A semi-proprietary design by Western Digital in 1980s.
- Had slots to fix riser cards; and expansion cards were fixed on these riser cards.
- Thus expansion cards were parallel to the motherboard.
- The rear connectors protrude through the back side of the case. This special design helped to make slim systems than Baby AT.
- Stopped production with the introduction of Pentium II processors and AGP cards, which needed more cooling.



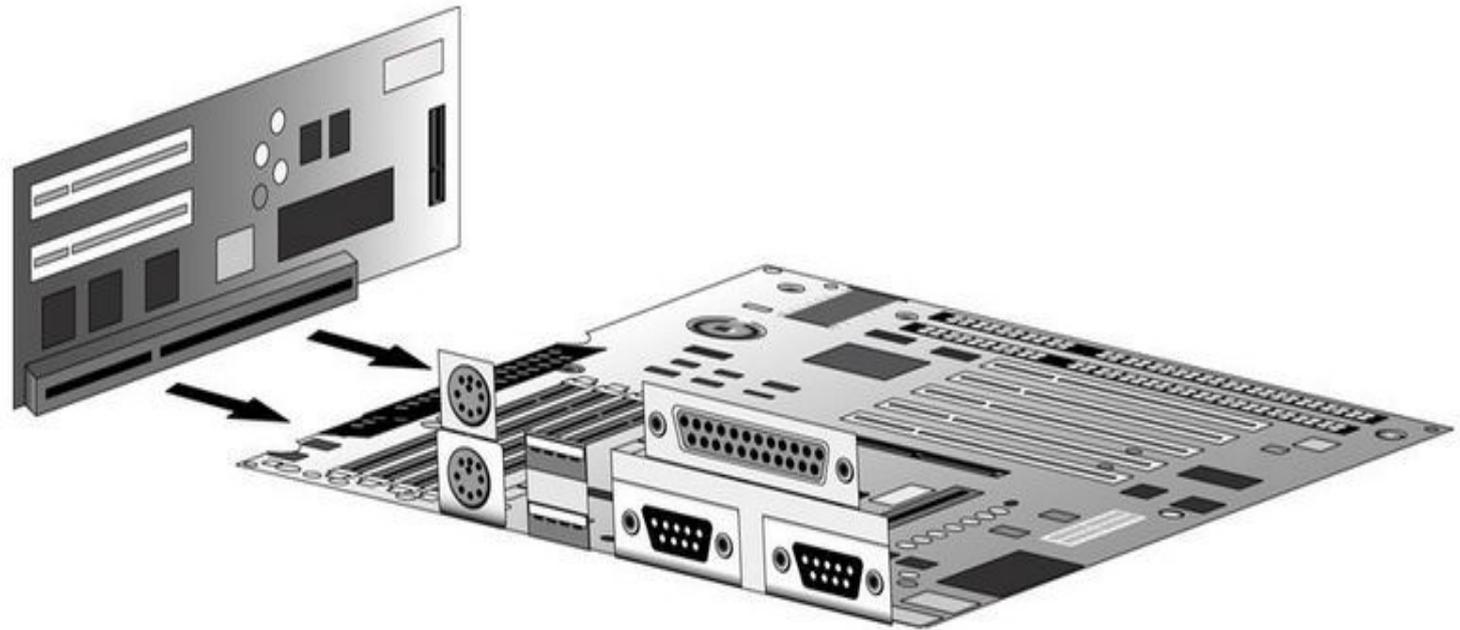
LPX (Low Profile Extension) and mini LPX:

Raiser Card

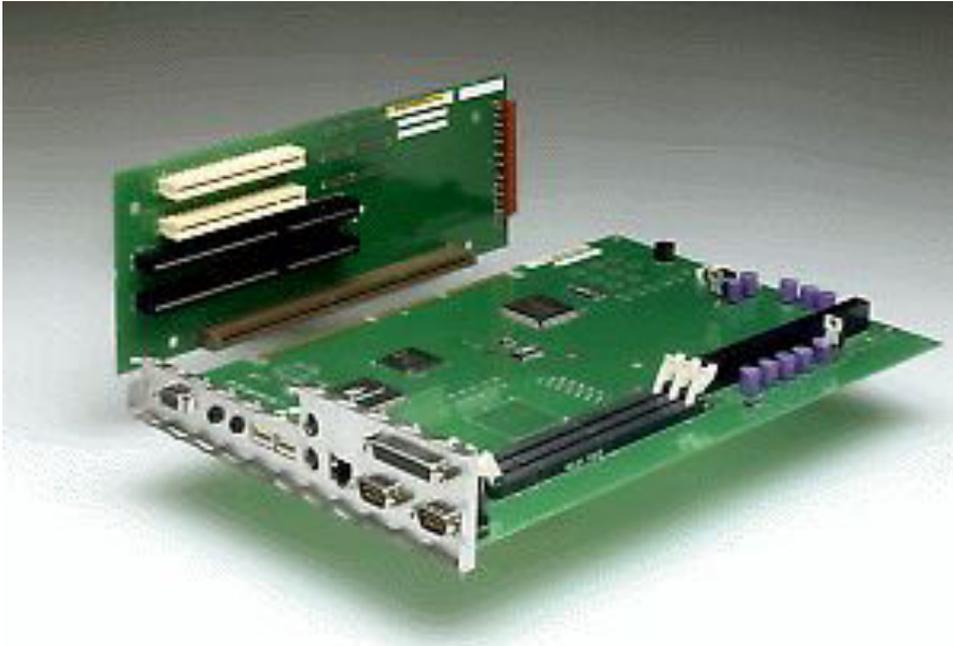


NLX (New Low-profile Extension)

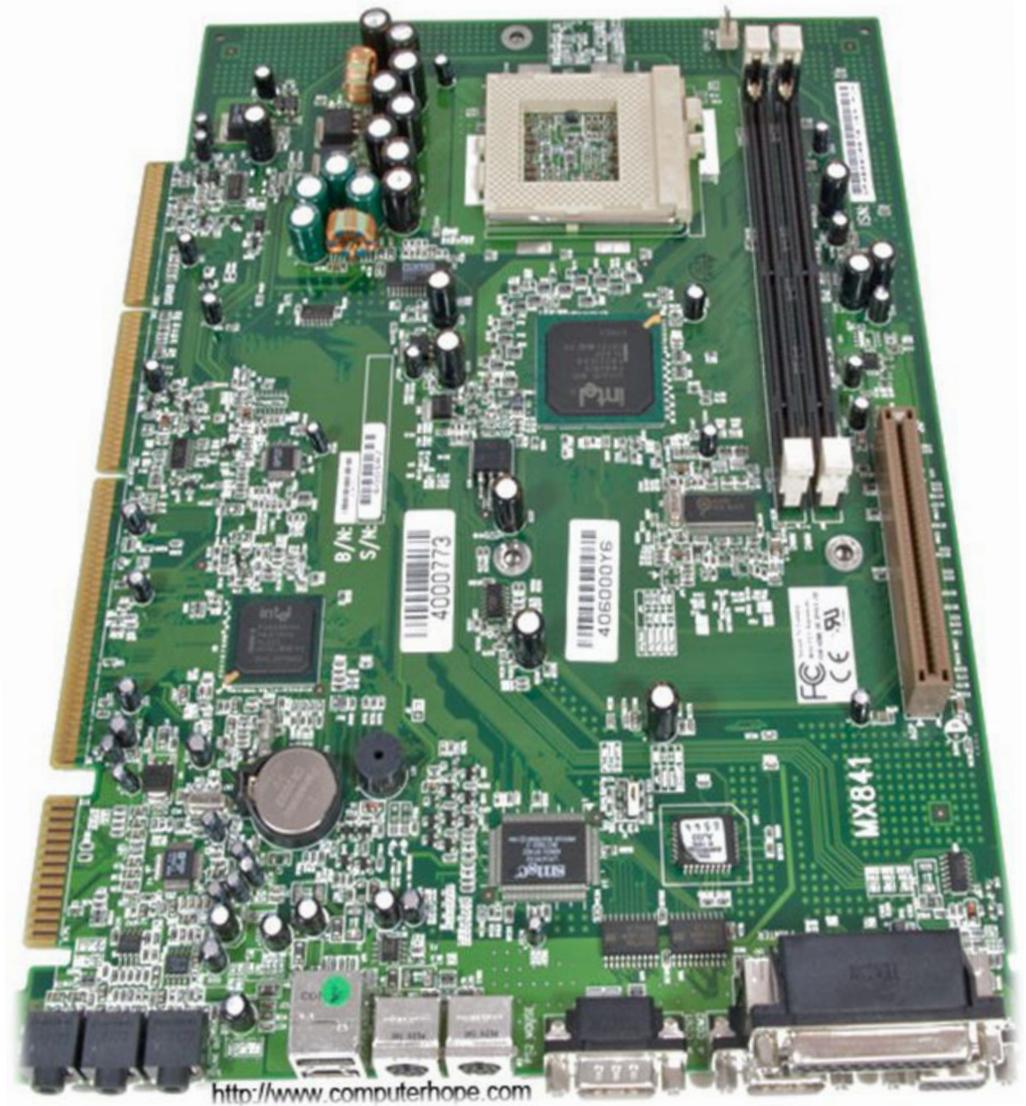
- Modified form of LPX but fully standardised.
- 8.8 in X 13 in
- A riser card is fixed on the case, and the motherboard itself is plugged into the riser.
- Everything such as drive cables, the power supply, the front panel light, switch connectors, etc are plugged into the riser. Therefore, the motherboard can be removed from the system without disturbing the riser or any of the expansion cards plugged into it.
- Hence there are literally no internal cables.
- Very easy maintenance/repair and improved cooling.



NLX (New Low-profile Extension)



NLX Motherboard



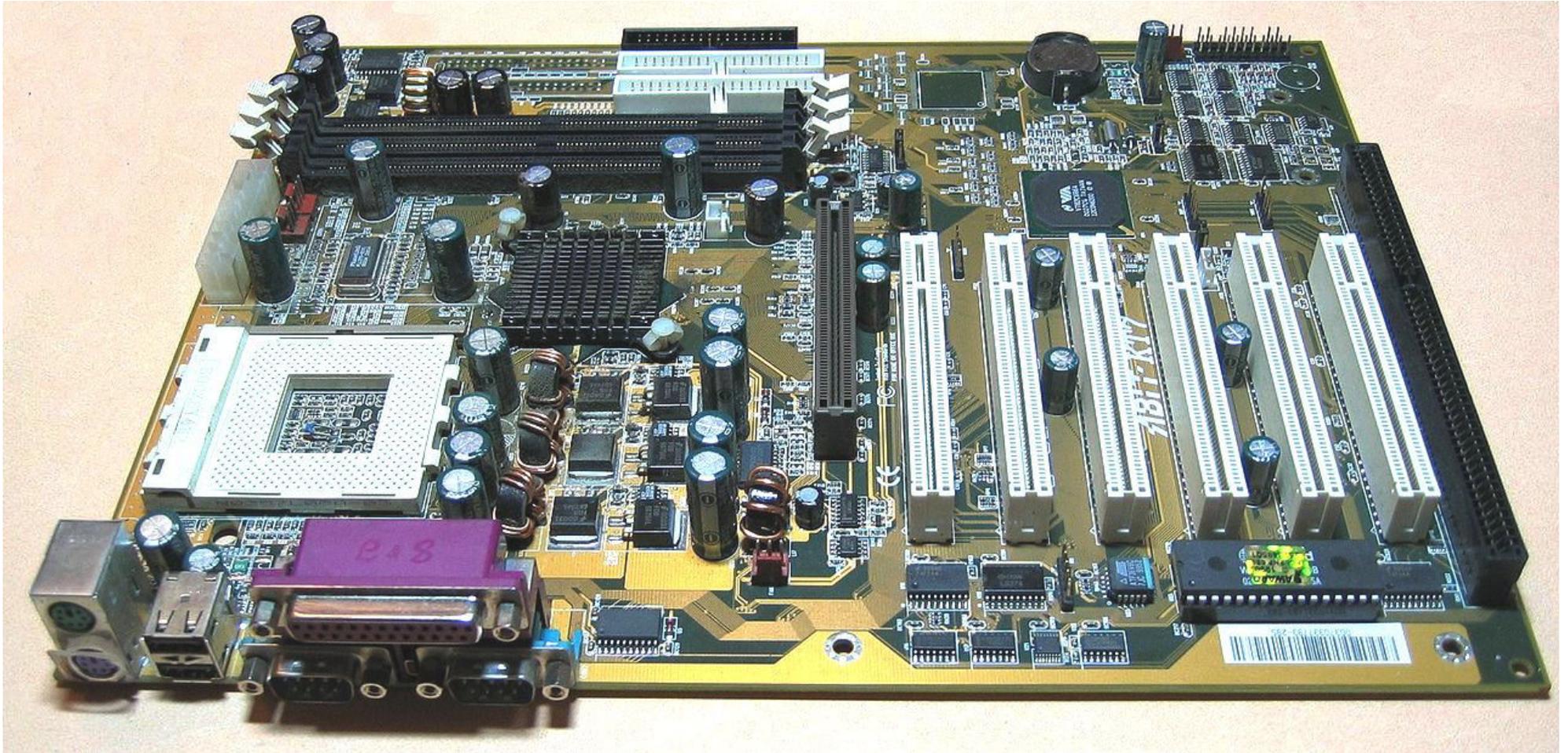
ATX (Advanced Technology eXtended) form factor:

- Designed by Intel in 1995 by considering the best features of BabyAt and NLX form factors.
- But incompatible to both.
- Standard ATX motherboard has the size 12 inches x 9.6 inches.

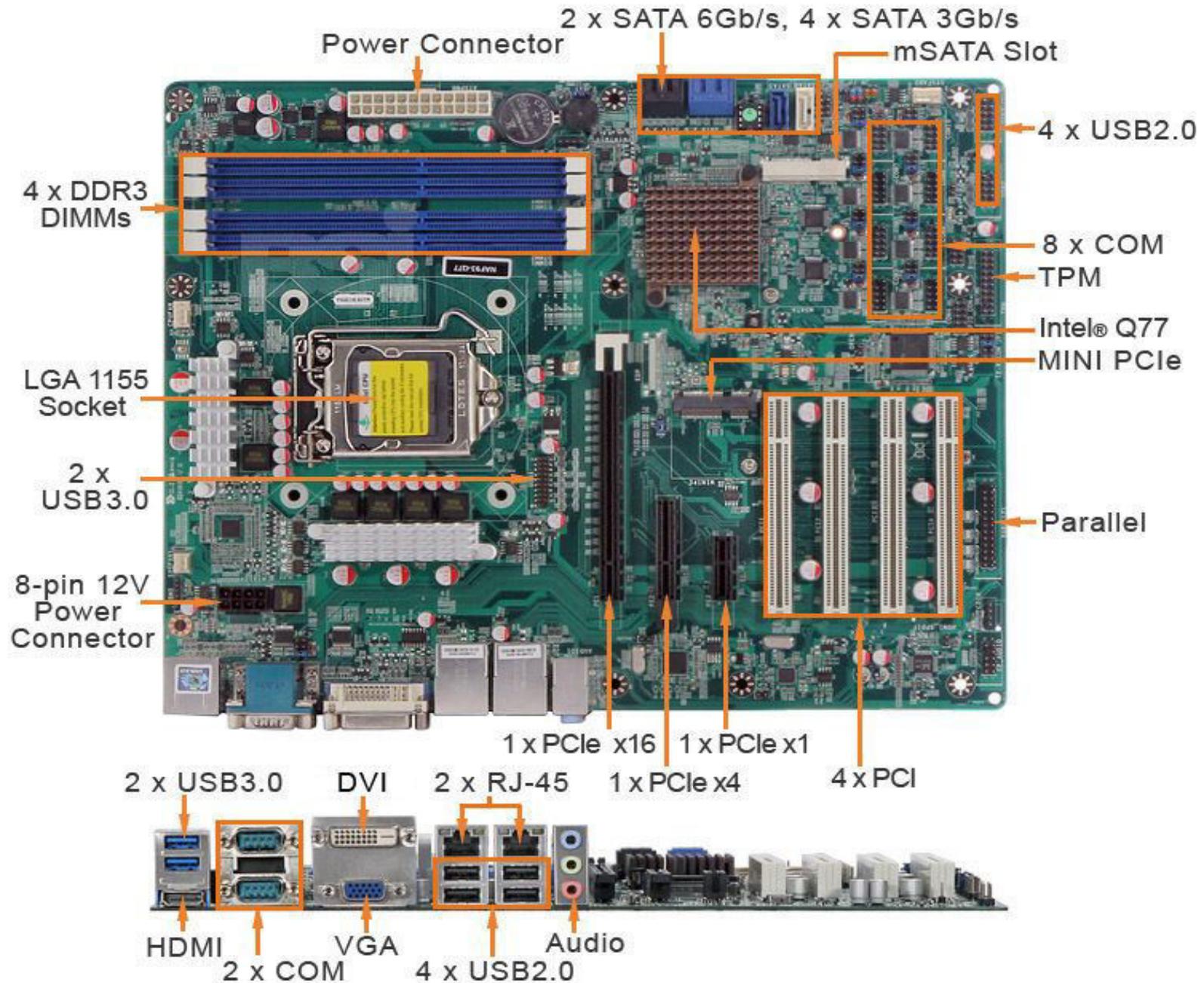
Features

- *Single main keyed internal power supply connector.*
- *Processor and memory slots at right angles to the expansion cards, which improved cooling.*
- *Possible to install full-length expansion cards.*
- *Lower cost to manufacture.*
- *The power supply blows air over the CPU rather than pulling air from the chassis.*
- *Place all the connectors directly on the motherboard.*

ATX (Advanced Technology eXtended):



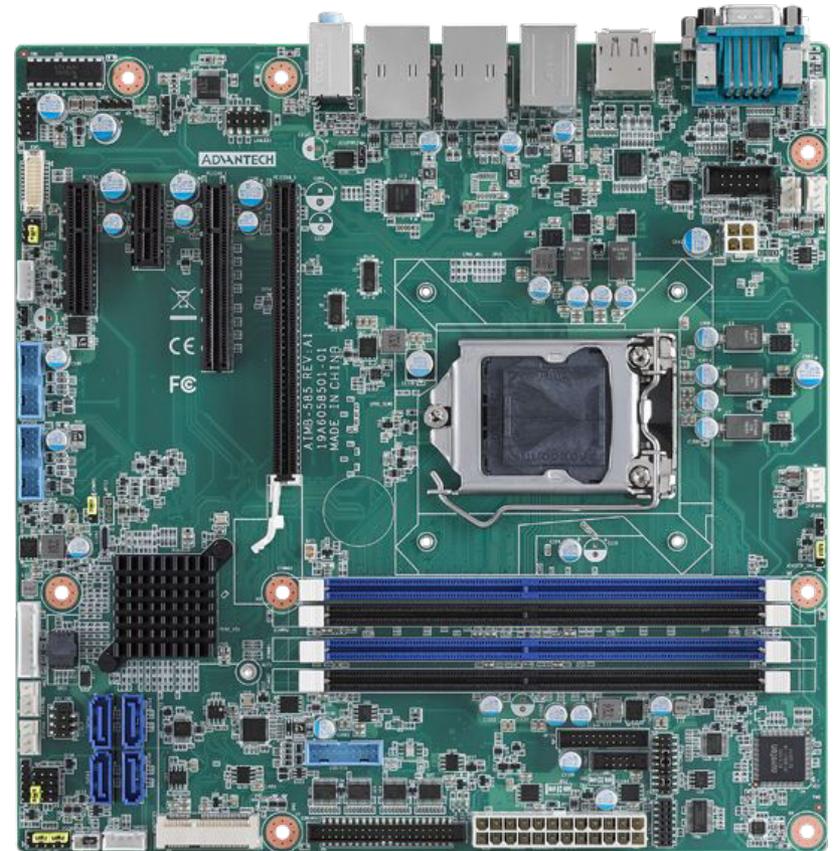
ATX (Advanced Technology eXtended):



Micro ATX (also referred to as μ ATX):

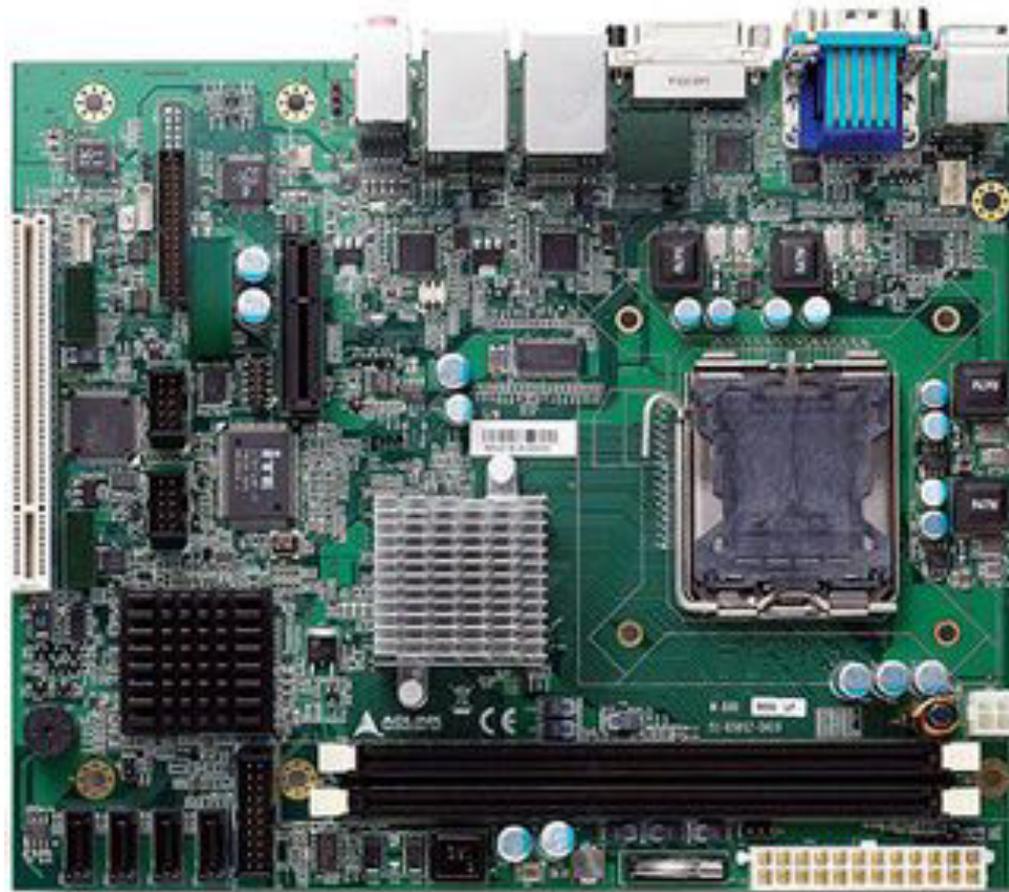
- Introduced by Intel by reducing the size and functionalities of ATX for low-power, low-cost systems
- Backward compatible with ATX and fit into ATX cases.
- Standard size of 9.6in X 9.6in
- Since smaller, less number of memory slots, expansion slots, and integrated components.
- All results in less-power and less-heat.

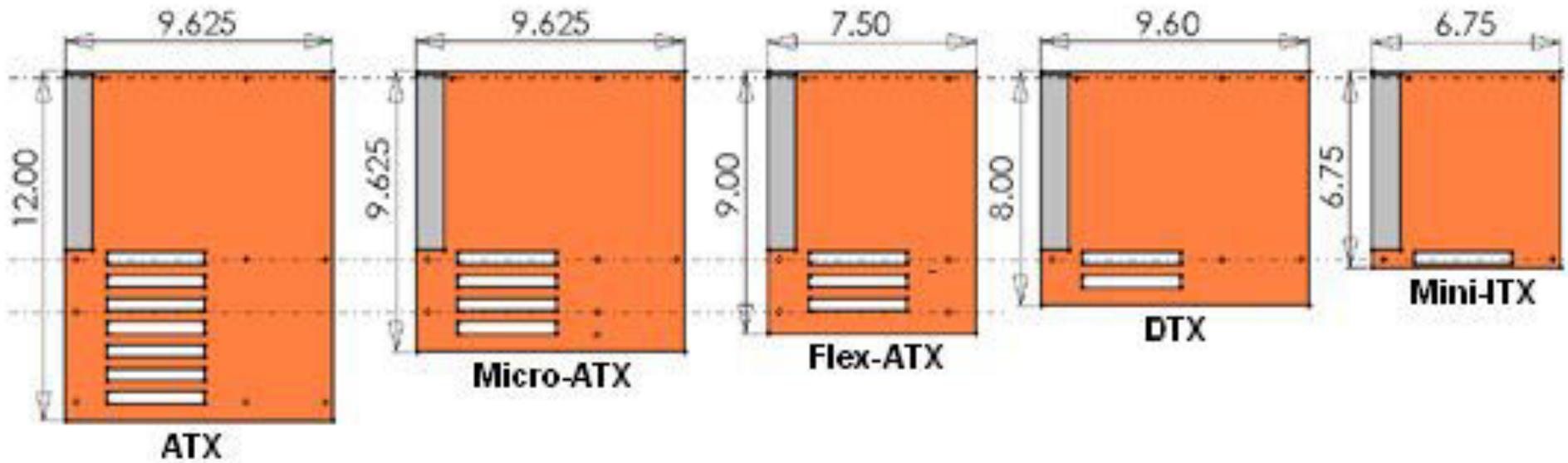
Micro-ATX Motherboard with Intel® Xeon® LGA1151 with DP/DVI/HDMI/eDP, SATAIII, 6 COM



Flex ATX:

- Designed from ATX for extremely inexpensive, smaller, consumer-oriented, appliance-type systems.
- Some does not have expansion slots; expansion only through USB like ports.
- 9 in × 7.5 in
- Backward compatible to ATX and Micro-ATX.





Standard-ATX



Micro-ATX



Mini-ITX



Nano-ITX



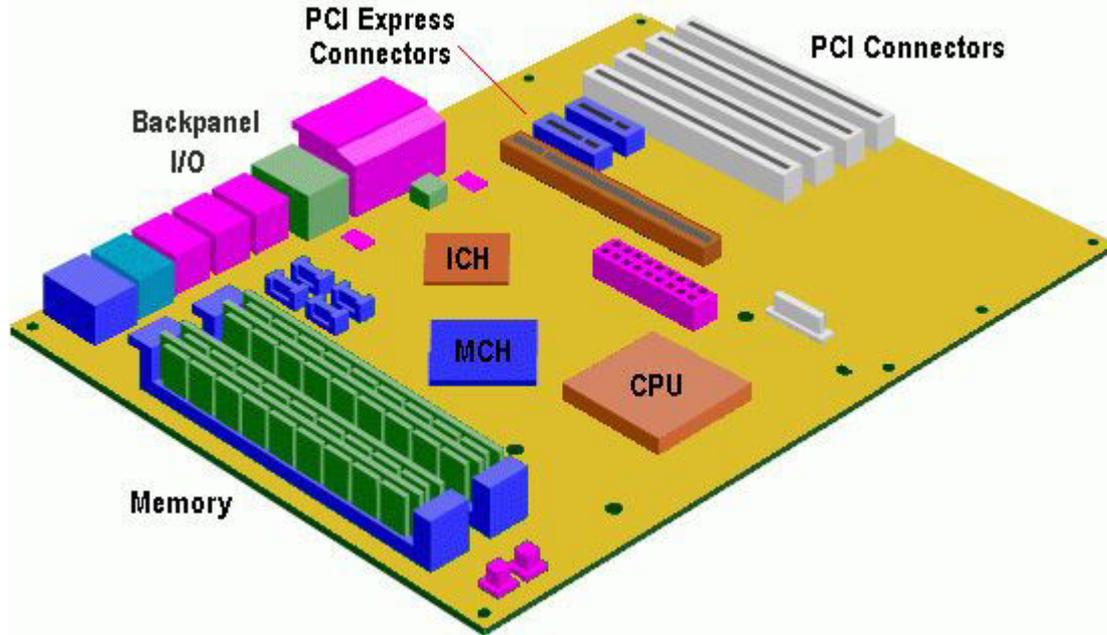
Pico-ITX



Size comparison of various motherboards

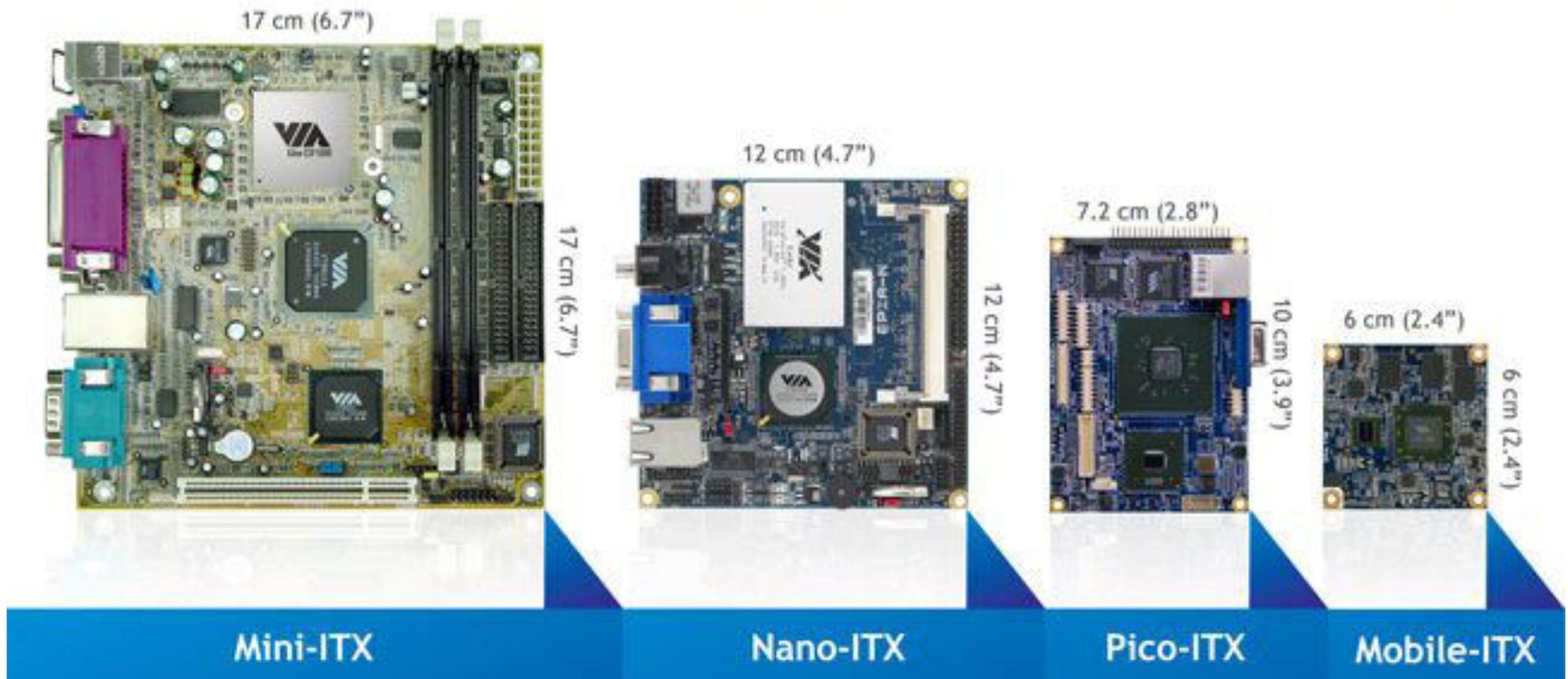
BTX (Balanced Technology eXtended):

- Introduced by Intel as a replacement for ATX.
- Offered scalability in system design by variety of board sizes.
- Internal components are arranged in such a way as to allow the CPU heat sink and other hot-running chips to be cooled by a single airflow stream from a chassis fan.
- Less popular and became obsolete by the flexibility of ATX and its derivatives.



ITX (Information Technology eXtended) family:

- Introduced by VIA.
- A low-power, small form factor (SFF) board for specialty uses, such as home-theater systems and as embedded components such as set-top boxes.
- ITX family includes Mini-ITX, Nano-ITX, Pico-ITX and Mobile-ITX form factors.
- Mini-ITX boards are compatible with ATX cases, but others are used in embedded systems.



Size Comparisons of Various Motherboards

| Form Factor | Length | Width |
|-------------|----------------|---------------|
| ATX | 12.0" (30.5cm) | 9.6" (24.4cm) |
| Mini ATX | 11.2" (28.4cm) | 8.2" (20.8cm) |
| Flex ATX | 9.0" (22.9cm) | 7.5" (19.1cm) |
| Micro ATX | 9.6" (24.4cm) | 9.6" (24.4cm) |
| ITX | 8.5" (21.5cm) | 7.5" (19.1cm) |
| Mini-ITX | 6.7" (17cm) | 6.7" (17cm) |
| Nano-ITX | 4.7" (12cm) | 4.7" (12cm) |

Motherboard Components:

Many of the following components can be found on a typical motherboard:

- Chipsets
- Expansion slots and buses
- Memory slots and external cache
- CPUs and their sockets
- Power connectors
- Onboard disk drive connectors
- Keyboard connectors
- Integrated peripheral ports and headers
- BIOS/firmware
- CMOS battery
- Jumpers and DIP switches
- Front-panel connectors

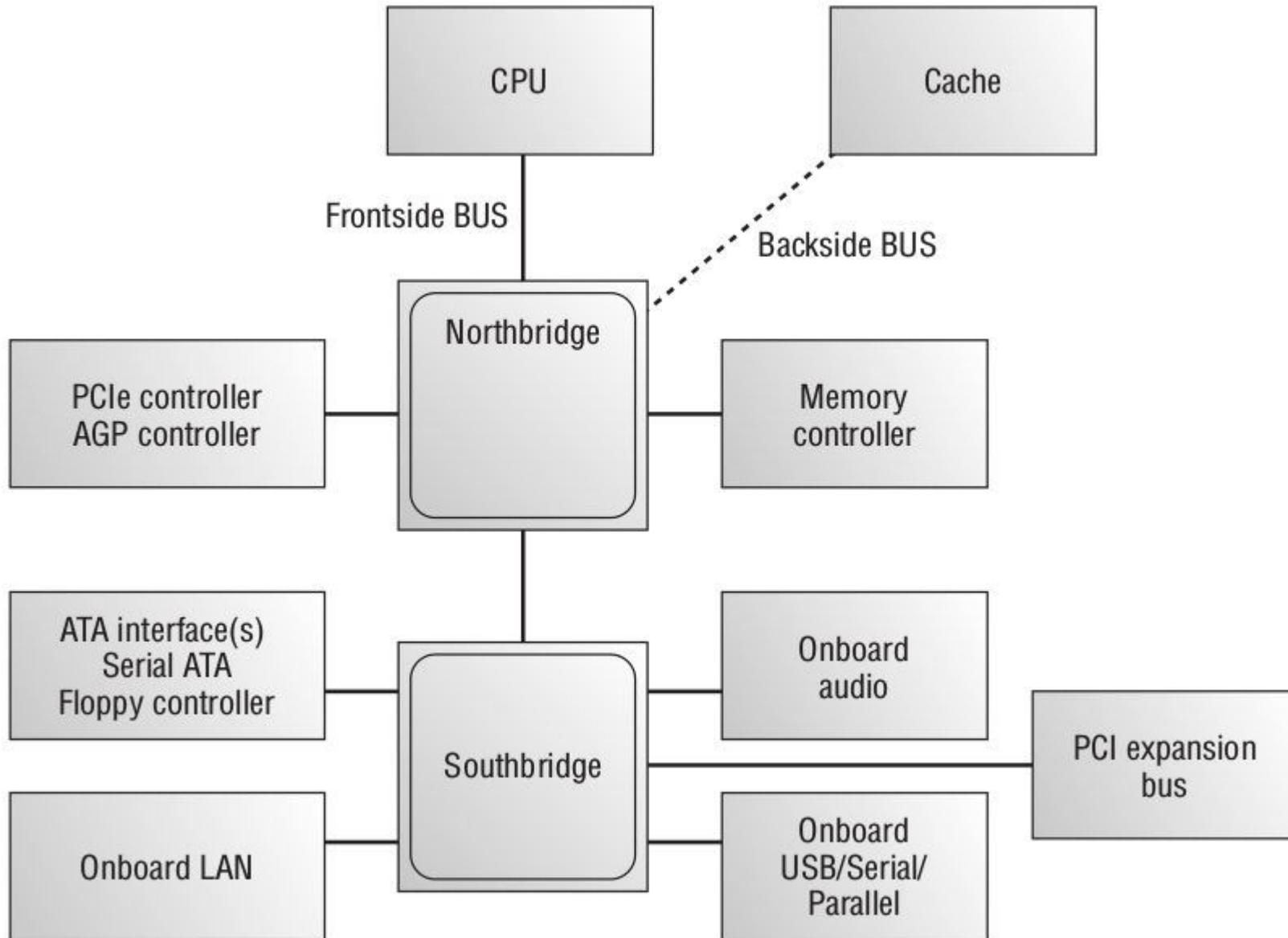
Bus Architecture:

- Bus: Communication pathway between internal components, or between internal and external components.
- Each device is connected to at least one bus.
- Buses have a hierarchy based on speed, ie from faster to slower.
- Each bus is connected to another bus above it in the hierarchy, through some devices such as chipsets.
- Some examples of buses are processor bus, I/O buses, expansion buses, etc.
- Buses can be parallel buses or serial buses.
- Parallel bus: Transfer several bits parallelly
 - Eg: PCI and AGP
- Serial bus: Transfer bits one by one.
 - Eg: Serial ATA (SATA), Universal Serial Bus (USB), IEEE 1394/FireWire, and Peripheral Component Interconnect Express (PCIe).

Chipsets

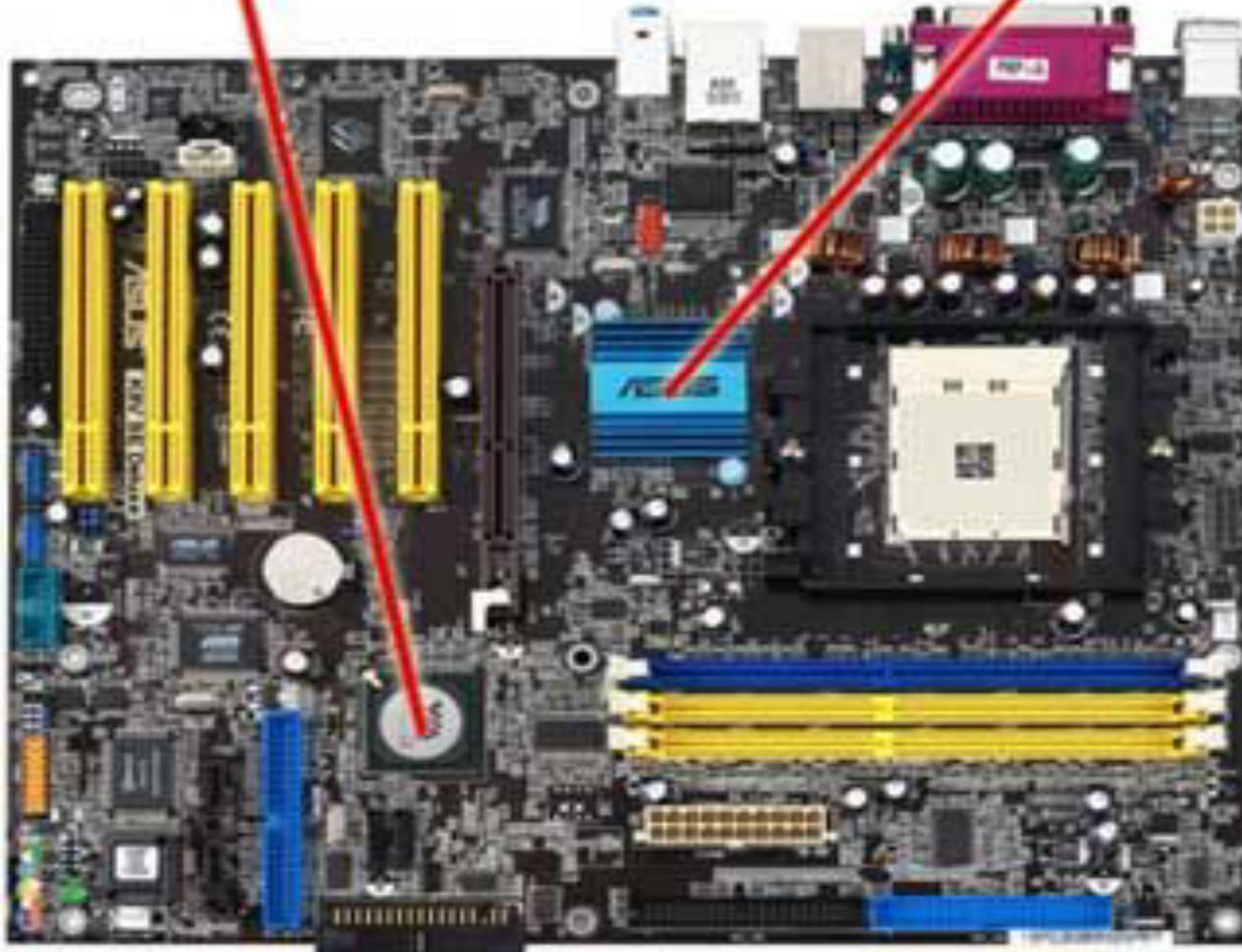
- Collection of chips for interfacing different devices with the processor
- Perform interface and peripheral functions for the processor
- It is the glue that connects the processor to the rest of the computer
- Integrated to the motherboard, so cannot be replaced
- Two major chips:
 - North bridge (for high speed devices)
 - South bridge (for others)
- Some manufacturers are: AMD, Broadcom, Intel, NVIDIA, SiS and VIA Technologies.
- Old north bridges are sometimes called **PAC** (PCI AGP Controller)
- In Intel's Hub Architecture, the Northbridge is called *Memory Controller Hub (MCH)*.
- In Intel's Hub Architecture, the Southbridge is called *I/O Controller Hub (ICH)*.
- Some boards have Super IO chips for dealing slow devices and BIOS NVRAM
- Companies that make super I/O controllers include Nuvoton, ITE, Fintek, and Microchip Technology (old SMSC chip).

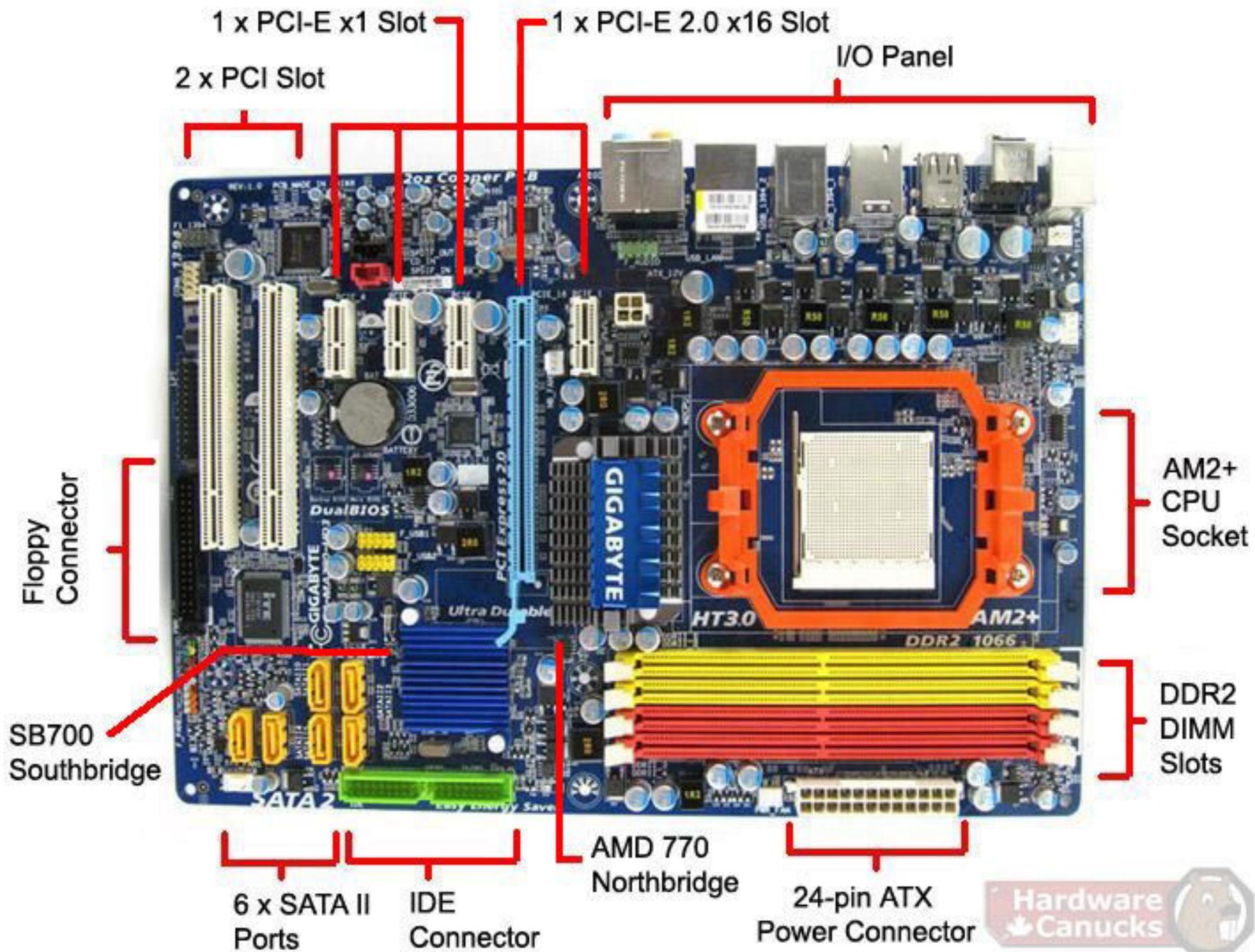
Chipsets - traditional (as per text)

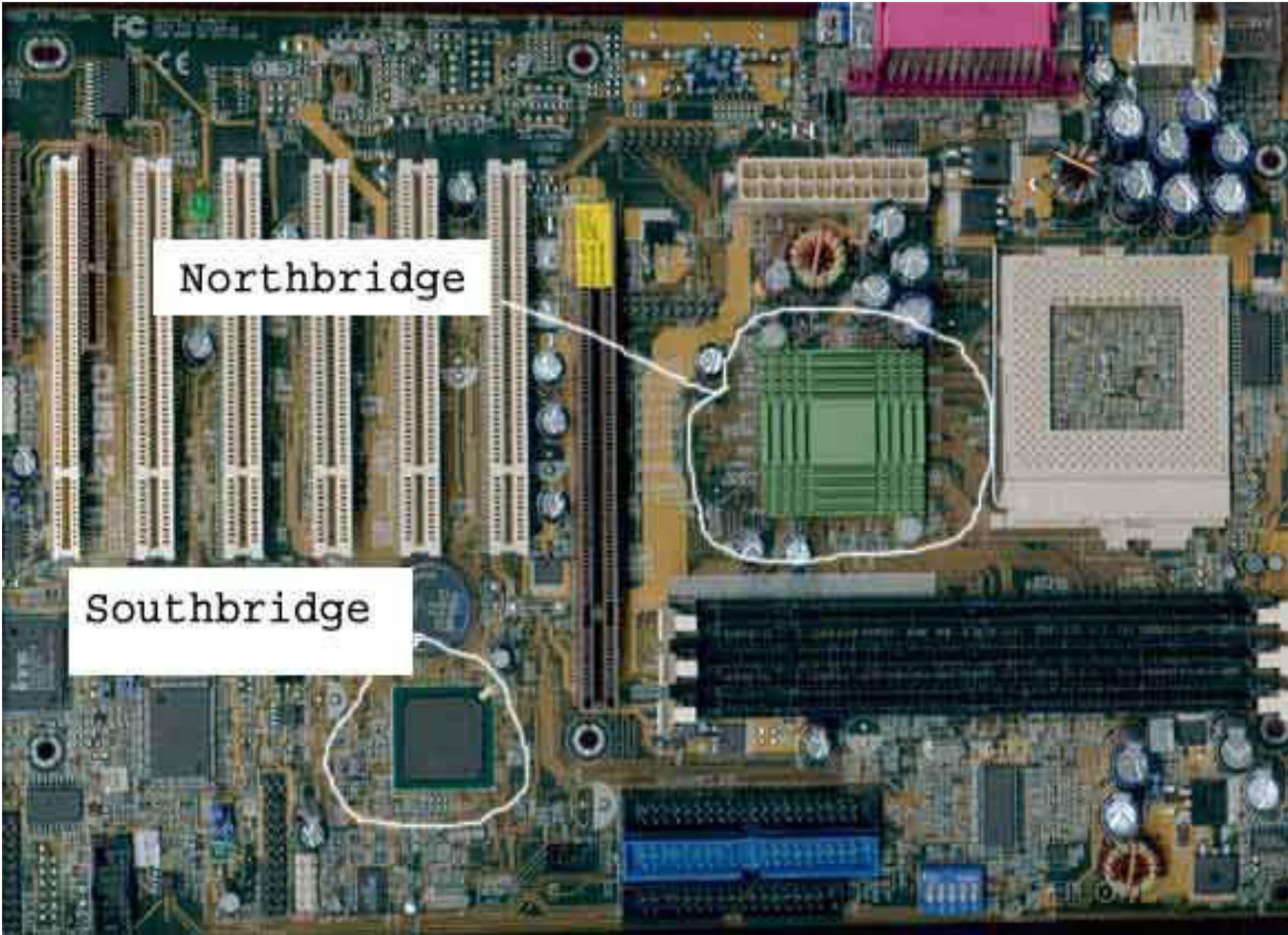


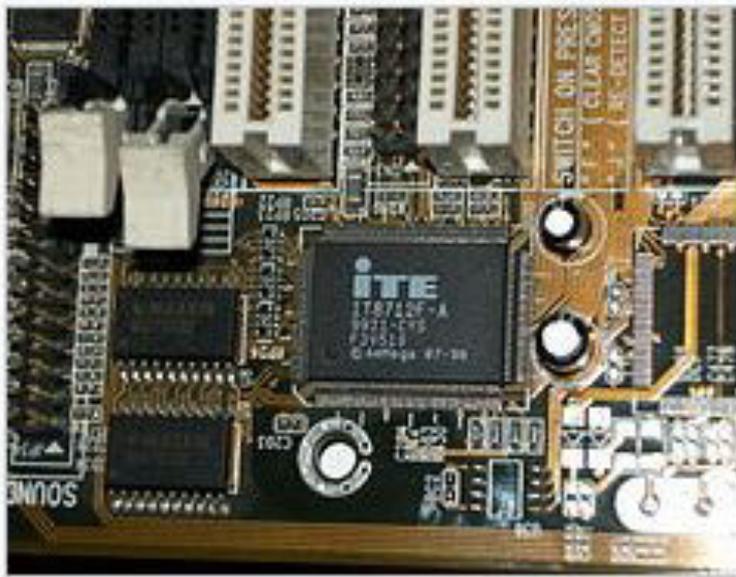
South Bridge

North Bridge









ITE Super I/O chip (IT8712F)

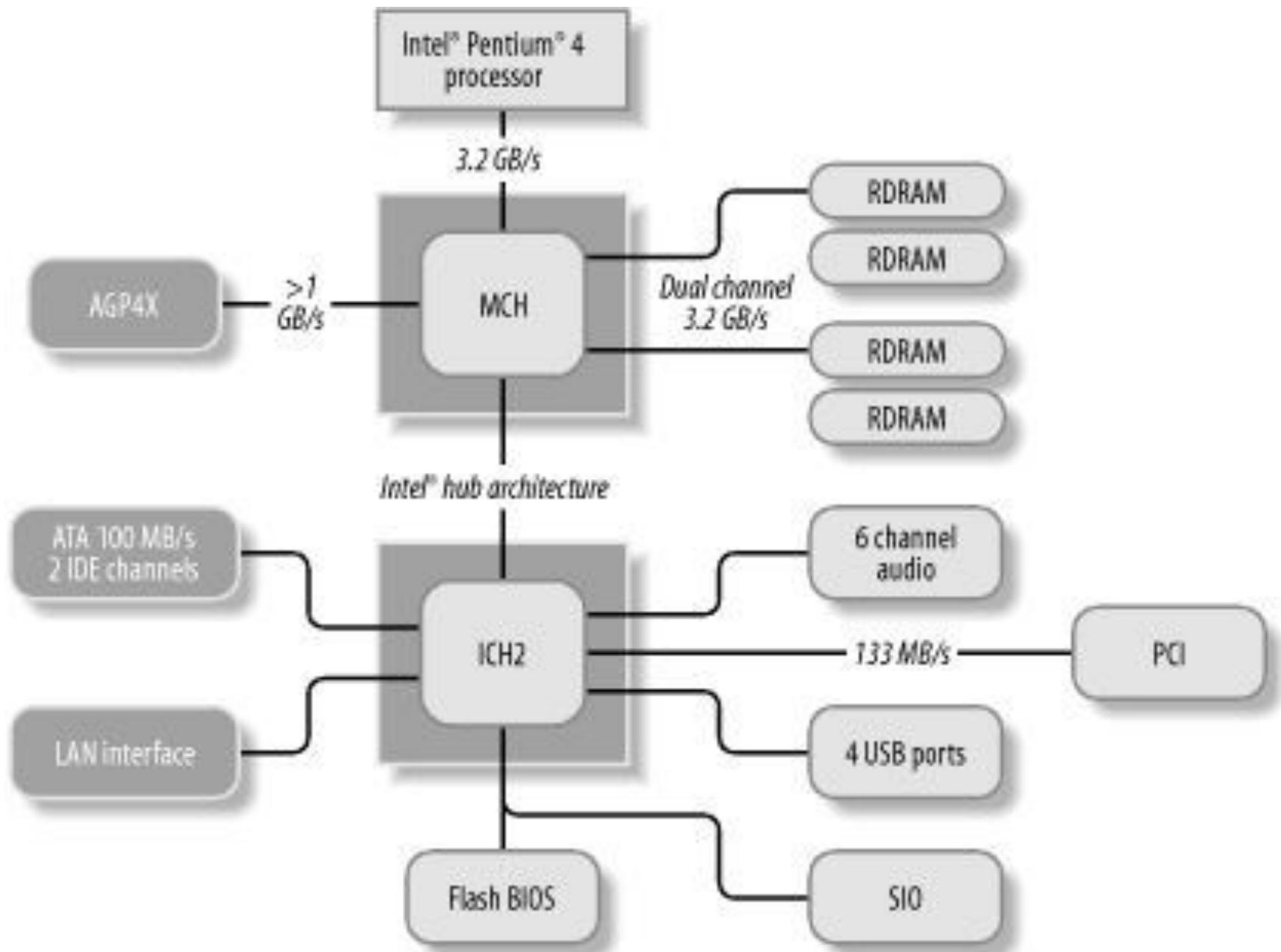


SMSC (now Microchip) Super I/O chip (FDC37M813) on IBM motherboard



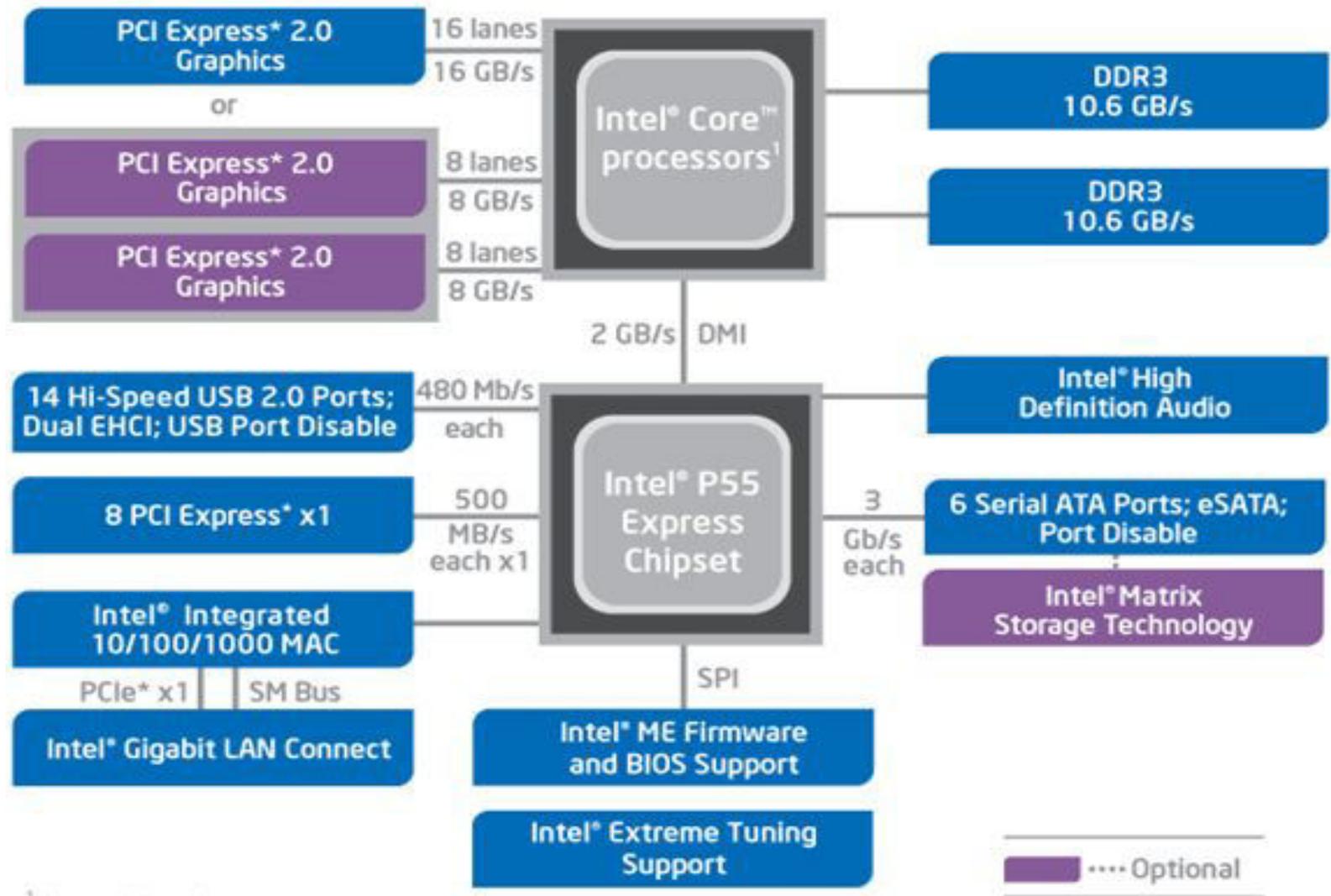
Nuvoton Super I/O chip

Intel Hub Architecture

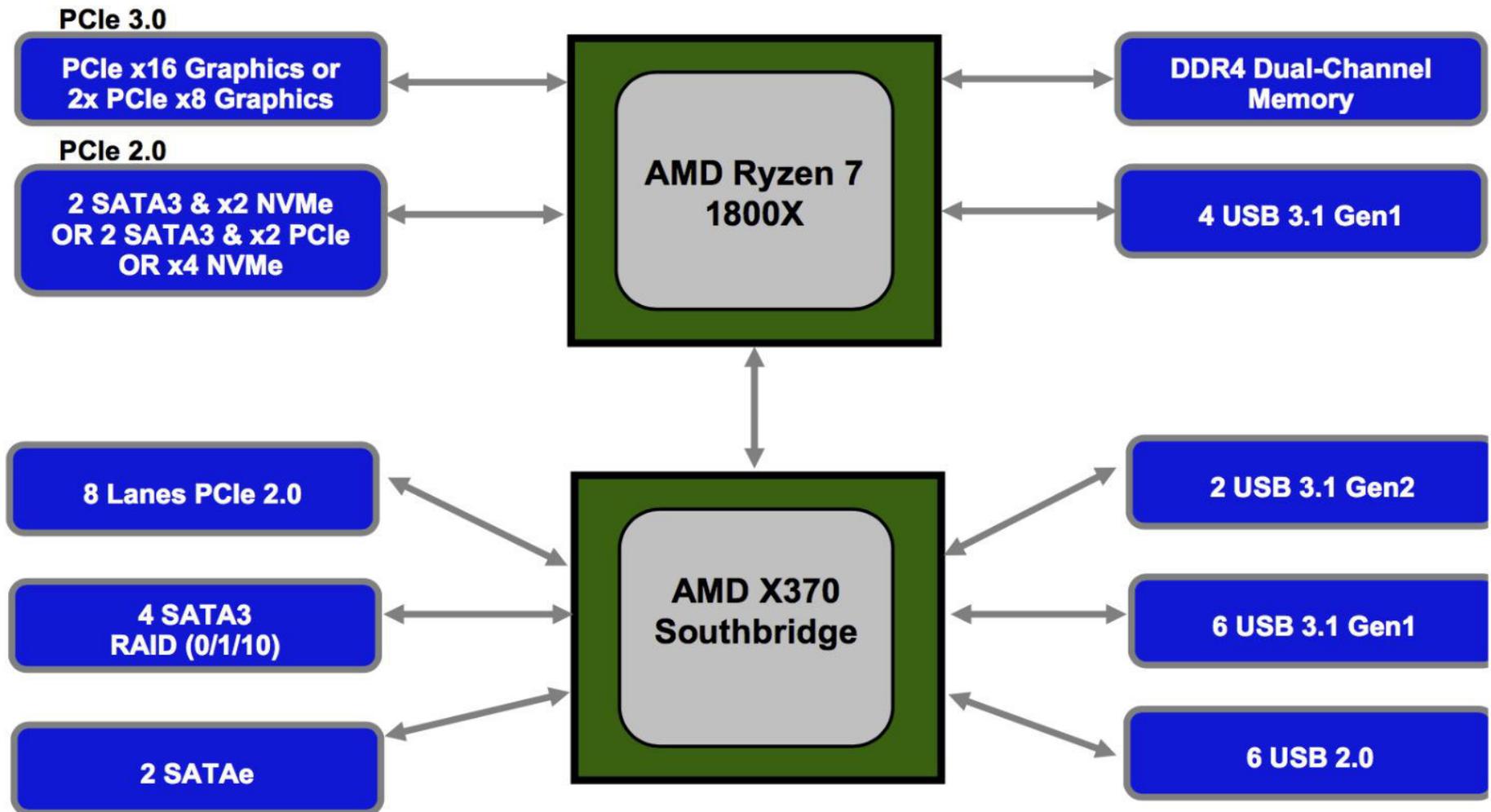


Chipset – New (Intel Core i series and AMD 64 series)

- Graphics and memory controller functions are integrated into the processor; and the South Bridge does the rest



New AMD boards for Ryzen CPUs...



Expansion Slots:

- Slots to expand the capabilities of motherboards
- Usually 1 to 6 inches long and half inch wide
- The slots may be for memory, video, network, sound, or disk interface
- Examples are given below. Some of them are obsolete.
 - ISA - Network card, Sound card, Video card
 - EISA - SCSI, Network card, Video card
 - VESA - Video card
 - AMR - Modem, Sound card
 - CNR - Modem, Network card, Sound card
 - PCI - Network card, SCSI, Sound card, Video card
 - PCI-X - Network card, SCSI, Sound card, Video card
 - AGP - Video card
 - PCI Express - Video card, Modem, Sound Card, Network Card

ISA (Industry Standard Architecture)

- By IBM.
- First it was an 8-bit slot, later became 16-bit with backward compatibility.
- An 8-bit ISA card uses the first 62 pins, while a 16-bit card uses all 98 pins.
- Obsolete. Replaced mostly by PCI



ISA 8 bits



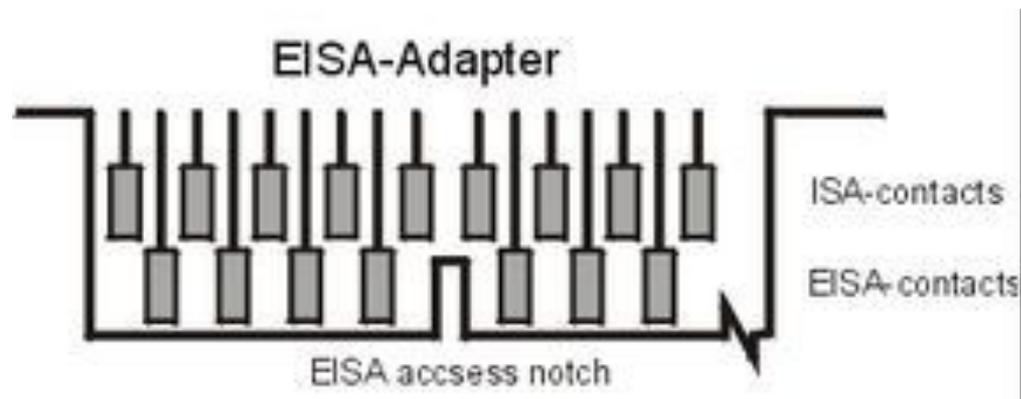
ISA 16 bits

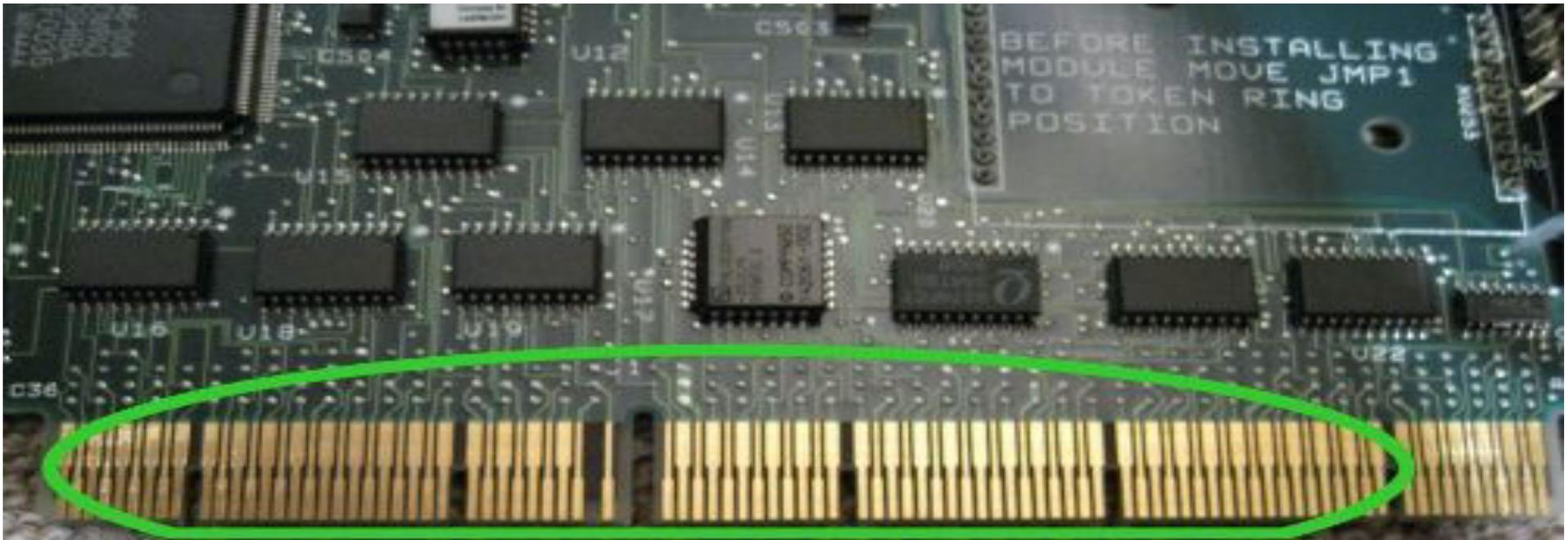
MCA (Micro Channel Architecture)

- Proprietary by IBM.
- 16- and 32-bit versions.
- Bus mastering – direct communication between cards

EISA (Extended Industry Standard Architecture)

- A counter to MCA proprietary bus
- 32-bit, but compatible to 16- and 8-bit ISA cards, through pin-inlay
- Extension of ISA
- Mostly for SCSI or network cards
- Vanished by VESA Local Bus and later PCI
- Bus mastering – direct communication between cards

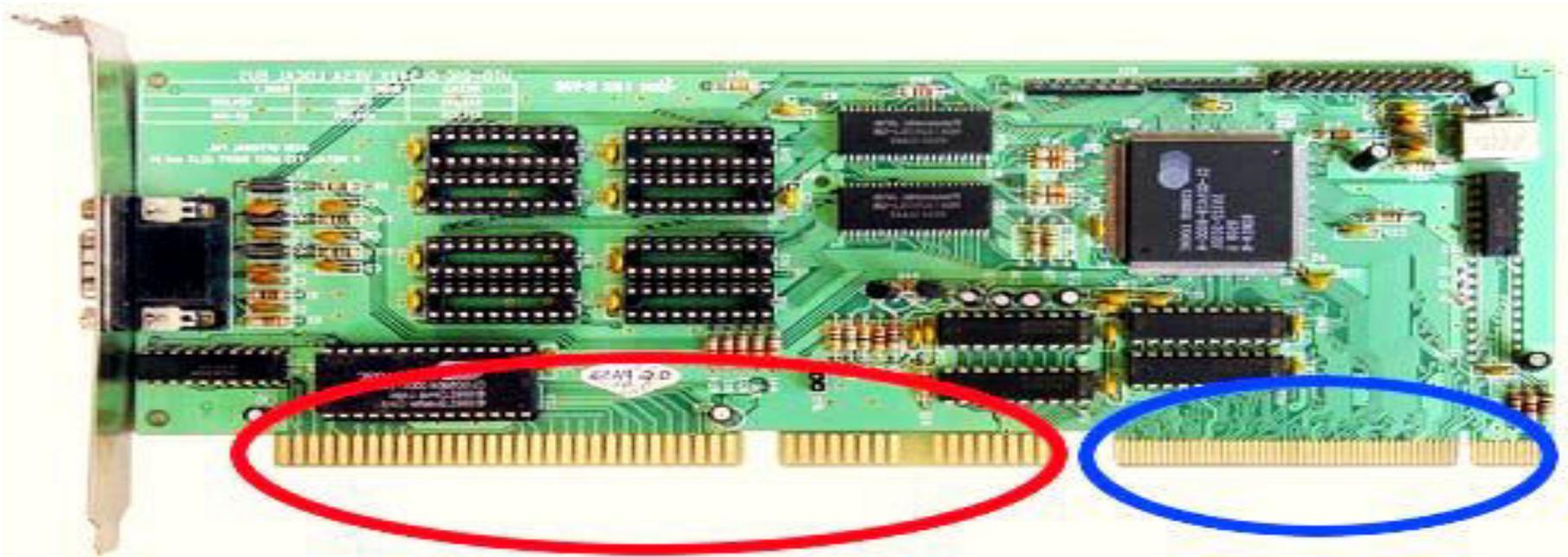


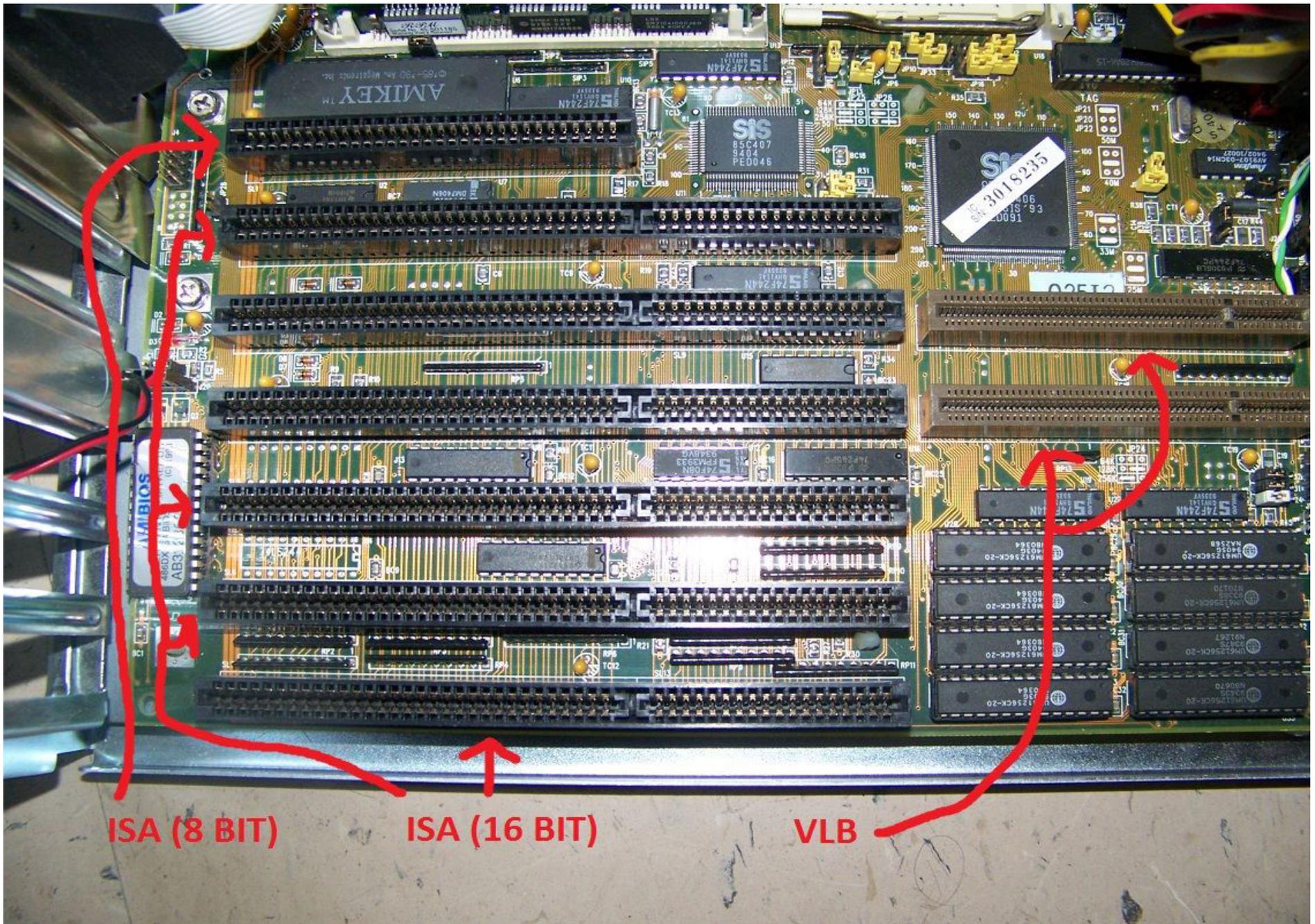


An EISA Card

VESA Local Bus (VL Bus) slot

- VESA - Video Electronics Standard Association
- 32-bit. Compatible with 8 bit ISA, 16 bit ISA
- Local bus means that it works almost the same speed of the processor (at that time)
- Mainly used for video
- VLB slot is a 16-bit ISA slot with third and fourth slot connectors added on the end.





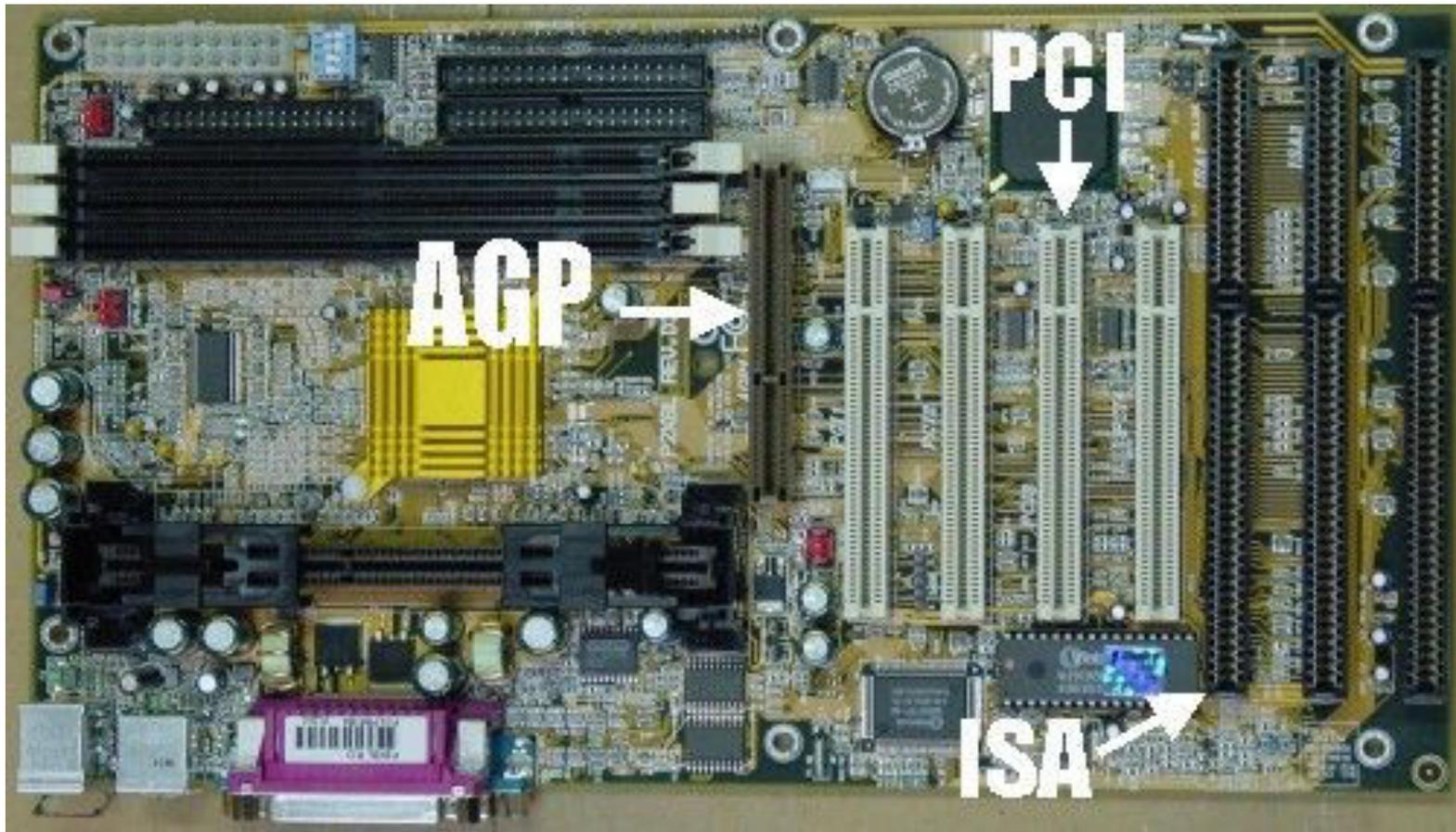
PCI (Peripheral Component Interconnect)

- 32-bit and 64-bit variants.
- Mostly white in colour.
- Became popular with Pentium-class processors.
- PCI follows the Intel's PnP specification and hence did not require any jumpers or DIP switches.
- PCI devices are configured through softwares.
- Used to form network cards, sound cards, modems, extra ports such as USB or serial, TV tuner cards, disc controllers and video cards.
- PCI video cards later replaced by AGP cards
- Also called mezzanine bus
- All PCI slots in a motherboard shares a common bus.
- Speed of any PCI device will depend on the slowest device in all the PCI slots.
- Operates on 33 MHz and 66 Mhz
- Speeds of 32-bit versions:
 - $33.33\text{MHz} \times 4 \text{ bytes (32 bits)} = 133\text{MBps}$ (It is most common)
 - $66.66\text{MHz} \times 4 \text{ bytes (32 bits)} = 266\text{MBps}$
- 64-bits versions are used in servers. Speeds: 266 MBps and 533 MBps.

PCI (Peripheral Component Interconnect)...

- PCI comes in 5V specification (for stationary systems) and 3.3V specification (for portable systems).
- Universal specification works on both type of systems.
- How to identify the PCI type?
 - 64-bit PCI are longer than 32-bit ones.
 - For 5V specification the notch on the contact area is towards the front of the motherboard; while 3.3V ones, the notches are towards rear of the board.

| PCI Bus Type | Bus Width (Bits) | Bus Speed (MHz) | Data Cycles per Clock | Bandwidth (MBps) |
|---------------------|-------------------------|------------------------|------------------------------|-------------------------|
| PCI | 32 | 33 | 1 | 133 |
| PCI 66MHz | 32 | 66 | 1 | 266 |
| PCI 64-bit | 64 | 33 | 1 | 266 |
| PCI 66MHz/64-bit | 64 | 66 | 1 | 533 |

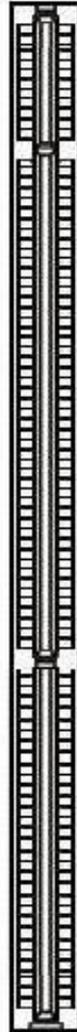


Back of Computer

3.3V PCI
32 Bit



3.3V PCI
64 Bit



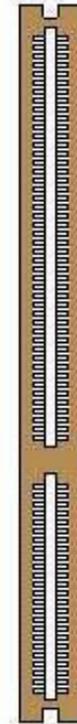
5V PCI
32 Bit

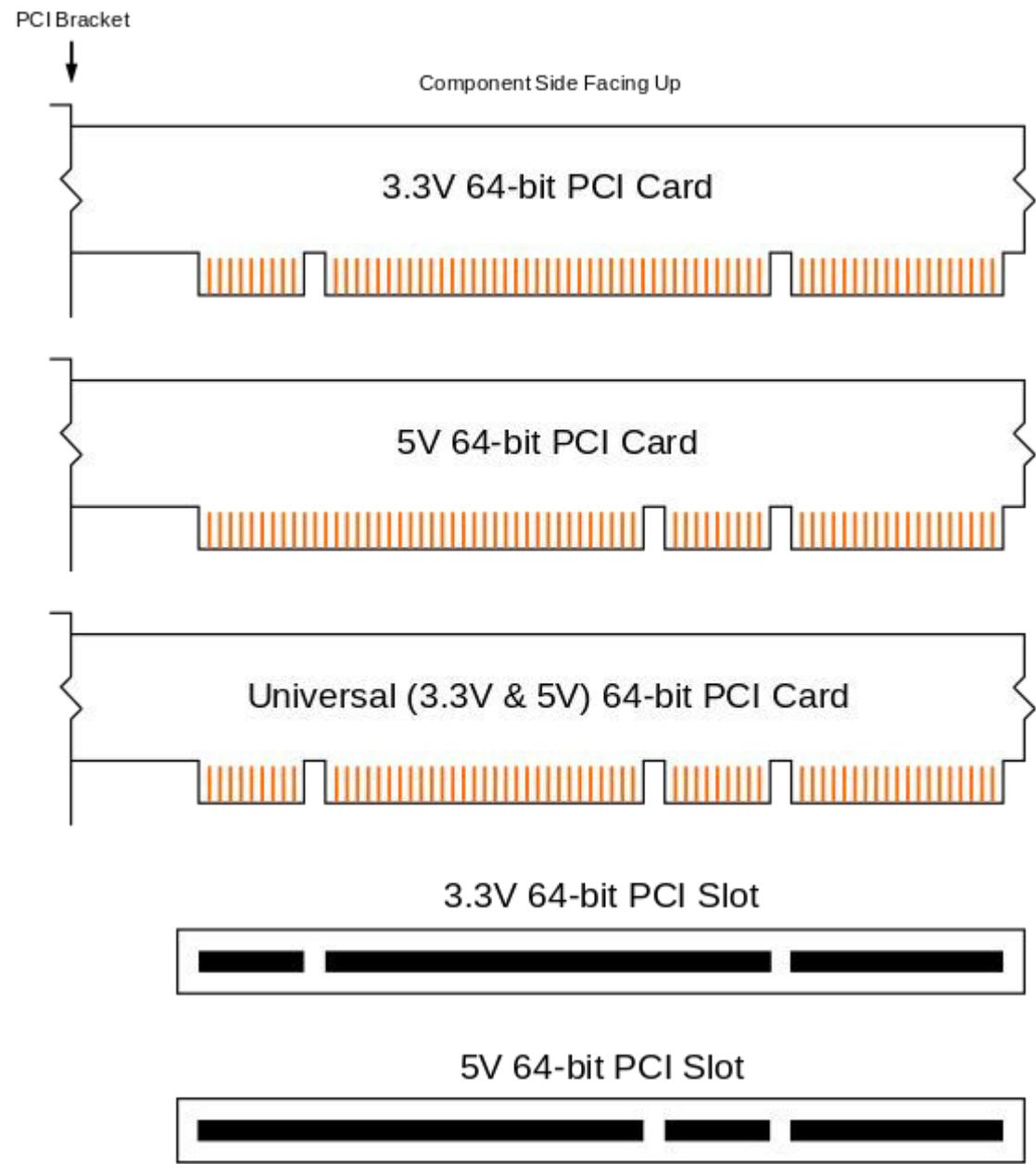
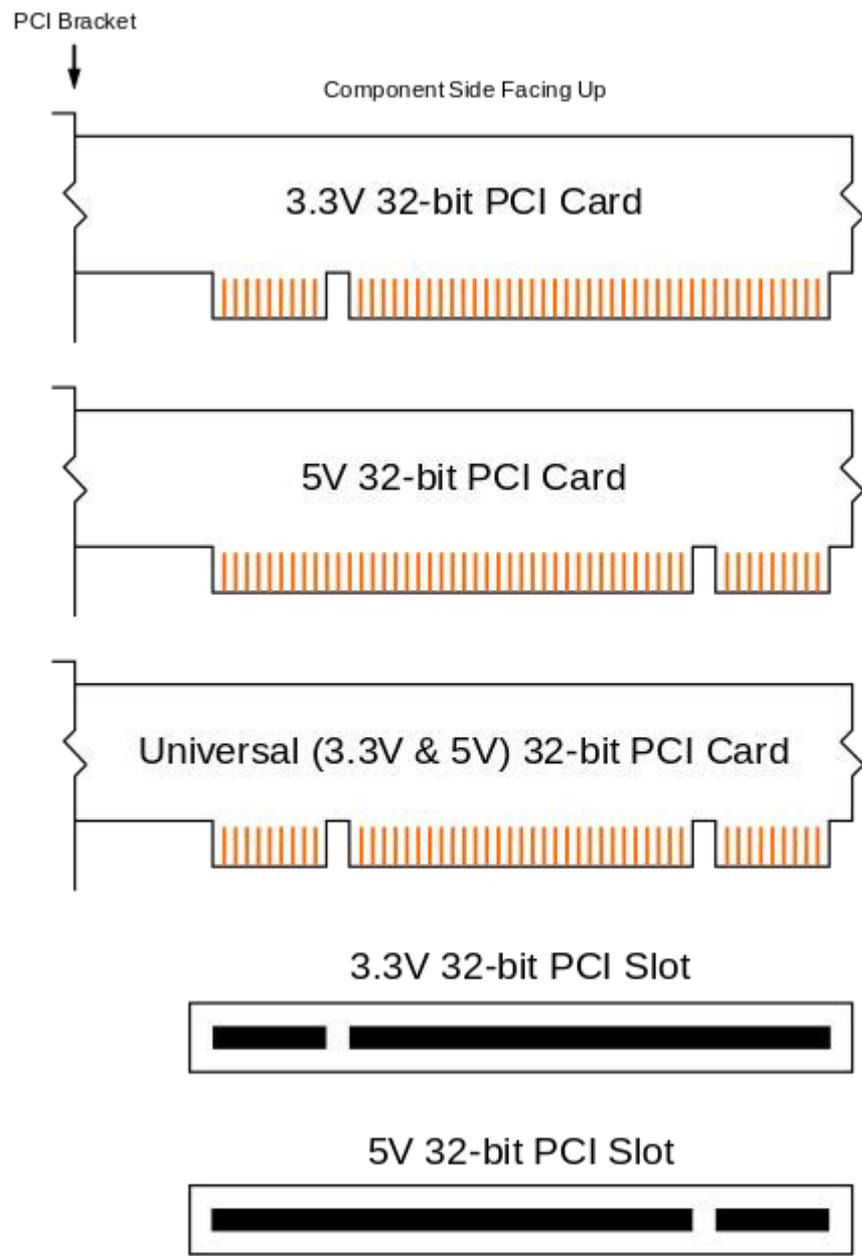


5V PCI
64 Bit



AGP (NOT PCI)





PCI-X (PCI eXtended)

- Created from PCI for higher bandwidth demands in servers and workstations.
- 64-bit
- Visually similar to PCI, but effective frequency ranges from 66MHz to 533 Mhz
- Speed ranges from 533 MBps to 4266 MBps
- Backward compatible with PCI.
- Suffers shared bus topology, like PCI.

| PCI Bus Type | Bus Width (Bits) | Bus Speed (MHz) | Data Cycles per Clock | Bandwidth (MBps) |
|---------------------|-----------------------------|----------------------------|----------------------------------|-----------------------------|
| PCI-X 64 | 64 | 66 | 1 | 533 |
| PCI-X 133 | 64 | 133 | 1 | 1,066 |
| PCI-X 266 | 64 | 133 | 2 | 2,132 |
| PCI-X 533 | 64 | 133 | 4 | 4,266 |

PCI Slot →

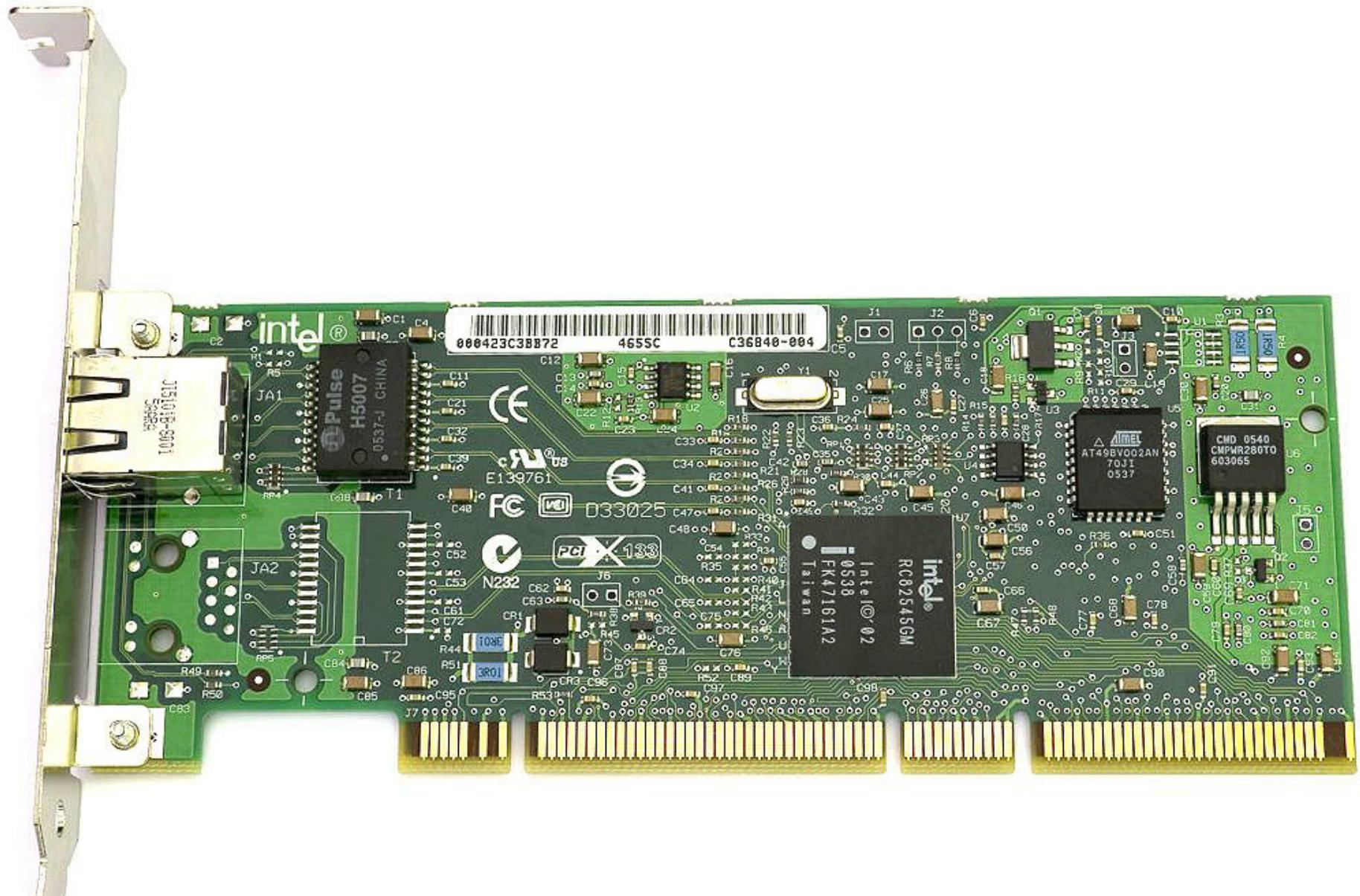


PCI-X Slot →



64-bit PCI-X card partially inserted in 32-bit PCI slot, showing compatibility.

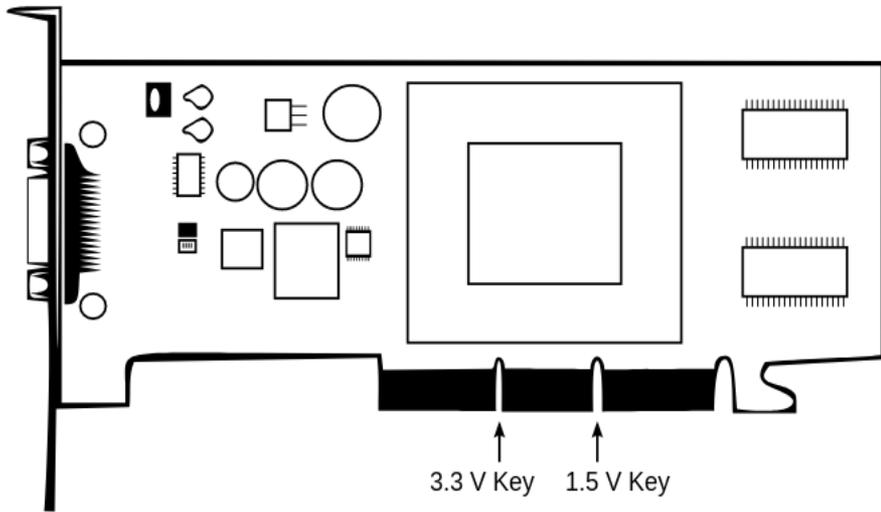
A PCI-X Gigabit Ethernet expansion card with both 3.3V and 5V support notches, similar to PCI



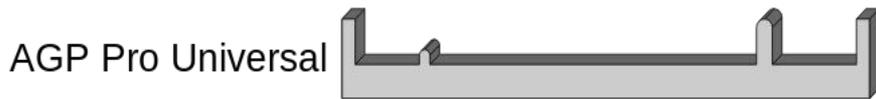
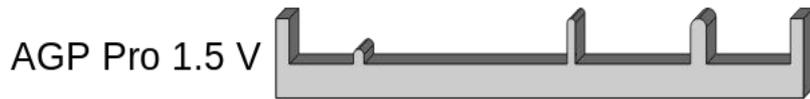
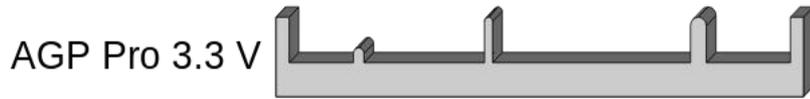
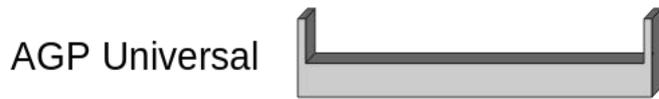
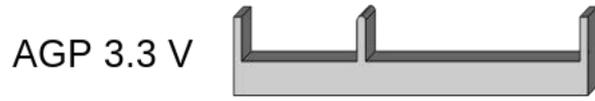
AGP (Accelerated Graphics Port) slot

- By Intel.
- 32-bit channel, 66MHz clock frequency, basic data rate 233MBps
- Dedicated for high performance graphics and video support.
- Based on PCI, but independent of PCI and has many enhancements.
- Direct connection between PC Memory and video circuitry on the card.
- Many PCI can be in a system, but only one AGP.
- Point-to-point high performance connection, no sharing of bus.
- Usually brown in colour, placed next to PCI, but a little bit back from the rear of the motherboard.
- Versions: AGP 1x, 2x, 4x and 8x; 1,2,4 and 8 are data cycles per clock
- 1x and 2x uses 3.3 Volts while 4x and 8x uses 1.5V volts
- 3.3V and 1.5V are having different notches. Universal type has no notches.

| Bus Type | Bus Width (Bits) | Bus Speed (MHz) | DataCycles per Clock | Bandwidth (MBps) |
|-----------------|-------------------------|------------------------|-----------------------------|-------------------------|
| AGP | 32 | 66 | 1 | 266 |
| AGP 2X | 32 | 66 | 2 | 533 |
| AGP 4X | 32 | 66 | 4 | 1,066 |
| AGP 8X | 32 | 66 | 8 | 2,133 |

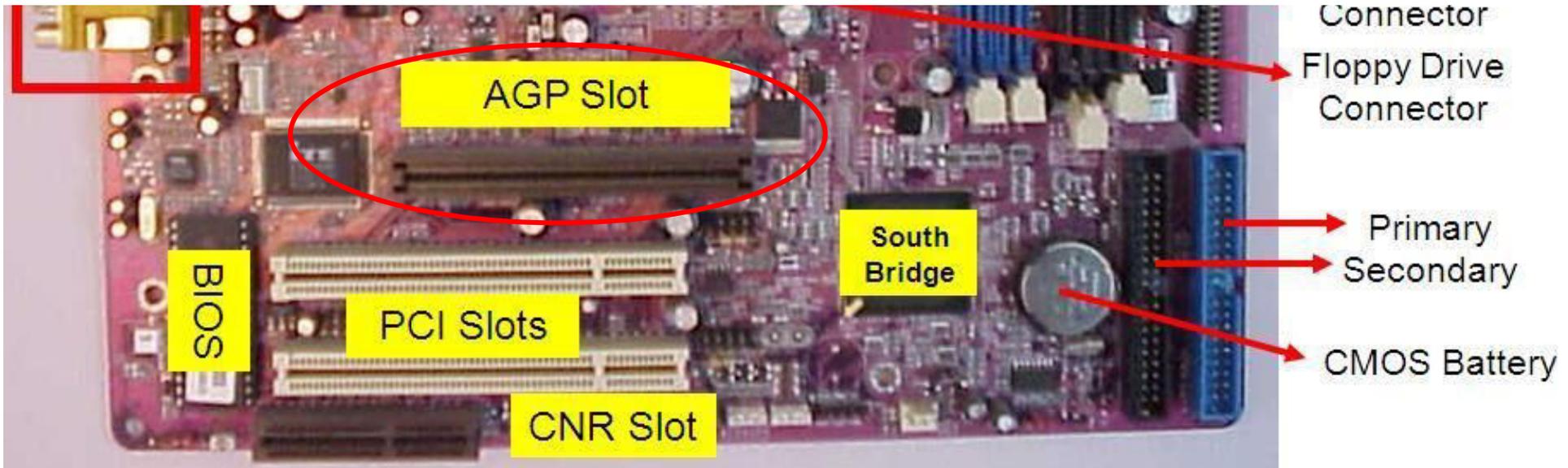


- **AGP Pro** defined a larger slot, with more voltage pins, for high-consumption 3D video cards.
- AGP Pro slot is compatible with the previous versions of the AGP bus.





AGP Pro graphics card



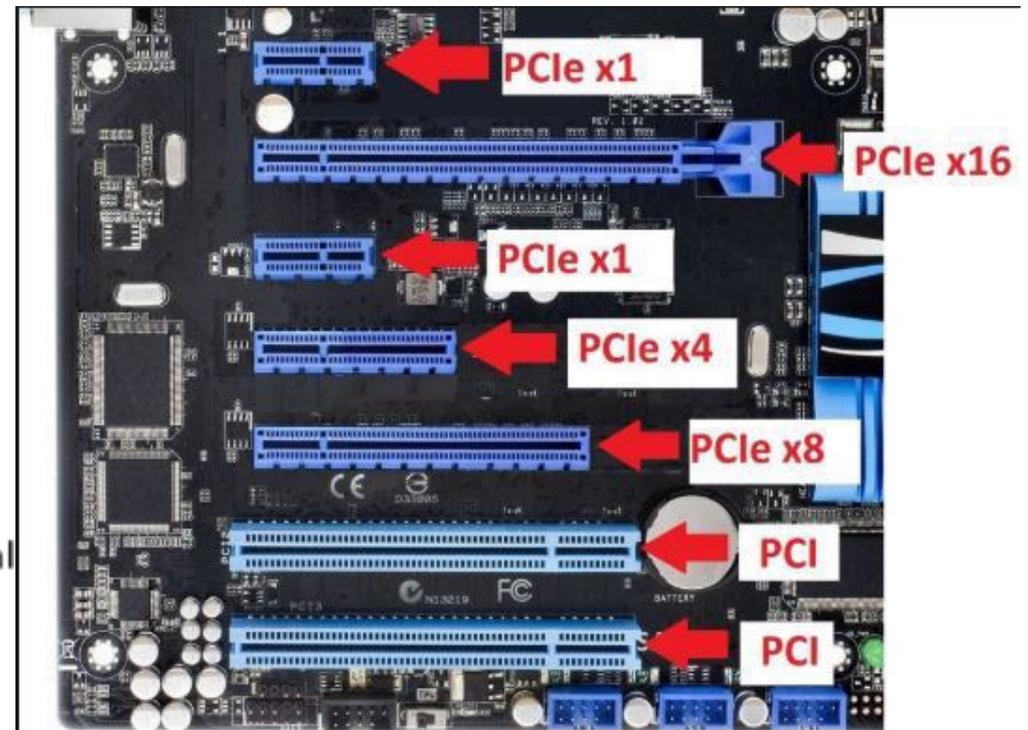
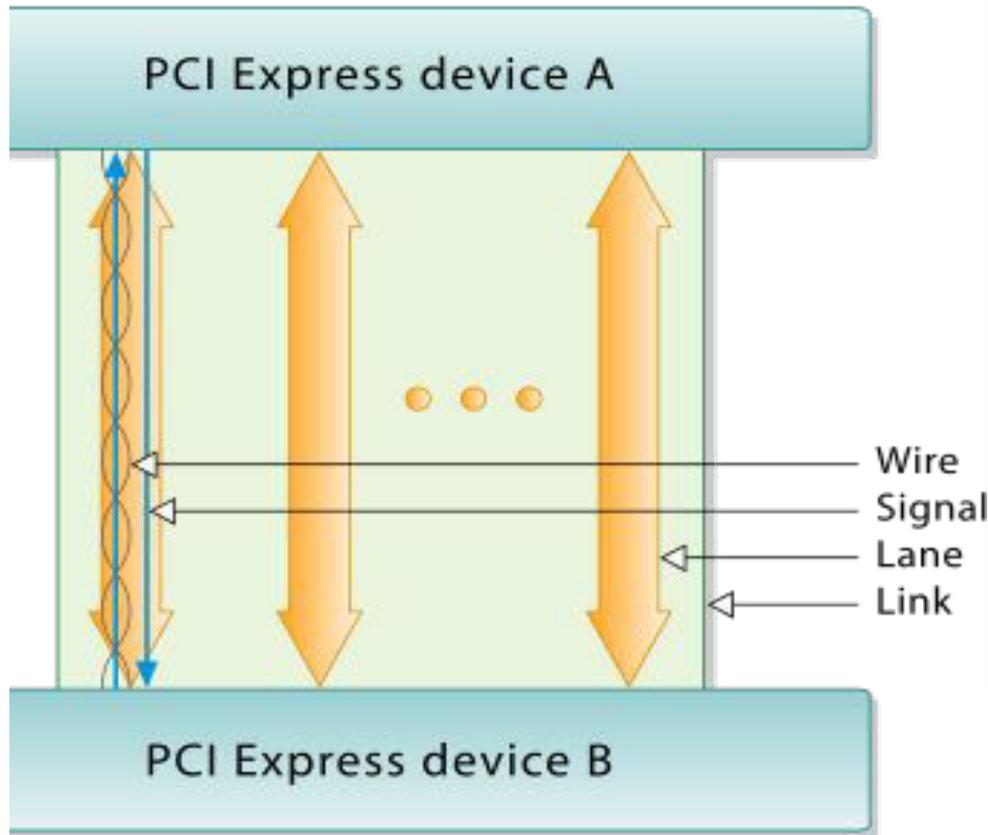
AGP Slot

PCIe (PCI Express) slot:

- Designed by PCI-SIG (Special Interest Group) to replace PCI and AGP
- Faster than AGP and flexible like PCI (different types cards can be made).
- Not compatible to PCI and AGP.
- While PCI, AGP etc are parallel, PCIe is SERIAL
- Transfers bits one-by-one at higher data rates through one or more serial paths.
- PCIe uses a switching component with point-to-point connections to slots, giving each component full use of the corresponding bandwidth and producing a star topology.
- Between any two PCIe devices, there are one or more bidirectional serial paths for transfer of bits in both directions. Each such bidirectional path is called a LANE.
- One or more lanes that the switch interconnects two devices is called LINK.
- Based on the number of links there are seven PCIe types.
 - PCIe x1, x2, x4, x8, x12, x16 and x32; 1, 4 and 16 are most common.
- As the number of links increases, the size of slot also increases.

PCIe (PCI Express) slot...

- Every PCIe slot has a 22-pin portion in common towards the rear of the motherboard for voltage and ground leads.



PCIe slots - Size comparison

- PCIe has undergone several large and smaller revisions, improving on performance and other features.
- PCIe 1.x (2003), 2.x (2007), 3.x (2010), 4.x (2017), 5.0 (2019), 6.x (planned for 2021)

| PCI Bus Type | Bus Width (Bits) | Bus Speed (MHz) | Data Cycles per Clock | Bandwidth (Mbps) |
|---------------------|-------------------------|------------------------|------------------------------|-------------------------|
| PCI Express 1.x | 1 | 2,500 | 0.8 | 250 |
| PCI Express 1.x | 16 | 2,500 | 0.8 | 4,000 |
| PCI Express 1.x | 32 | 2,500 | 0.8 | 8,000 |
| PCI Express 2.x | 1 | 5,000 | 0.8 | 500 |
| PCI Express 2.x | 16 | 5,000 | 0.8 | 8,000 |
| PCI Express 2.x | 32 | 5,000 | 0.8 | 16,000 |
| PCI Express 3.x | 1 | 8,000 | ~0.98 | 1,000 |
| PCI Express 3.x | 16 | 8,000 | ~0.98 | 16,000 |
| PCI Express 3.x | 32 | 8,000 | ~0.98 | 32,000 |

PCI Express 1.x and 2.x use 8b/10b encoding, which transfers 8 bits of data for every 10 bits sent.

PCI Express 3.x uses 128b/130b encoding, which transfers 128 bits of data for every 130 bits sent.

AMR and CNR

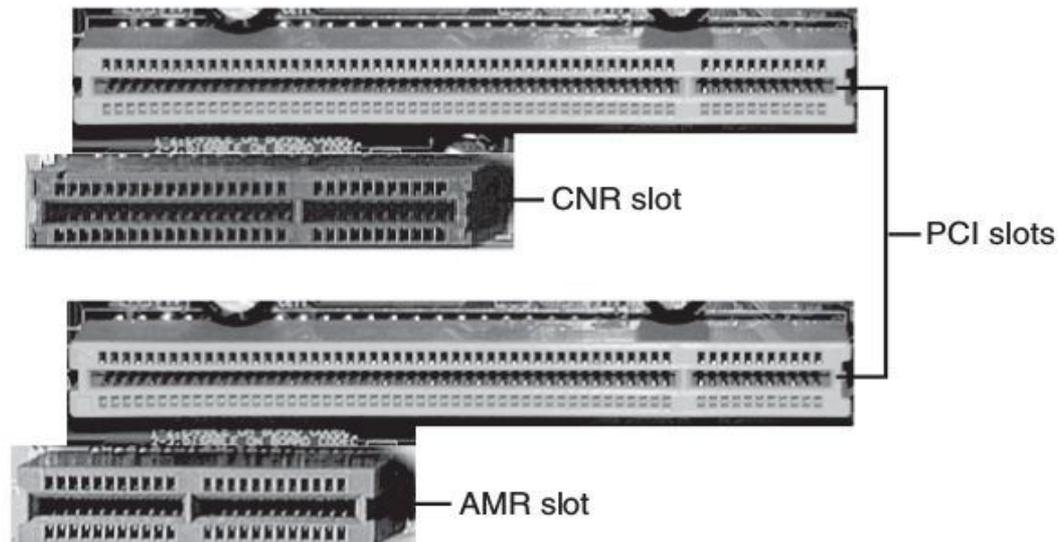
- AMR: Audio Modem Riser
- CNR: Communication and Networking Riser
- Old slots for modems, sound cards and network cards.

AMR:

- By Intel
- Provides analog functionality such as modem, sound, etc
- Three drawbacks of AMR are that it eliminates one PCI slot, it is not plug and play, and it does not allow hardware acceleration.

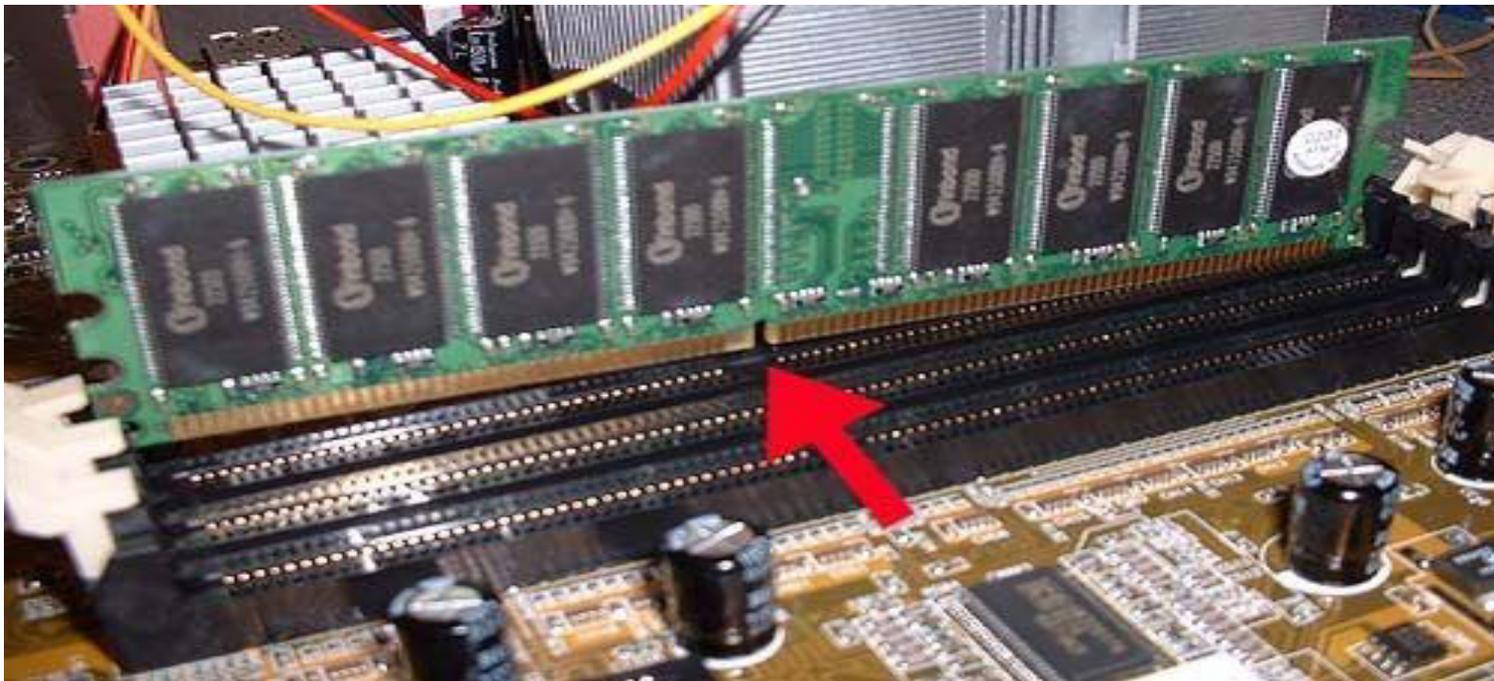
CNR:

- By Intel to replace AMR
- Plug and play compatible and hardware acceleration possible.
- Larger than AMR
- Shared with a PCI slot. That PCI can be used unless the CNR slot is in use.



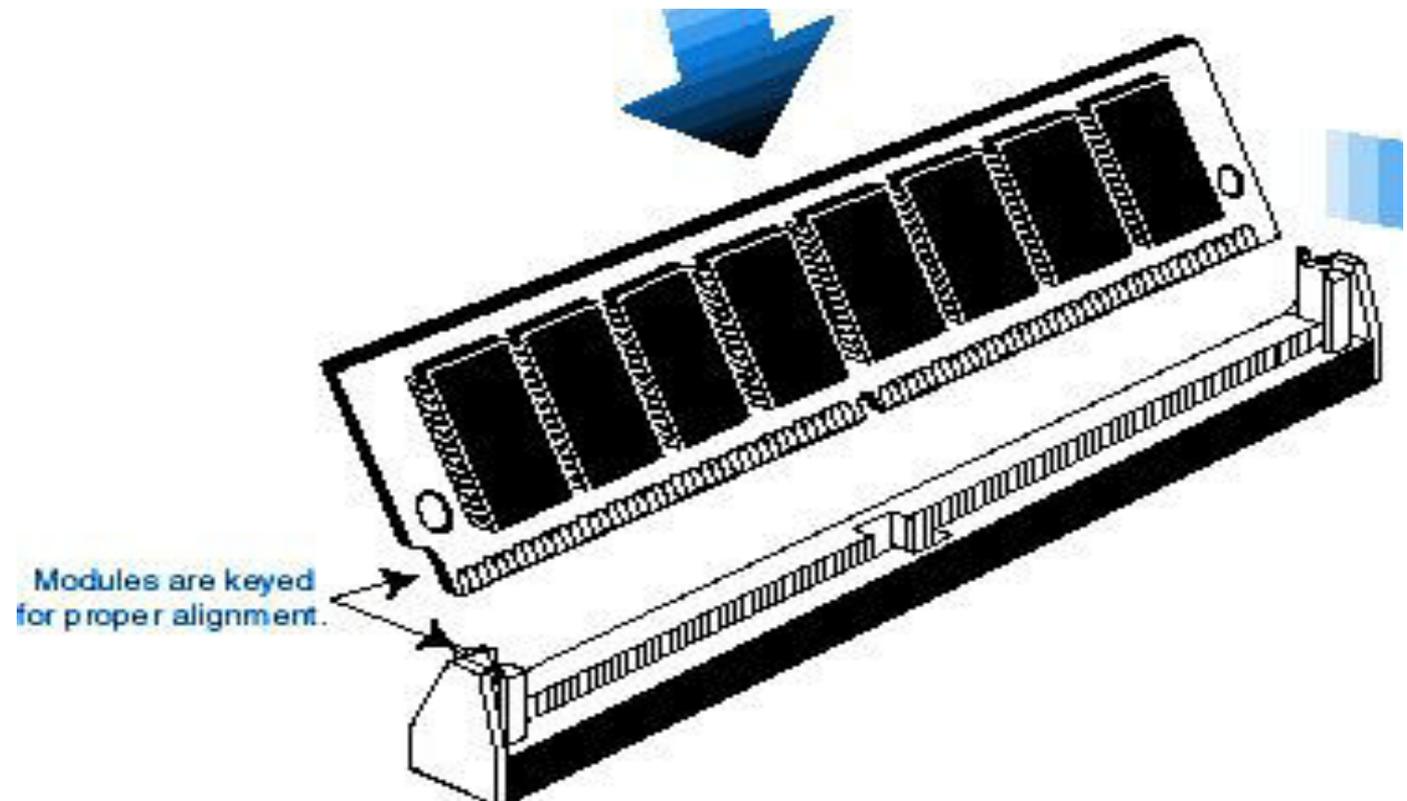
Memory Slots

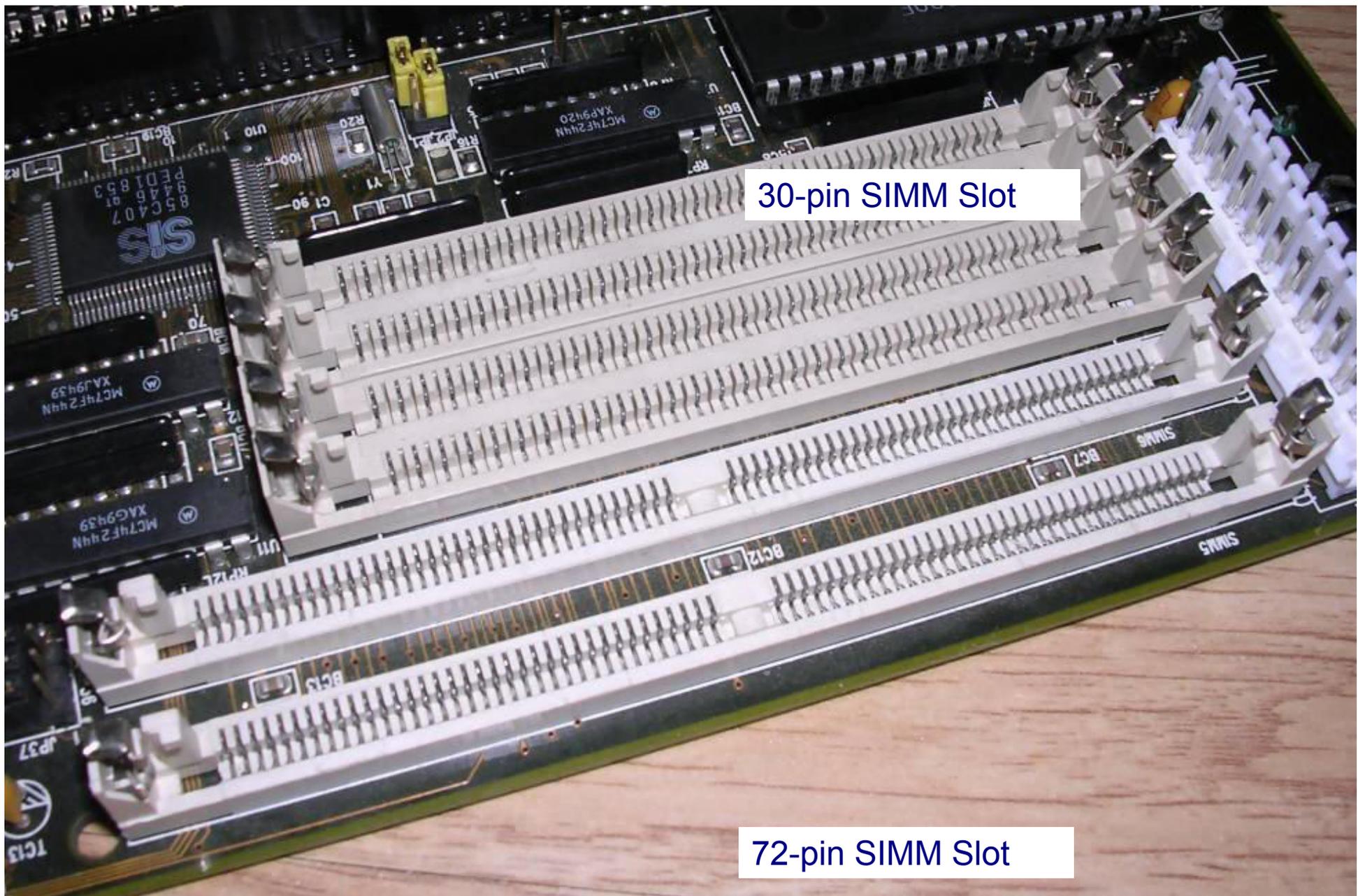
- To insert the main memory modules.
- Number of slots varies in motherboards.
- Type differs with different types of memory modules.
- Slots have locks on their ends to keep the modules securely.
- Major evolutions are SIMM and DIMM.



SIMM Slots (Single Inline Memory Module)

- Older types, now obsolete
- Similar contacts on both sides, hence the name.
- Mainly 30-pin and 72-pin models, some had 64-pins.
- 30-pin slots were shorter and they provided 8 bits of data..
- 72-pin slots provided 32 bits of data.
- RAM had to be installed at an angle and pushed upright into place.
- Notch on both ends of the memory module that was clipped by arms on opposite ends of the slot.



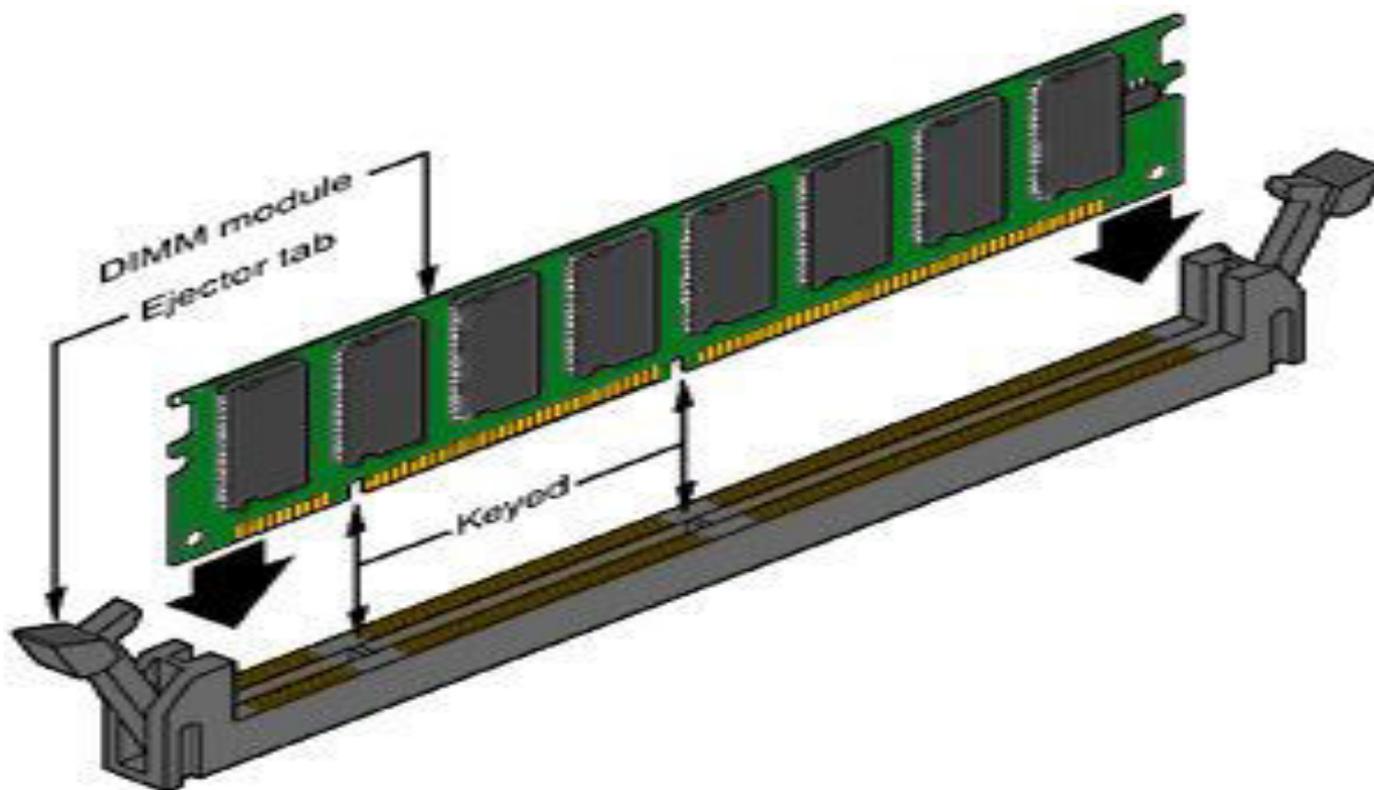


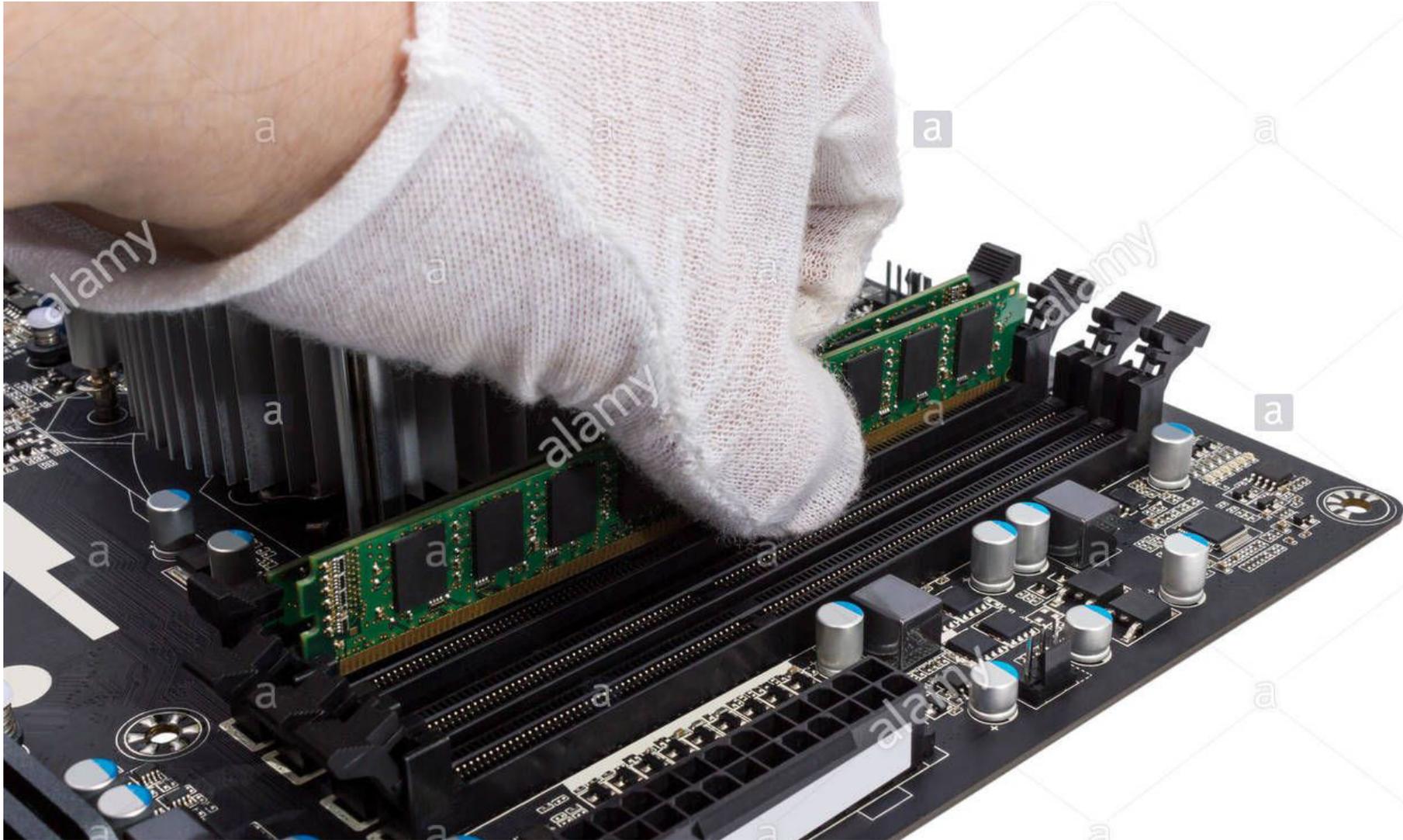
30-pin SIMM Slot

72-pin SIMM Slot

DIMM Slots (Dual Inline Memory Module)

- Modern type slots
- For DIMMs there are separate contacts on both sides of the slot.
- More number of pins (168, 184, 240, etc)
- Clips at both ends.
- Modules can be pressed straight into the slot and clipped into place.
- Since there are different types of memory chips (SDR, DDR, DDR2, DDR3, etc) on DIMMs, there are different types of DIMM slots with different keyings and clips.

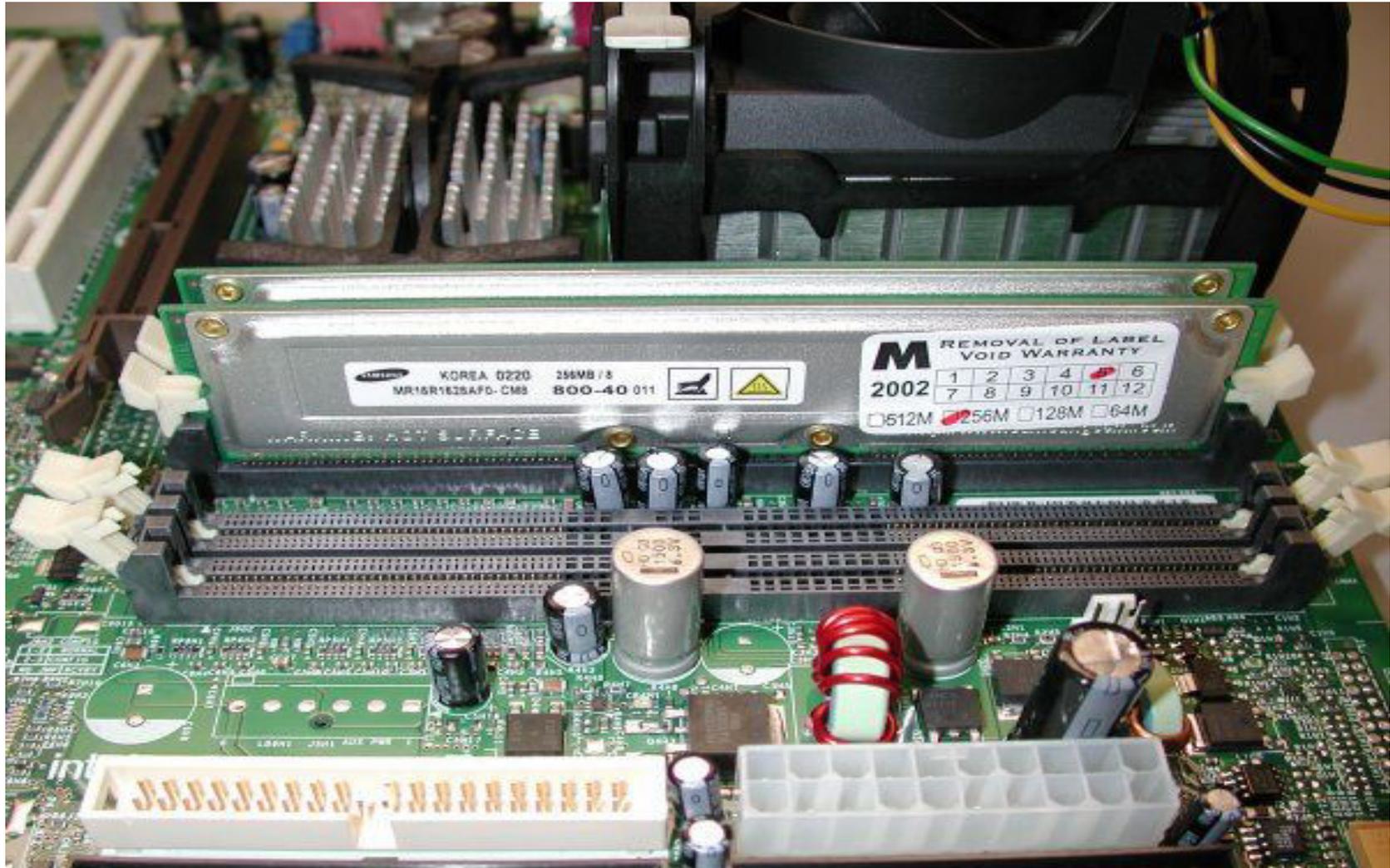






RIMM Slots (Rambus Inline Memory Module)

- For the proprietary RIMM
- Slots seems in pair; the modules have to be inserted in pair.
- Empty slots need to be filled with C-modules for *continuity* of memory bus.



SODIMM Slots (Small Outline Dual Inline Memory Module) and Micro DIMM

- For laptops, notebooks, routers, high-end printers, etc
- SODIMM is only half the size of DIMM.
- Micro DIMM is again smaller.



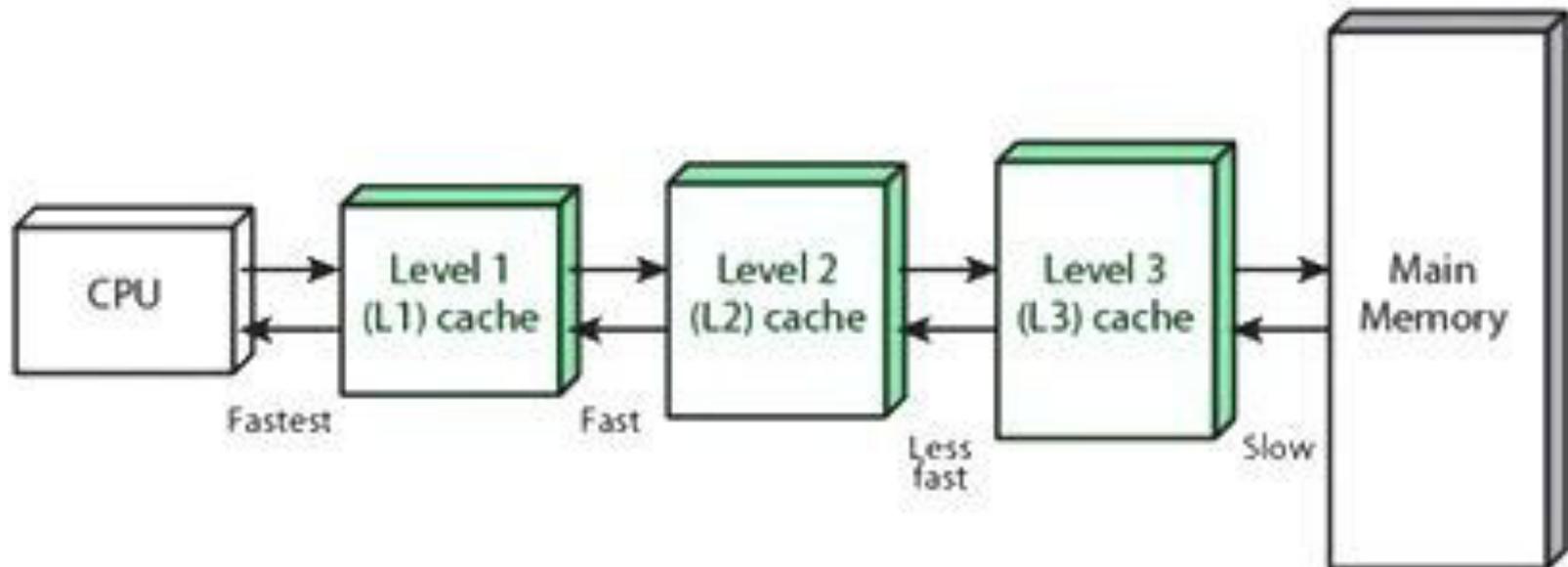
SODIMM and its slot



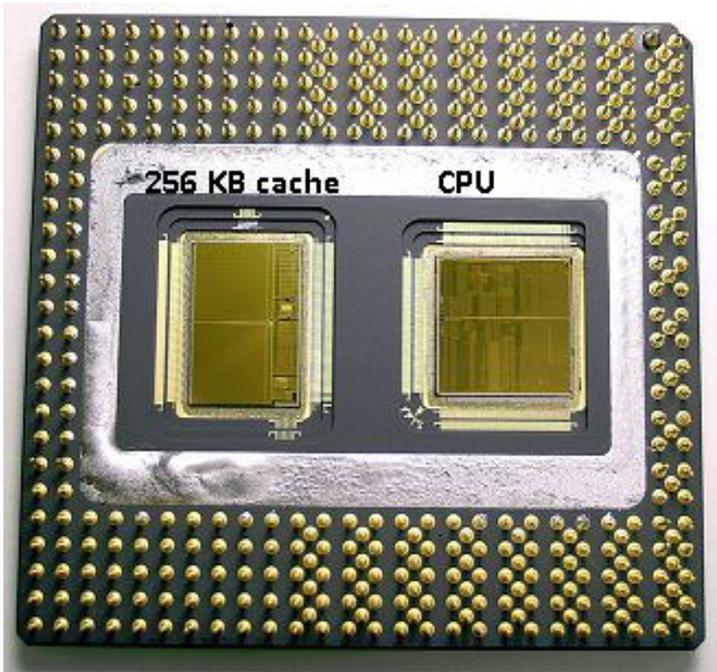
Micro DIMM and its slot

Cache memory

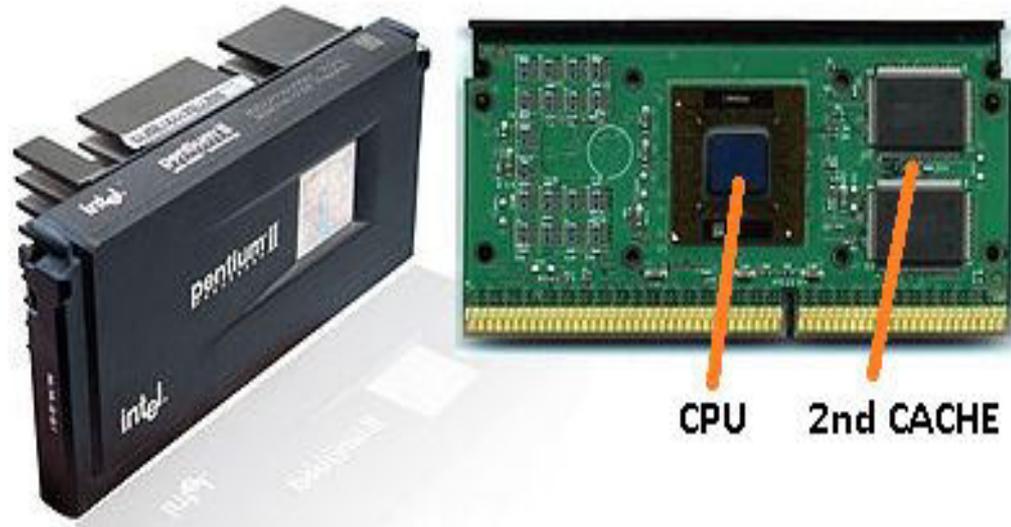
- Cache: Small buffers to increase the speed/performance of the processor.
- They are small pieces of Static RAM placed internally and/or externally to the processor.
- SRAMs are very much faster than Dynamic RAM (DRAM makes the main memory).
- SRAMs are much expensive and less dense. Hence small in amount.
- Normally, 3 levels: L1, L2 and L3.
- Now-a-days L1 and L2 may be separate for different cores, but L3 may be shared.
- L1 cache may be divided into Instruction cache and Data cache (L1i and L1d).



- 80486 had 8kB unified cache on the processor itself. L2 cache was separately placed on the motherboard.
- 80586 or Pentium 1 used a split cache (i and d) with 8kB each.
- Pentium 2 and 3 used a PCB with the CPU and L2 cache placed separately on it. Thus the slot type processors were developed.



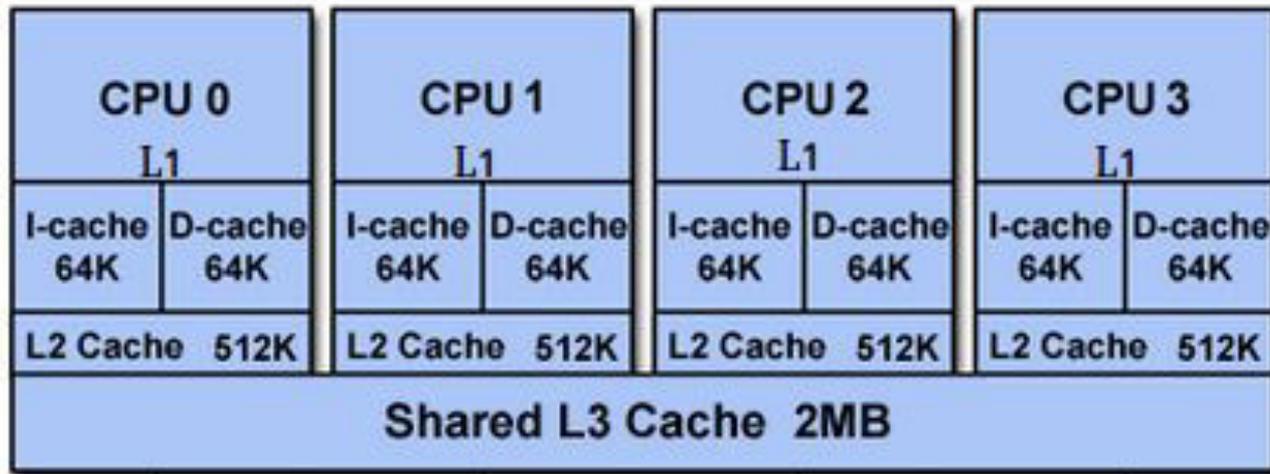
Pentium Pro ("80686") - L1 cache



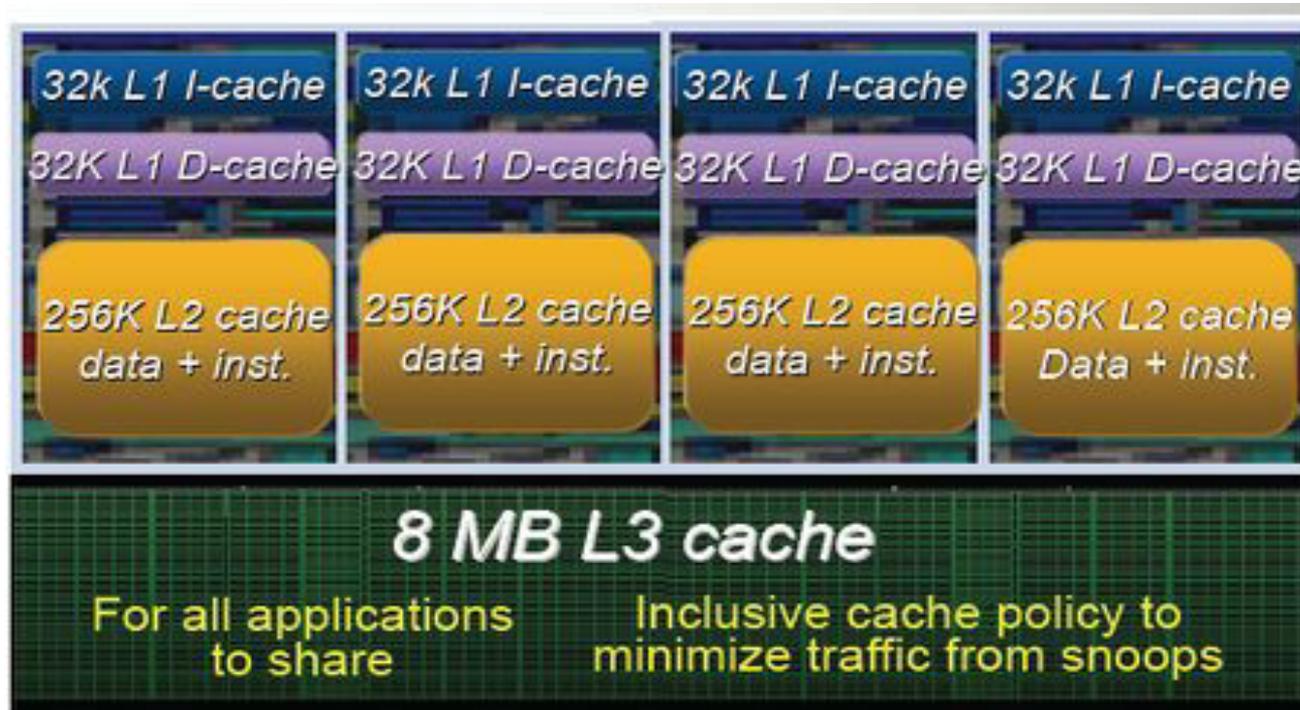
Pentium 2,3 and 4 – Slot type processors were developed to engage L2 cache.



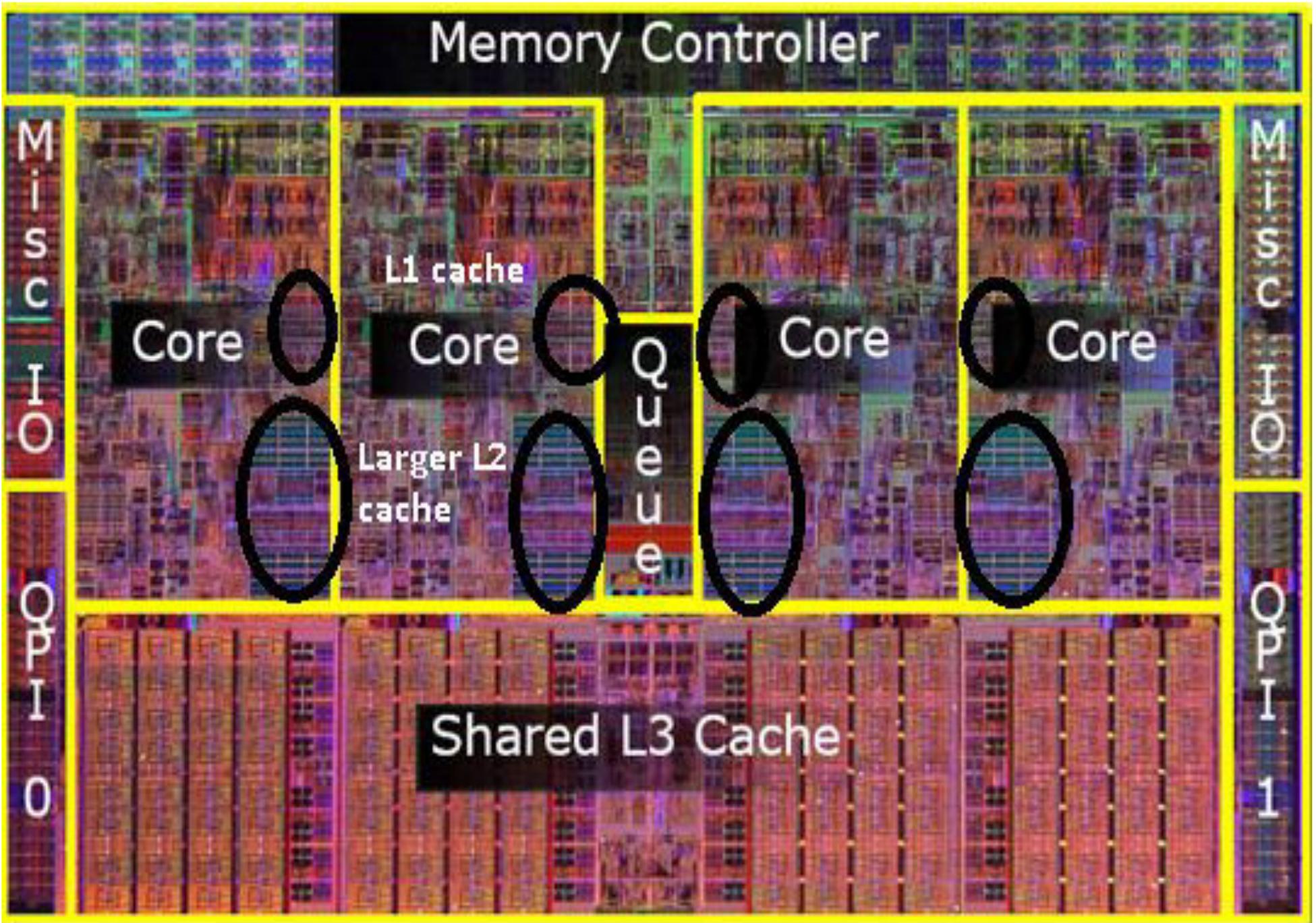
Separate L2 Cache - Intel 80486



Quad core
AMD
Opteron



Intel Core i7

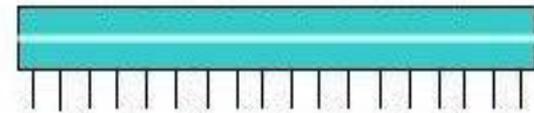


An Intel Quad Core Processor core

CPU and Processor Socket

- Processor: Brain of the computer
- Produce very much heat, hence provided with heat sink and CPU fan
- Socket type or Slot type
- Common processor packagings are PGA (Pin Grid Array), LGA (Land Grid Array) and BGA (Ball Grid Array)
- Package names are based on whether the contact points of the processor are pins, flat lands/pads or small solder balls.
- For each of the processor packaging and each model, the sockets also vary.

(Pin Grid Array ;PGA)



(Land Grid Array ;LGA)



(Ball Grid Array ;BGA)

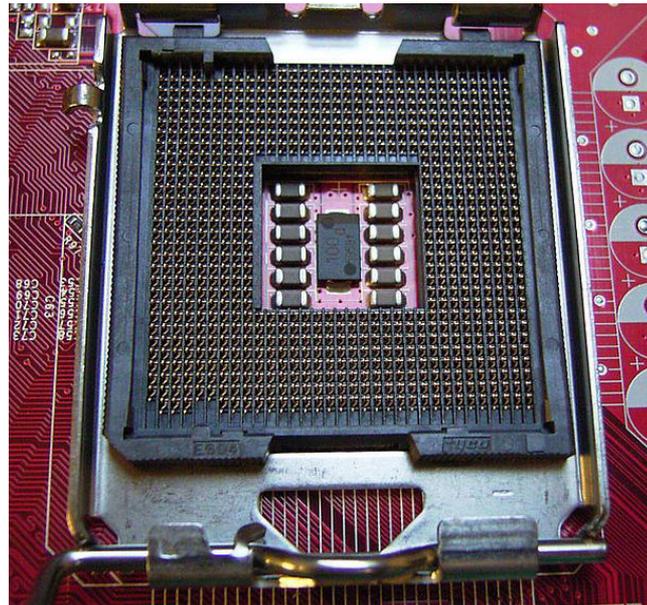


CPU and Processor Socket...

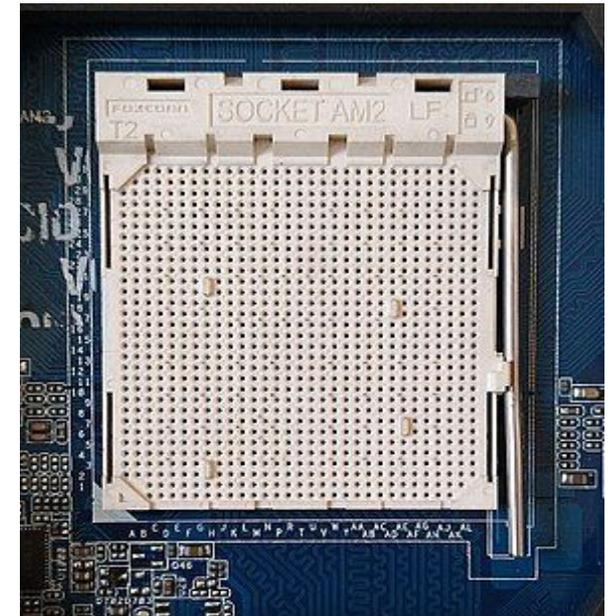
- The socket of PGA processors are normally called **ZIF (Zero Insertion Force) Socket**. PGA sockets have holes to hold the pins. The ZIF socket design was introduced by Intel.
- LGA sockets have pins to make contacts with the pads. They use an L-shaped lever to hold the processor above the socket.



Socket 1 - for Intel 80486 PGA processors, with pin count 169



LGA 775 socket - Also called Socket T - for Intel Pentium 4 processors, with land count 775



Socket AM2 - for AMD Athlon 64 PGA processors, with 940 contacts

CPU and Processor Socket...

- To introduce L2 cache Intel and AMD moved to slot based processors (Intel Pentium II, III).
- Slot 1 was the first one for Intel and Slot A was that of AMD.
- Slot type processors were mostly for servers/workstations with low profile motherboards
- Later L2 cache moved to processor die, processors became socket based.



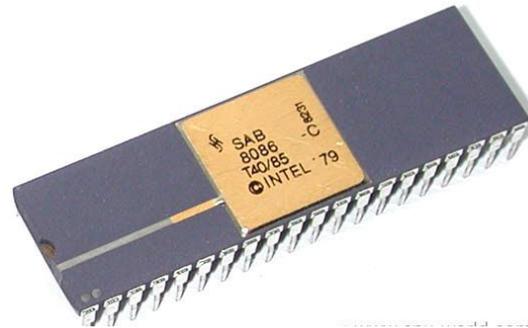
Slot 1 - for Intel Pentium II slot type processor



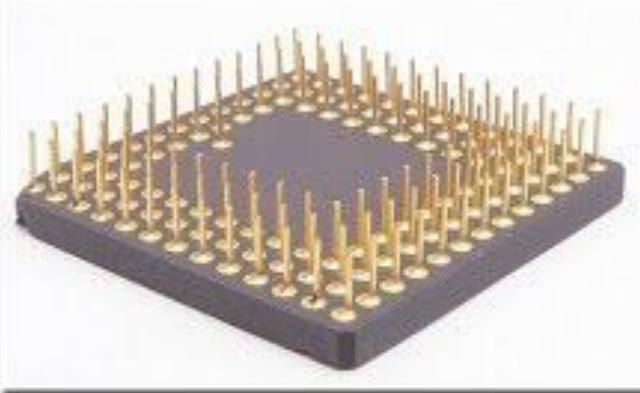
Intel Pentium II processor inside cartridge

Processor Packaging

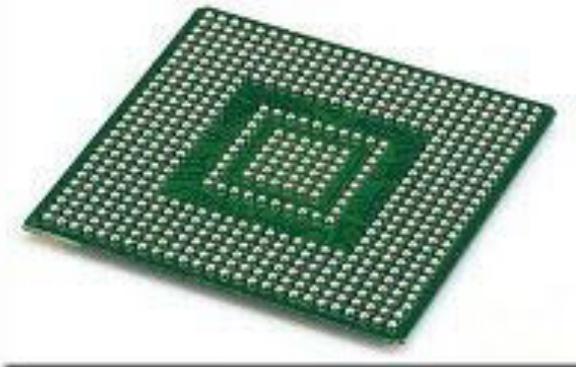
- First chips were DIP (Dual Inline Package).
- Later PGA (Pin Grid Array) came with Zero Insertion Force (ZIF) sockets.
- Ball Grid Array (BGA) and Land Grid Array (LGA) are other popular packages.



Intel 8086 DIP



PGA
(PIN Grid Array)



BGA
(Ball Grid Array)



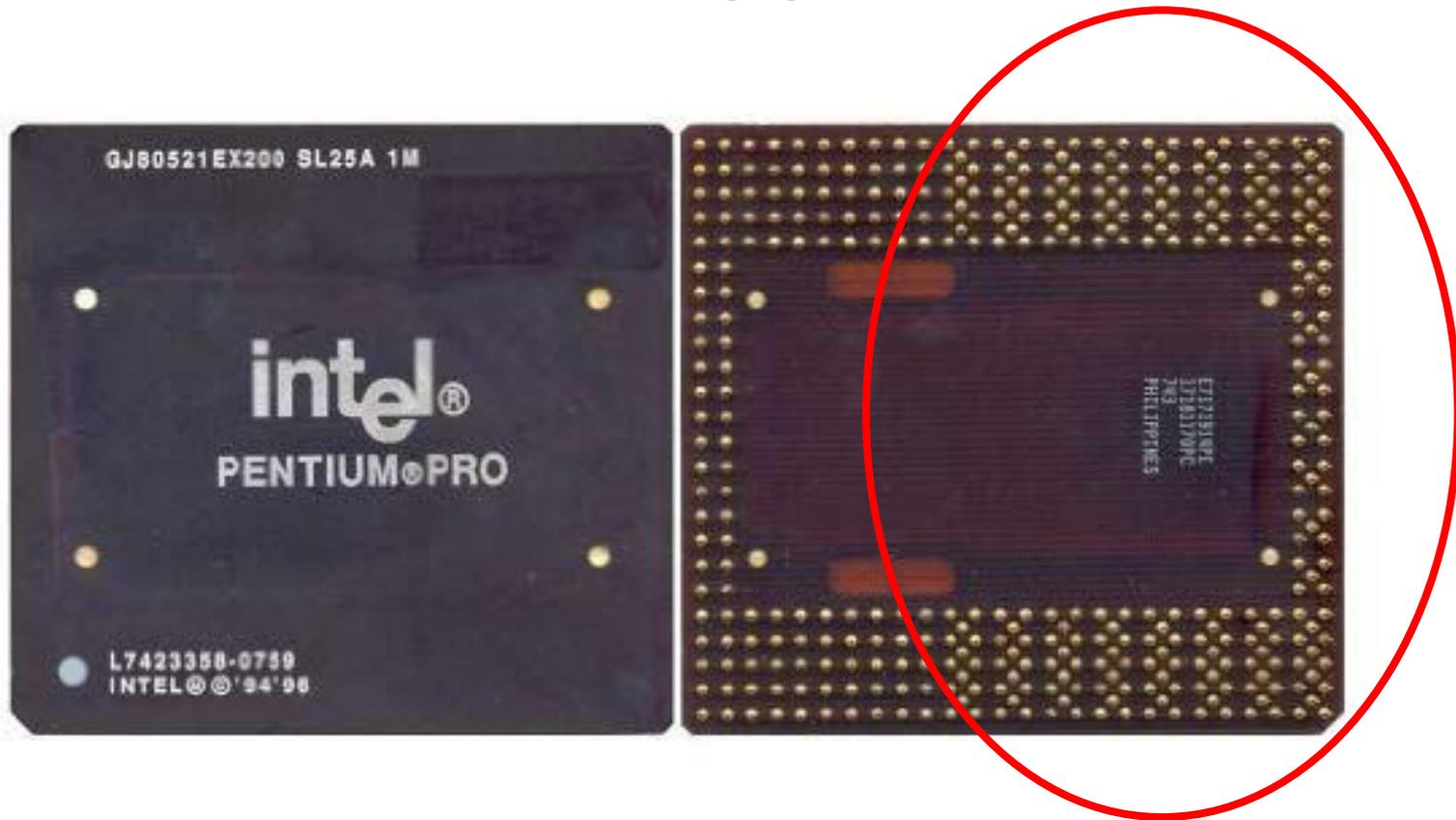
LGA
(LAND Grid Array)



LGA processor

Processor Packaging..

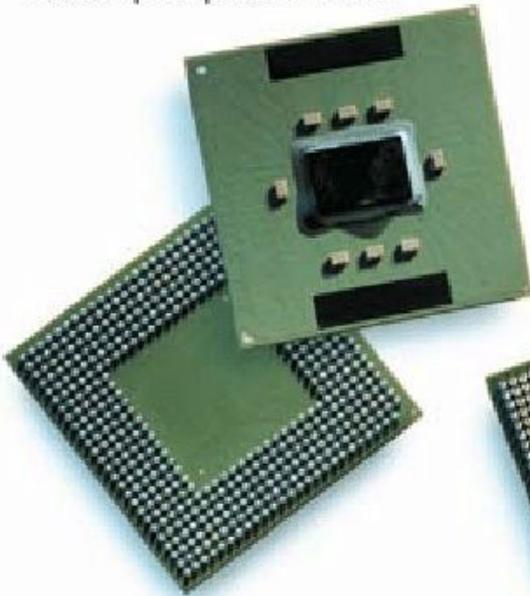
- **Staggered PGA (SPGA)** - pins are staggered on the underside of the chip rather than in standard rows and columns; hence pins became closer, more pins can be included.
- Intel Pentium Pro used a partial SPGA packaging.



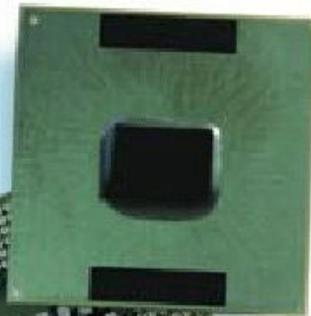
Processor Packaging..

- **Flip Chip PGA (FC-PGA) and FC-BGA:** Processor Die over the substrate.
- The Die faces downwards on the top of the substrate with the back of the die exposed. This allows the die to have a more direct contact with the heatsink.
- Primarily heat problems since the heatsink act like a pedestal.
- Then heat spreader was introduced to spread the heat evenly (FC-PGA-2)

Micro Flip Chip BGA—Front



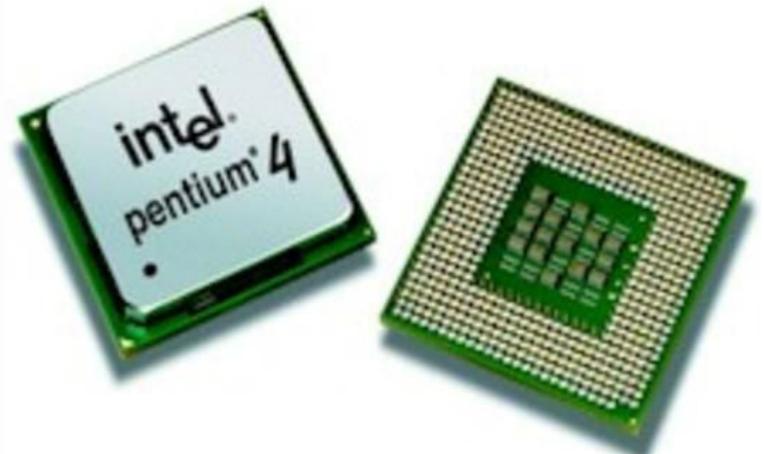
Micro Flip Chip PGA—Front



Micro Flip Chip BGA—Back



Micro Flip Chip PGA—Back



FC-PGA 2, with heat spreader

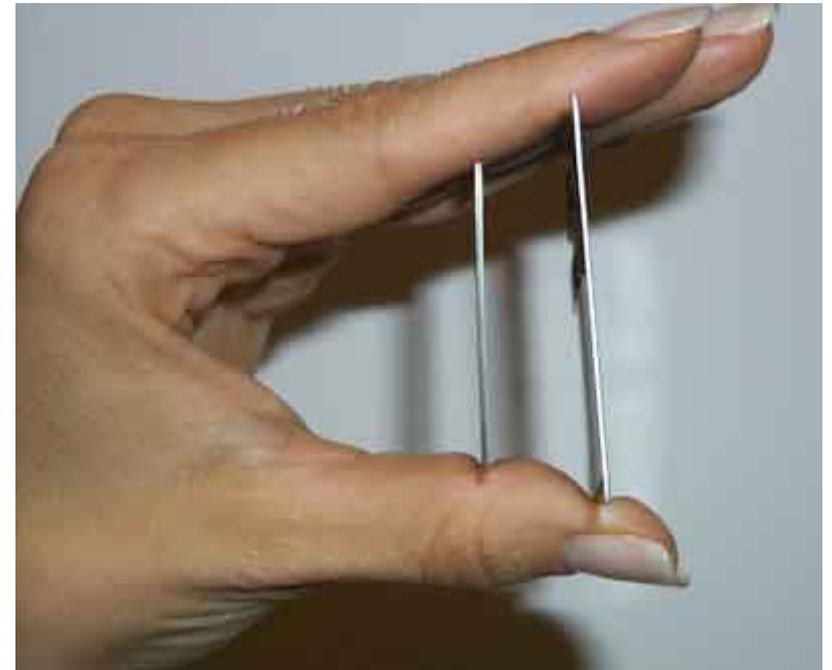
Processor Packaging..

- **Bumpless build-up layer (BBUL)** packaging embeds the die completely in the package.
- The package layers are built up around and on top of the die, fully encapsulating it within the package.
- This embeds the chip die and allows for a full flat surface for attaching the heatsink.



BBUL

Ordinary

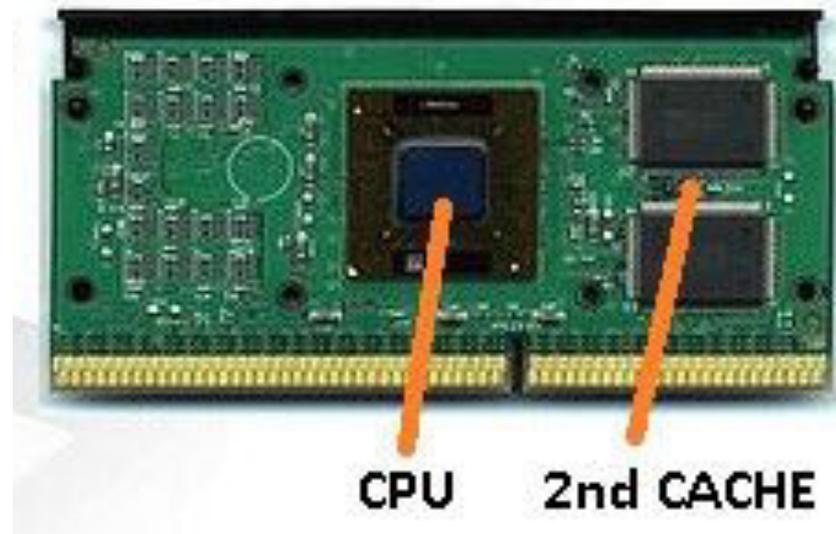


BBUL chip and a credit card

Processor Packaging..

Single edge contact cartridge (SECC) or single edge processor package (SEPP)

- For slot based processors.
- Introduced for integrating L2 cache near the processor.

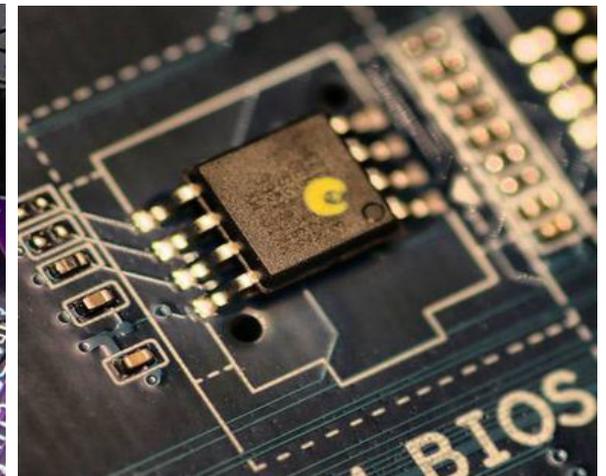


Characteristics of Modern Processors

- Hyperthreading
 - Simultaneous multithreading (SMT). Intel named it Hyper Threading Technology.
 - Single processor seems like two to the OS.
- Multicore
 - Completely *separate processor dies (silicon wafer)* in the same package.
- Throttling
 - Automatically reduces speed if load is less, hence reduced energy and less heat.
- Speed
 - Safe running speed is specified, in MHz or GHz
 - Actual speed will be multiples of FSB.
 - Effective speed depends on FSB, chipset, bus width, etc.
- 32- and 64-bit processors
- Virtualization support
 - Called VT (Virtualization Technology) by Intel and AMD-V by AMD
- Integrated GPU

BIOS and CMOS

- Basic Input Output System.
- Firmware, programs stored on ROM chip on the motherboard.
- Manufacturers: AMI (American Megatrends Inc.), Phoenix/Award, etc.
- BIOS has four main functions;
 - POST – Power On Self Test
 - Setup information
 - Bootstrap loader
 - Loads drivers that act as a basic interface between the OS and hardware
- CMOS (Complementary Metal Oxide Semiconductor) NVRAM and CMOS Battery
 - Stores setup information
 - Keeps real time clock
 - Memory might be integrated into the BIOS chip or the Southbridge



Identifying Purposes and Characteristics of Memory

- Workspace for the processor.
- Its features are given below
- Parity Checking and Memory Banks:
 - Parity - Single bit error-checking scheme that offers no error correction.
 - For an 8 bit data a ninth bit is added as parity.
 - Even parity in a byte tells that the number of 1's in that byte should be even. If yes, a zero bit is added at the ninth place as the parity bit, if not (ie, the number of 1's is odd), a 1 is added at the ninth place to make the parity even.
 - Parity bit is not the part of data.
 - A memory bank represents a collection of memory chips that is needed to feed the processor.
 - One 32 bit memory module forms a bank for a 32 bit processor.
 - Two 32 bit modules or a single 64 bit module form a bank for a 64 bit processor.
- Error Checking and Correction: (In some memory structure)
 - Check-bits are generated and stored with the data and recalculated at the destination
 - ECC can *detect* single- and double-bit errors and *correct* single-bit errors.

Identifying Purposes and Characteristics of Memory...

- Single- and Double-Sided Memory:
 - Some memory modules have chips on one side while others have chips on both sides.
 - Each side is treated as separate memory modules.
 - Memory controller switches between the two sides for data transfer.
 - More memory in less number of slots.
- Single-, Dual-, and Triple-Channel Memory
 - Most memory transfers 64 bits at a time (ie, single-channel).
 - Powerful processors can operate on more bits that a memory bank can provide at a time.
 - Dual-channel memory controller coordinates two memory banks to work as a synchronized set, effectively doubling the data width (ie, 128 bits instead of 64 bits).
 - Triple-channel memory the coordinates of three memory modules at a time through interleaving which provides more performance than dual-channel.
 - The motherboard documentation specifies which channel it supports.
 - The channels are normally identified by the colour of the memory slots.

Types of Memory

- Primary memory consists of RAM and ROM
- RAM has two variants: Dynamic RAM (DRAM) and Static RAM (SRAM)
- DRAM:
 - Used for main memory.
 - Highly dense and less costly to manufacture.
 - Each cell made of a transistor and a capacitor to store a bit (1 or 0).
 - The capacitor discharges slowly, hence periodic refreshing is needed (*refresh signal*)
 - Some cells drain faster; causing soft errors (blue screen, file corruption, system off,..)
- SRAM:
 - Used in cache memory.
 - Less dense and very costly.
 - Each cell is made of six transistors.
 - No refreshing is needed.
 - Very much faster than DRAM.

Types of DRAM

- Asynchronous DRAM (ADRAM) and Synchronous DRAM (SDRAM)
- Asynchronous DRAM has many advancements
 - FPM DRAM
 - EDO DRAM
 - BEDO DRAM
- Synchronous DRAM
 - SDR SDRAM
 - DDR SDRAM
 - DDR2 SDRAM
 - DDR3 SDRAM
 - DRDRAM

Fast Page Mode (FPM) DRAM

- Faster than conventional ADRAM
- Send the row address only once for consecutive data transfers.
- Improved access time.
- Does not need any compatibility support with conventional ADRAM
- Used in 386, 486, and Pentium systems from 1987 through 1995
- Either 30-pin or 72-pin SIMM form with 5V operating voltage.



Extended Data Out (EDO) DRAM

- Most common type of *asynchronous* DRAM.
- Modification of FPM memory.
- Sometimes called *hyper page mode DRAM*
- A memory access starts before the previous one finishes; hence faster than FPM.
- Need support from chipset.
- 72-pin SIMM form with 5V operating voltage.



EDO DRAM (SIMM)

Burst EDO (BEDO) DRAM

- Modification of EDO memory
- When a memory address is given it access the next three locations too (*burst* mode).
- Technology owned by Micron
- Soon replaced by SDRAM



Synchronous DRAM (SDRAM)

- Synchronous with system clock.
- Work with the speed of the FSB.
- 64 bits (8 byte) wide bus.
- Comes in 168 pin DIMMs with **two** keyings.
- Intel specified the standards: PC66, PC100, and PC133 (clock: 66MHz, 100MHz and 133MHz) and run at 3.3V.
- Data transfer occurs at the leading edges of the clock.
- Only one data cycle per clock. Hence the name **Single Data Rate SDRAM (SDR SDRAM)**.

SDR

1 transfer
per clock cycle



Clock Freq = 100MHz
Data Freq = 100MHz

SDRAM



Two notches

Synchronous DRAM (SDRAM)...

SDRAM Module (168-Pin DIMM) Speeds and Transfer Rates

| Module Type | Chip Type | Clock Speed | Cycles per Clock | Bus Speed | Bus Width | Transfer Rate |
|--------------------|------------------|--------------------|-------------------------|------------------|------------------|----------------------|
| PC66 | 15ns 10ns | 66MHz | 1 | 66MTps | 8 bytes | 533MBps |
| PC100 | 8ns | 100MHz | 1 | 100MTps | 8 bytes | 800MBps |
| PC133 | 7.5ns 7ns | 133MHz | 1 | 133MTps | 8 bytes | 1,066MBps |

MHz = Million cycles per second

MTps = Million transfers per second

MBps = Million bytes per second

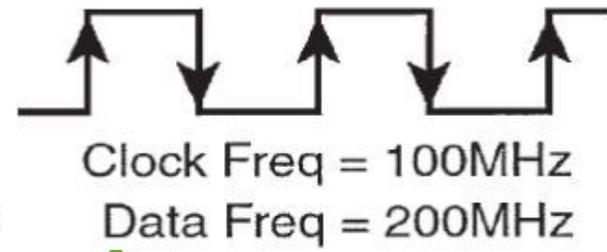
ns = Nanoseconds (billionths of a second)

Double Data Rate SDRAM (DDR SDRAM)

- Data transfer occurs at the rising and falling edges of the clock.
- Two data cycle per clock. Hence the name **Double Data Rate SDRAM**.
- Twice the transfer rate at the **same** FSB clock frequency.
 - Eg: 100MHz clock becomes 200MHz effectively.
 - This chip is called a *DDR200* chip. And such module is called PC1600.
- Uses a DIMM module design with 184 pins and works with 2.5V.
- Most chipsets that support DDR also support dual-channel operation.
- DDR and conventional SDRAM chips use the *thin small outline package (TSOP)*.



DDR
2 transfers
per clock cycle



Double Data Rate SDRAM (DDR SDRAM)

Table JEDEC Standard DDR Module (184-Pin DIMM) Speeds and Transfer Rates

| Module Type | Chip Type | Base Clock Speed | Cycle Time | Cycles per Clock | Bus Speed | Bus Width | Module Transfer Rate | Dual-Channel Transfer Rate |
|-------------|-----------|------------------|------------|------------------|-----------|-----------|----------------------|----------------------------|
| PC1600 | DDR200 | 100MHz | 10.0ns | 2 | 200MTps | 8 bytes | 1,600MBps | 3,200MBps |
| PC2100 | DDR266 | 133MHz | 7.5ns | 2 | 266MTps | 8 bytes | 2,133MBps | 4,266MBps |
| PC2700 | DDR333 | 166MHz | 6.0ns | 2 | 333MTps | 8 bytes | 2,667MBps | 5,333MBps |
| PC3200 | DDR400 | 200MHz | 5.0ns | 2 | 400MTps | 8 bytes | 3,200MBps | 6,400MBps |

DDR = Double data rate

MHz = Million cycles per second

MTps = Million transfers per second

MBps = Million bytes per second

ns = Nanoseconds (billionths of a second)



DDR2 SDRAM

- Use differential pairs of signal wires to allow faster signaling without noise and interference problems. Hence twice as faster than DDR SDRAM.
- More pins (240) and less voltage (1.8V)
- Less power consumption and heat generation.
- More pins; hence use Fine-pitch Ball Grid Array (FBGA) packaging.
- FBGA has fine pitch solder ball connections at the base of the chip.
- For 100MHz clock, the effective clock rate will be 200MHz and has dual data rate; ie 400 MTps.
- Thus the chip is designated as DDR2-400. The module is designated as PC2-3200.



DDR2 SDRAM

DDR2 Module (240-Pin DIMM) Speeds and Transfer Rates

| Module Type | Chip Type | Base Clock Speed | Cycle Time | Cycles per Clock | Bus Speed | Bus Width | Module Transfer Rate | Dual-Channel Transfer Rate |
|--------------------|------------------|-------------------------|-------------------|-------------------------|------------------|------------------|-----------------------------|-----------------------------------|
| PC2-3200 | DDR2-400 | 200MHz | 5.00ns | 2 | 400MTps | 8 bytes | 3,200MBps | 6,400MBps |
| PC2-4200 | DDR2-533 | 266MHz | 3.75ns | 2 | 533MTps | 8 bytes | 4,266MBps | 8,533MBps |
| PC2-5300 | DDR2-667 | 333MHz | 3.00ns | 2 | 667MTps | 8 bytes | 5,333MBps | 10,667MBps |
| PC2-6400 | DDR2-800 | 400MHz | 2.50ns | 2 | 800MTps | 8 bytes | 6,400MBps | 12,800MBps |
| PC2-8500 | DDR2-1066 | 533MHz | 1.88ns | 2 | 1,066MTps | 8 bytes | 8,533MBps | 17,066MBps |

DDR = Double data rate

MHz = Million cycles per second

MTps = Million transfers per second

MBps = Million bytes per second

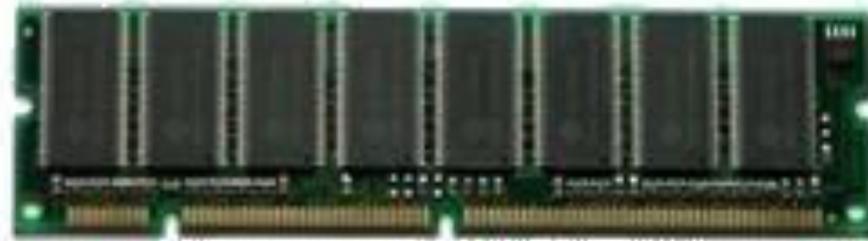
ns = Nanoseconds (billionths of a second)

DDR3 SDRAM

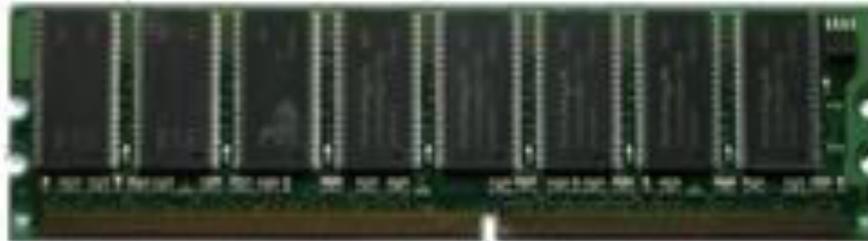
- Use advanced signaling techniques, including self-driver calibration and data synchronization, along with an optional onboard thermal sensor.
- Hence twice as fast as the DDR2 memory.
- 240-pins, 1.5V.
- For a clock rate of 400 MHz, the chip is called DDR3-800. And the module is called PC3-6400.

DDR3 Module (240-Pin DIMM) Speeds and Transfer Rates

| Module Type | Chip Type | Base Clock Speed | Cycle Time | Cycles per Clock | Bus Speed | Bus Width | Module Transfer Rate | Dual-Channel Transfer Rate | Tri-Channel Transfer Rate |
|--------------------|------------------|-------------------------|-------------------|-------------------------|------------------|------------------|-----------------------------|-----------------------------------|----------------------------------|
| PC3-6400 | DDR3-800 | 400MHz | 2.50ns | 2 | 800MTps | 8 bytes | 6,400MBps | 12,800MBps | 19,200MBps |
| PC3-8500 | DDR3-1066 | 533MHz | 1.88ns | 2 | 1,066MTps | 8 bytes | 8,533MBps | 17,066MBps | 25,600MBps |
| PC3-10600 | DDR3-1333 | 667MHz | 1.50ns | 2 | 1,333MTps | 8 bytes | 10,667MBps | 21,333MBps | 32,000MBps |
| PC3-12800 | DDR3-1600 | 800MHz | 1.25ns | 2 | 1,600MTps | 8 bytes | 12,800MBps | 25,600MBps | 38,400MBps |
| PC3-14900 | DDR3-1866 | 933MHz | 1.07ns | 2 | 1,866MTps | 8 bytes | 14,933MBps | 29,866MBps | 44,800MBps |
| PC3-17000 | DDR3-2133 | 1066MHz | 0.94ns | 2 | 2,133MTps | 8 bytes | 17,066MBps | 34,133MBps | 51,200MBps |



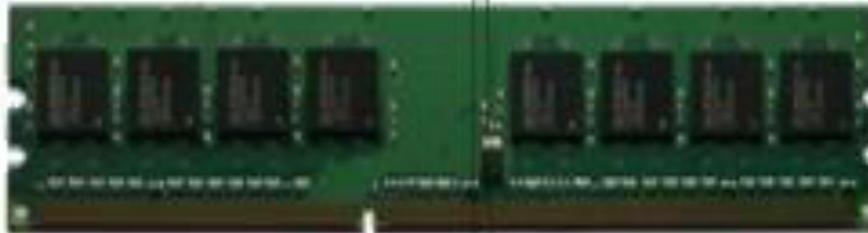
**SDRAM
168pin**



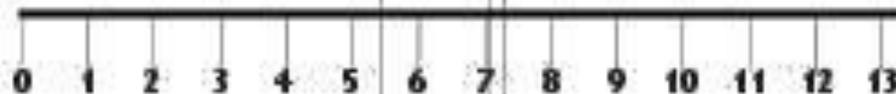
**DDR
184pin**



**DDR2
240pin**



**DDR3
240pin**



cm

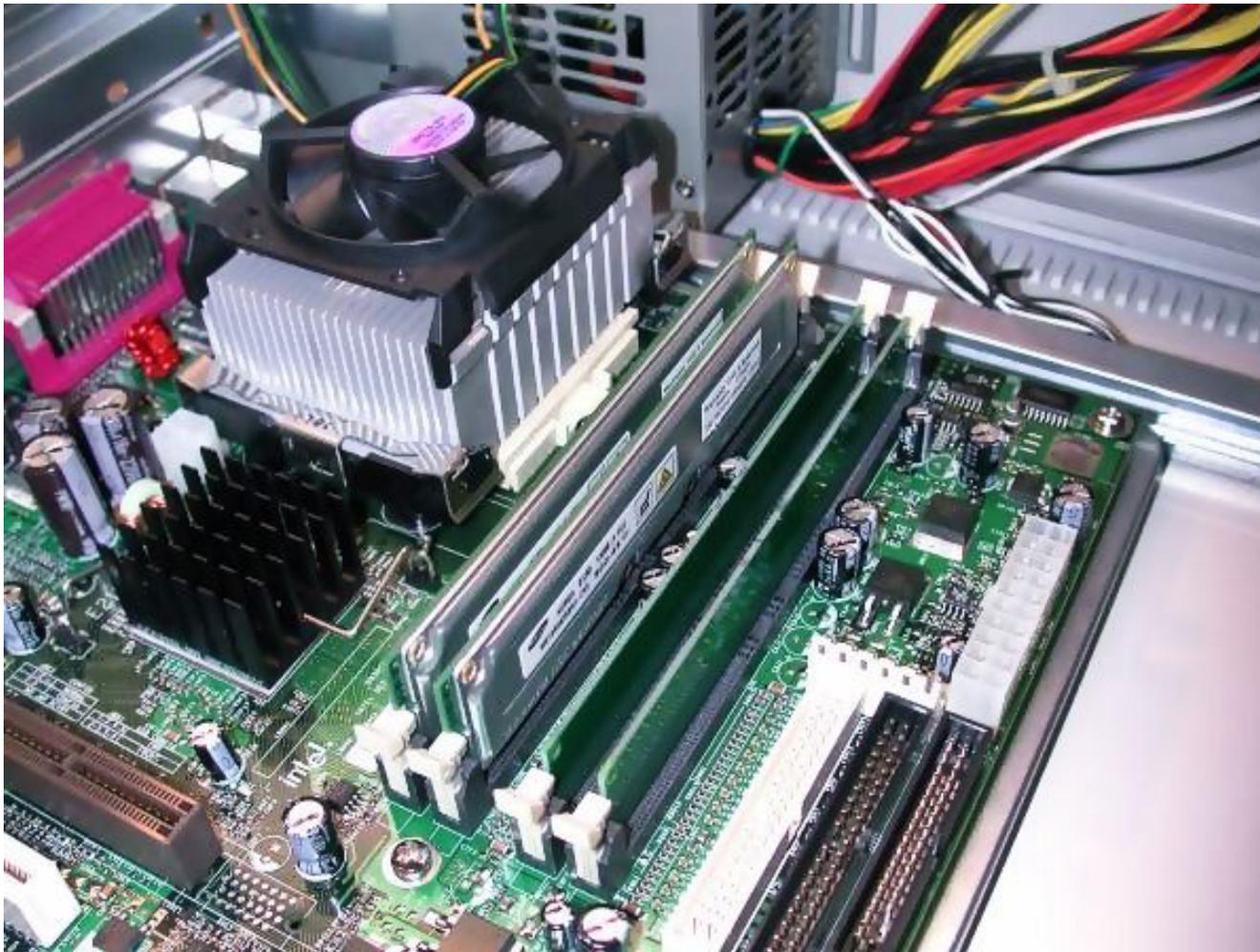
Direct Rambus DRAM (DRDRAM)

- Also called Rambus DRAM (RDRAM)
- Proprietary by a company called Rambus.
- Mostly used by Intel in servers with Pentium III and 4.
- While other DRAMs are 64 bit wide, RDRAM is only 16 bit wide.
- The 16 bit path is split into eight paths in the module and each chip in the module access each path separately.
- That means, 16 bit path is internally divided into 128 bit path.
- Works on 800MHz clock, hence speed is 2Bytes X 800MHz = 1600MHz
- With dual channel it gives 3200MBps (used in Intel Pentium 4).
- Due to high frequency, it produces heat and hence provided with heat sinks.
- Used 2.5V and had 184 pins.
- Any remaining open memory slots must be filled with continuity RIMMs (CRIMMs.)
These modules provide no extra memory, and only served to propagate the signal to termination resistors on the motherboard instead of providing a dead end where signals would reflect.

Direct Rambus DRAM (DRDRAM)



A Rambus continuity RIMM (CRIMM), also known as terminator or dummy.



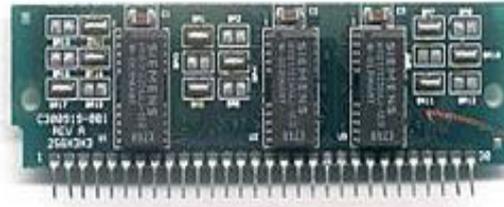
A Samsung RDRAM Installed with Pentium 4

Memory Packaging

- Memory can be both 8 bit and 9 bit (parity) configurations.
- From SDR there may be a small EEPROM chip on the module called SPD (serial presence detect) containing the module info.
- Registered DIMM (buffered DIMM) acts as an interface between the RAM and the chipset.
- Unbuffered DIMMs are mostly common.



DIP



SIPP



SIMM 30 pin



SIMM 72 pin



DIMM (168-pin)



DDR DIMM (184-pin).

Power Supply Unit (PSU)

>> It is a non-linear system (feedback controlled system)

>> operates on 120V-60Hz AC or 240V-50Hz AC and output DC voltages of various magnitudes such as +3.3V, +5V, +12V.

>> Since PSU operates by switching the internal voltage, it is called a Switched Mode Power Supply (SMPS).

>> Colour codes and voltages of wires of ATX standard SMPS.

Yellow: +12V (mostly for motors)

Red: +5V (for logic)

Orange: +3.3V

Black: Ground

Purple: 5V SB (standby voltage)

Green: PS_ON (Active Low. It can be shorted to ground to start PSU)

Grey: PWR_OK (power_good. status signal generated by PSU to indicate voltages are OK)

White: -5V (used by ISA; absent on newer ATX PSUs)

Blue: -12V (uses very small current of range mA, for LAN)

PS_ON (Power Supply ON)

>> Green colour, +5V, Active Low

>> Can turn the power supply (and thus the system) on or off via software/OS (during shut down or restart). It is sometimes known as the **soft-power feature**.

PG (Power Good or Power OK) signal

>> Grey colour, +5V, Active High

>> When SMPS is powered on, it checks whether its outputs are correct. If yes it makes the grey wire high. This signal is called the PG Signal.

>> The motherboard works only if the PG is high.

>> If something happens in the SMPS and the output varies, PG goes low, and the motherboard goes off.

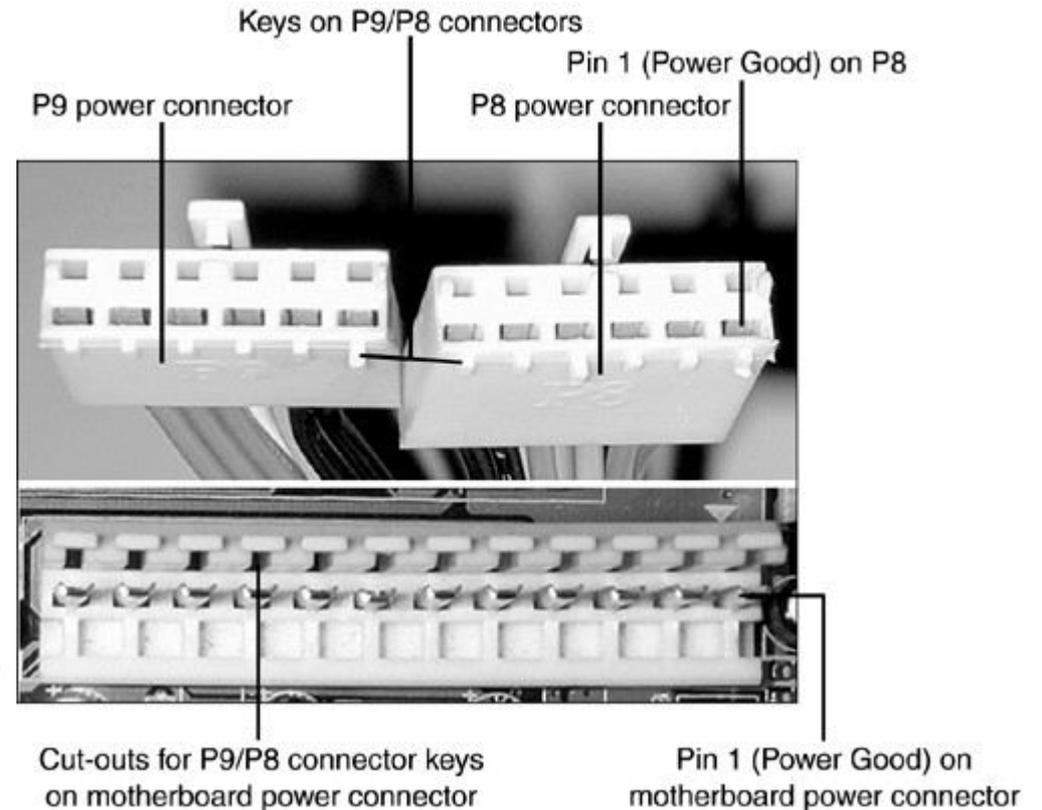
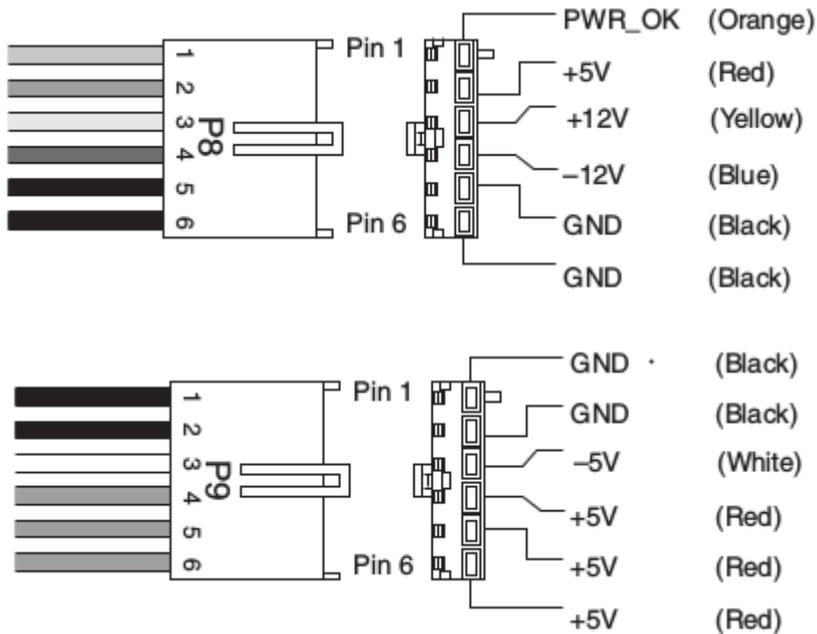
>> On ATX SMPS, it is on pin 8.

>> On pre ATX, it is on pin-1 of P8 connector

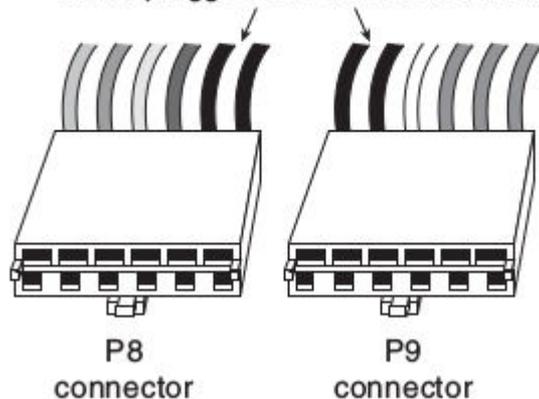
AT / LPX Power Supply Connectors

>> Used in Industry-standard PC, XT, AT, Baby-AT, and LPX motherboards.

>> two main power connectors (P8, P9) (sometimes called P1, P2) each with 6-pins.



Always position connectors such that the black wires in each connector are adjacent (side-by-side) when plugged into the motherboard

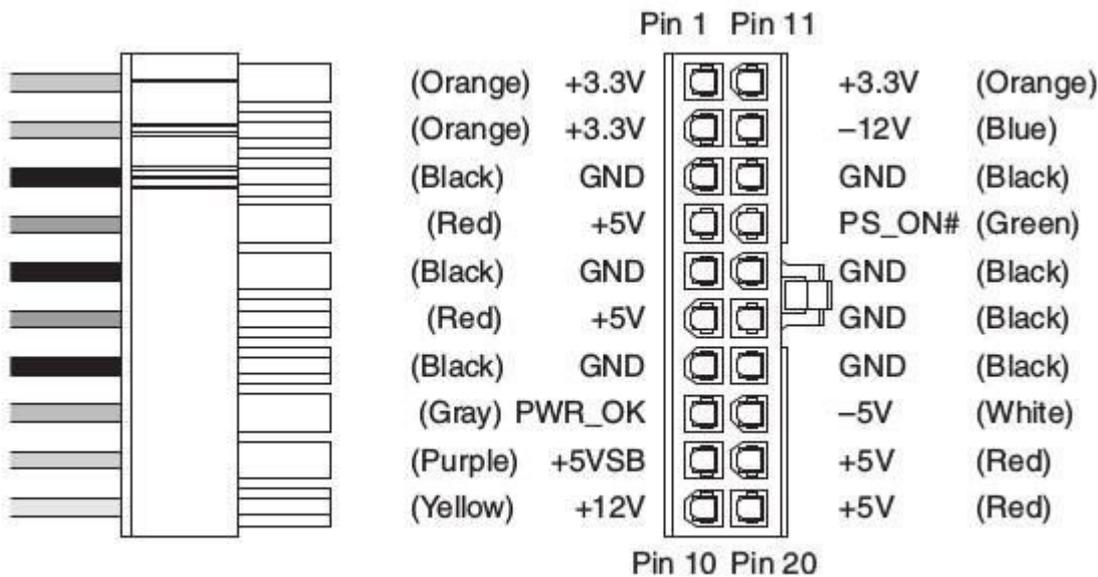


ATX connectors

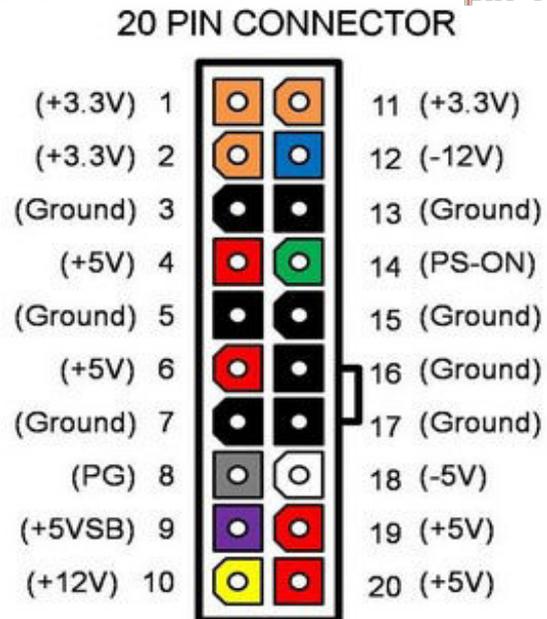
>> Single 20-pin Molex Mini-Fit Jr. Connector

>> This standard became ATX12V specification due to higher power requirement.

>> The connector has three variants; a standard version (each terminal support a current of 6A), an HCS (High Current System – supports 9A) version, and a Plus HCS (11A) version.



ATX 20-pin main power connector, side and terminal end view.

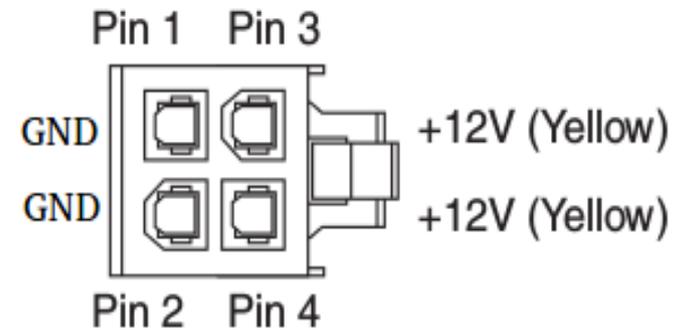
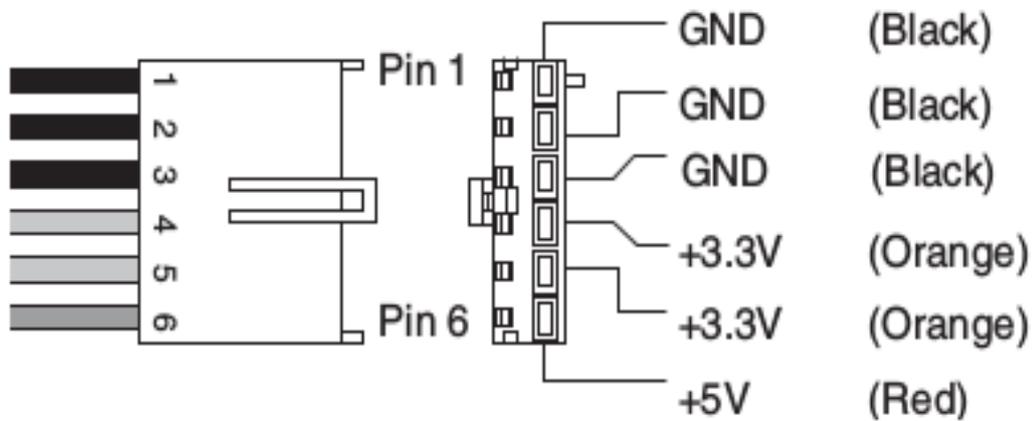


ATX12V 1.0 specification

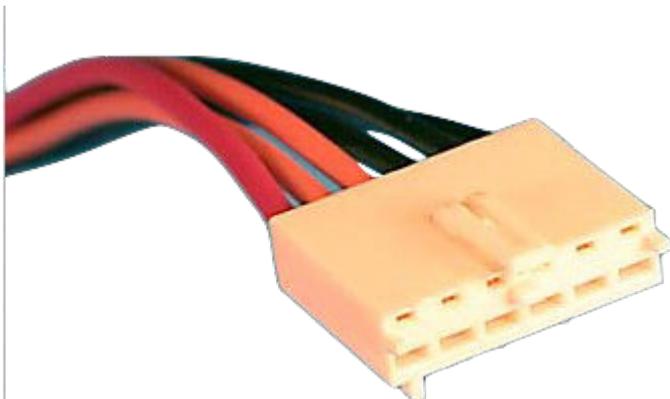
>> Pentium4 needed more power hence two additional power connectors came.

1. a single 6-pin P8/P9 AT type auxiliary connector that supplied additional +3.3V (2 nos.) and +5V leads, and their grounds.

2. a 4-pin square Molex Mini fit Jr. connector, referred to as a P4 (name came from Pentium4) connector.



ATX 2.02/2.03 and ATX12V 1.x auxiliary power connector, side and terminal end view.



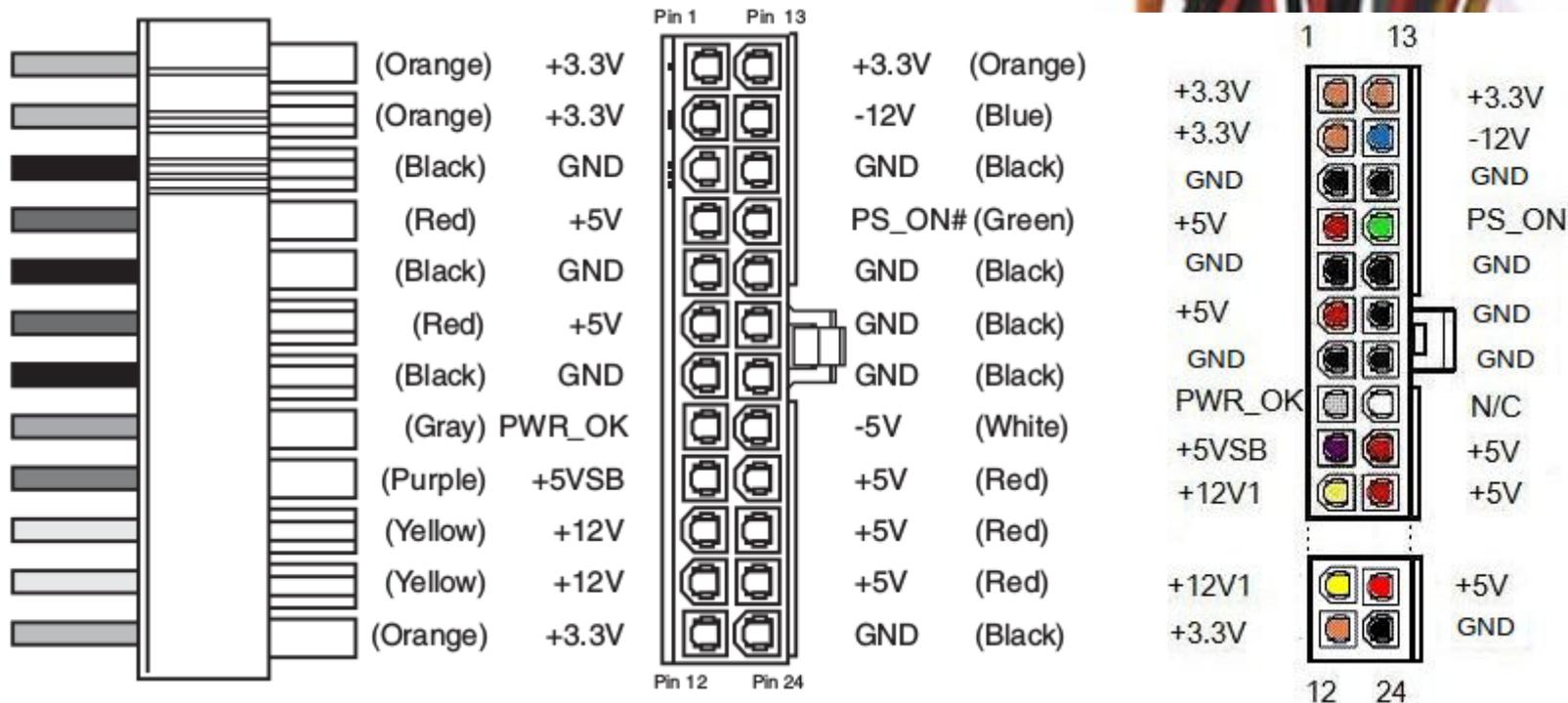
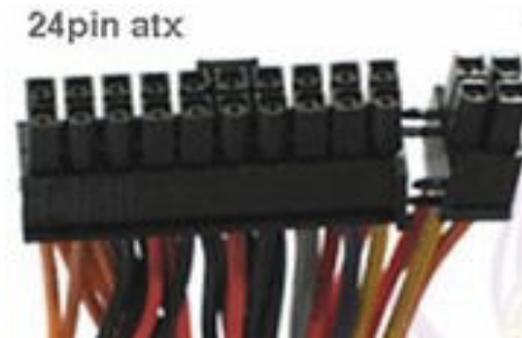
ATX12V 2.0 specification

>> ATX12V 1.0 power was inadequate when PCIe came.

>> ATX 20-pin main connector was replaced by a 24-pin connector.

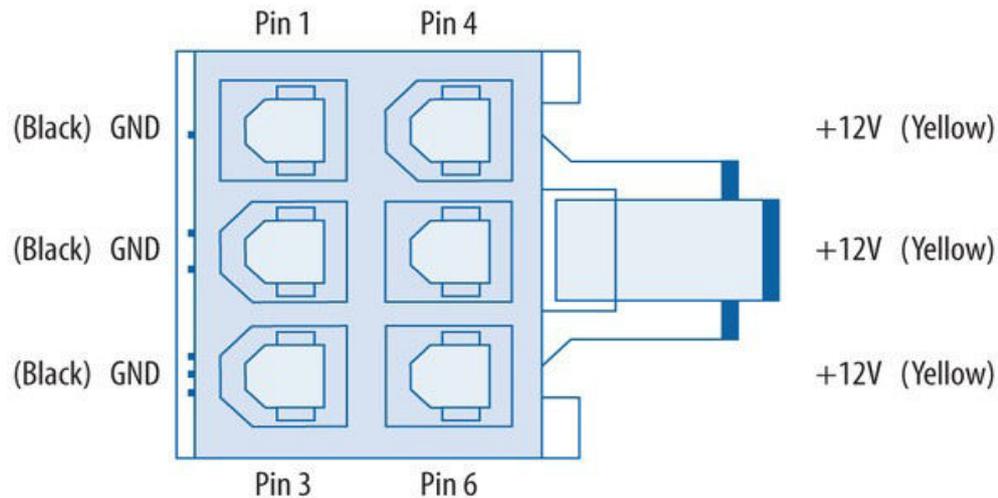
>> Here the 20-pins were similar to ATX standard. The additional 4-pins could be separated for backward ATX compatibility.

>> The 6-pin aux connector was removed.



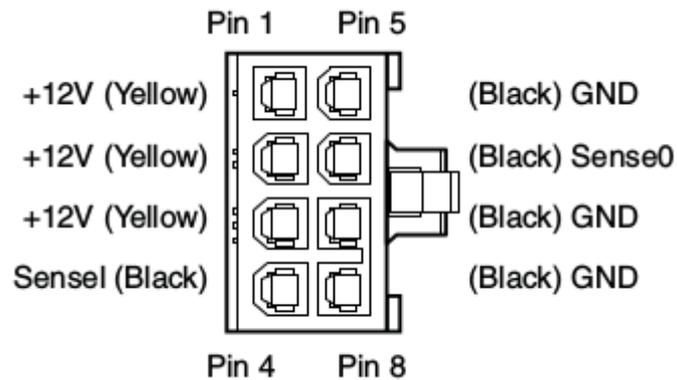
ATX12V 2.1 specification

>> brought a 6-pin molex connector dedicated for PCIe



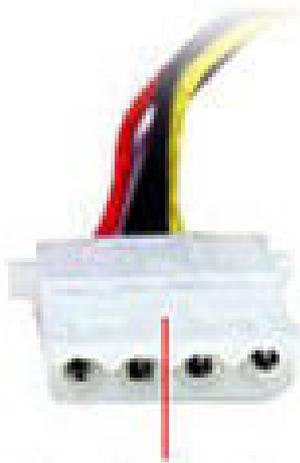
ATX12V 2.2 specification

>> replaced the 6-pin molex connector with an 8-pin molex connector.

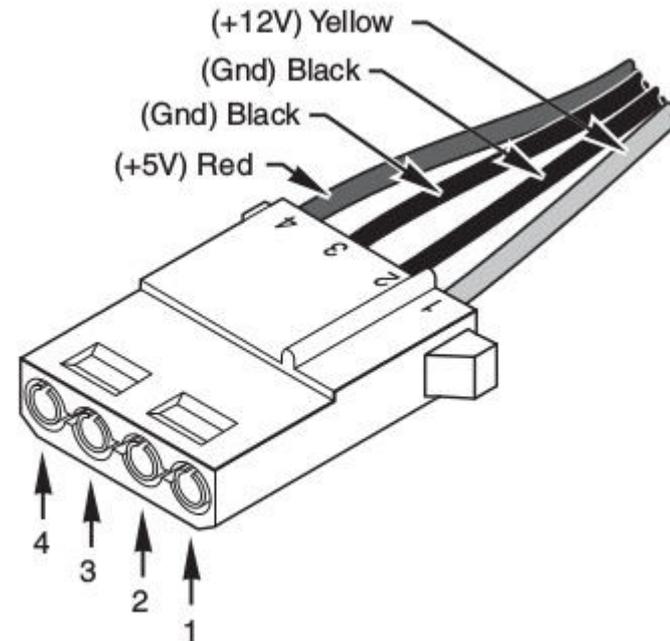


Standard Peripheral Power Connectors (Disk drive power connectors) - for AT/ATX

- >> On all PC power supplies from the original IBM PC to the latest systems built today.
- >> Most commonly used for disk drives (Hard disk drive, optical drives, etc)
- >> Also used in some systems to provide additional power to the motherboard, video card, cooling fans.



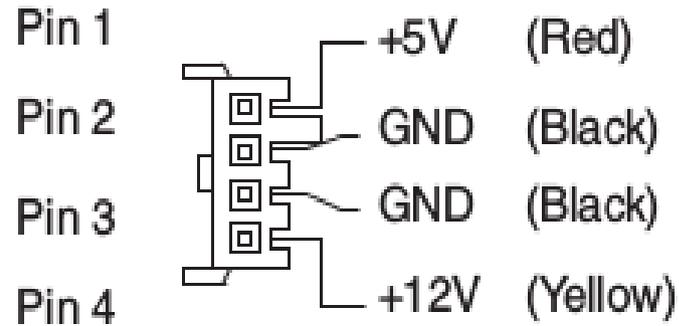
4-pin molex power connector



A peripheral power connector.

Floppy Power Connectors – for AT/ATX

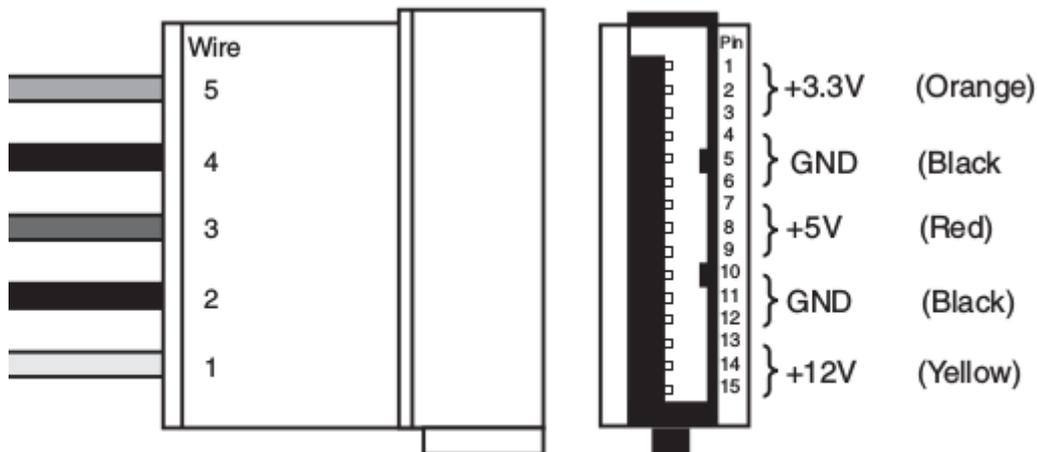
>> also called *Berg* connectors.



Serial ATA Power Connectors

>> Used for SATA drives. (HDD, DVD drives,..)

>> 15-pin connector fed by only five wires.



A SATA power connector.



IDE – SATA power adapter

Magnetic storage devices

- >> Information (0 and 1) are stored by aligning magnetic particles on a surface.
- >> Magnetic patterns can be read and converted back into the original stream of bits.
- >> Use electromagnetism.
- >> Eg: magnetic tape, floppy disks and hard disk drives (HDD).



Hard Disk Drive Systems (HDD or simplr Dard Disk)

>> Most important secondary storage device.

>> Contains three critical components.

1. Hard disks

2. Controllers

3. Host Bus Adapter (HBA)

>> Hard disks: 'hard' aluminium/glass disks coated by magnetic materials to store data.

>> Controllers: controls the gisk rotation, read/write head movements, logic circuits, etc.

It is integrated into the disk assembly. Common types are PATA, SATA.

>> HBA: Does the communication between the controller and the motherboard. Today its a part of motherboard.

Hard Disks

Track: A single ring of data on one side of a disk (platter).

Each track holds several megabytes of data.

Difficult to manage a track as such; hence a track is divided into sectors.

Tracks are numbered starting from 0 from outside.

Sectors: Arc-shaped pieces of a track.

The smallest addressible unit in a disk.

Sectors are numbered starting with 1 from outside.

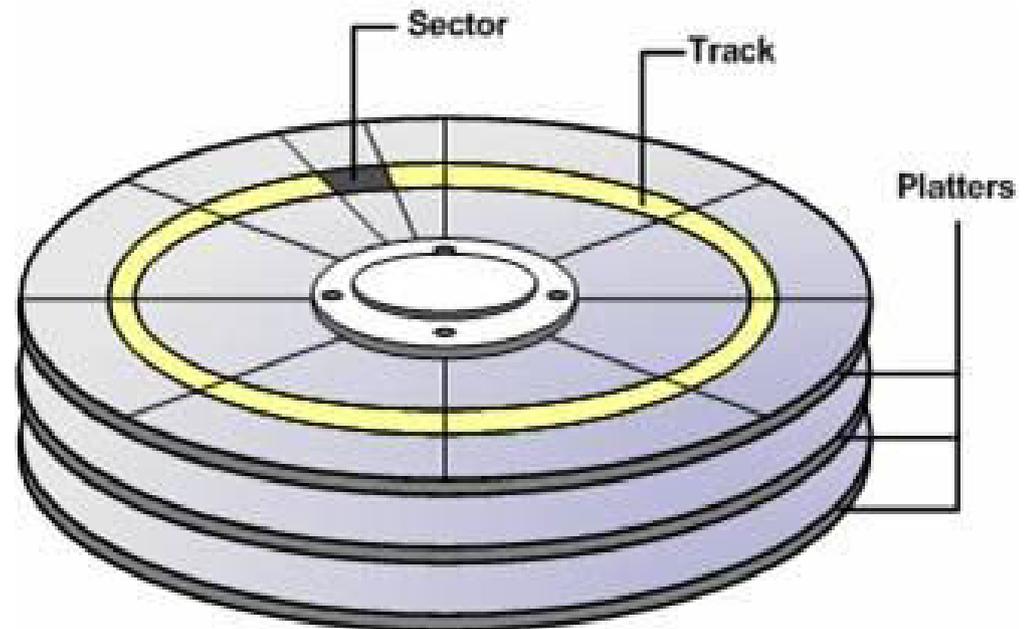
Each stores 512 or 4,096 bytes of data; some additional bytes used in sector headers and trailers to manage the tracks and sectors.

Cylinder: The identically aligned tracks on each side of every platter together make up a cylinder.

The outermost cylinder is numbered as cylinder 0.

Each sector in the HDD is addressed as
cylinder x, head y, sector z.

(CHS addressing)



Hard Disks...

Cluster: (or allocation unit)

A fixed number of continuous sectors (but not necessarily physically contiguous).

File system stores and accesses files on disks as clusters.

A cluster is the smallest unit of disk space that can be allocated to a file.

Every file must be allocated an integer number of clusters.

If contiguous clusters are not available, the data is written elsewhere on the disk, and the file is considered to be **fragmented**.

Anatomy of Hard Disk

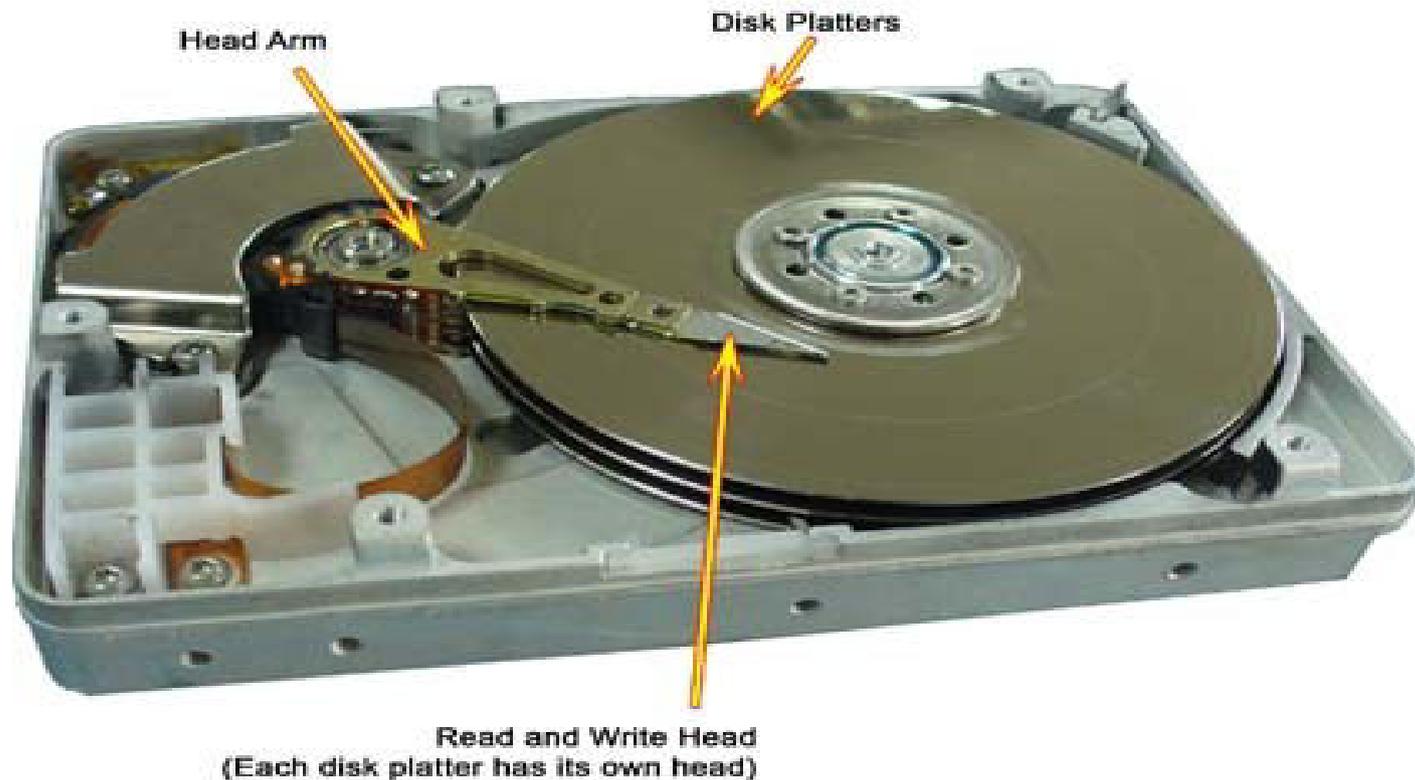
The basic components of a typical HDD are as follows.

- Disk platters
- Read/write heads
- Head actuator mechanism (actuator, axis and arm)
- Spindle motor (inside platter hub)
- Logic board (controller or Printed Circuit Board)
- Cables and connectors
- Configuration items (such as jumpers or switches)



Platters

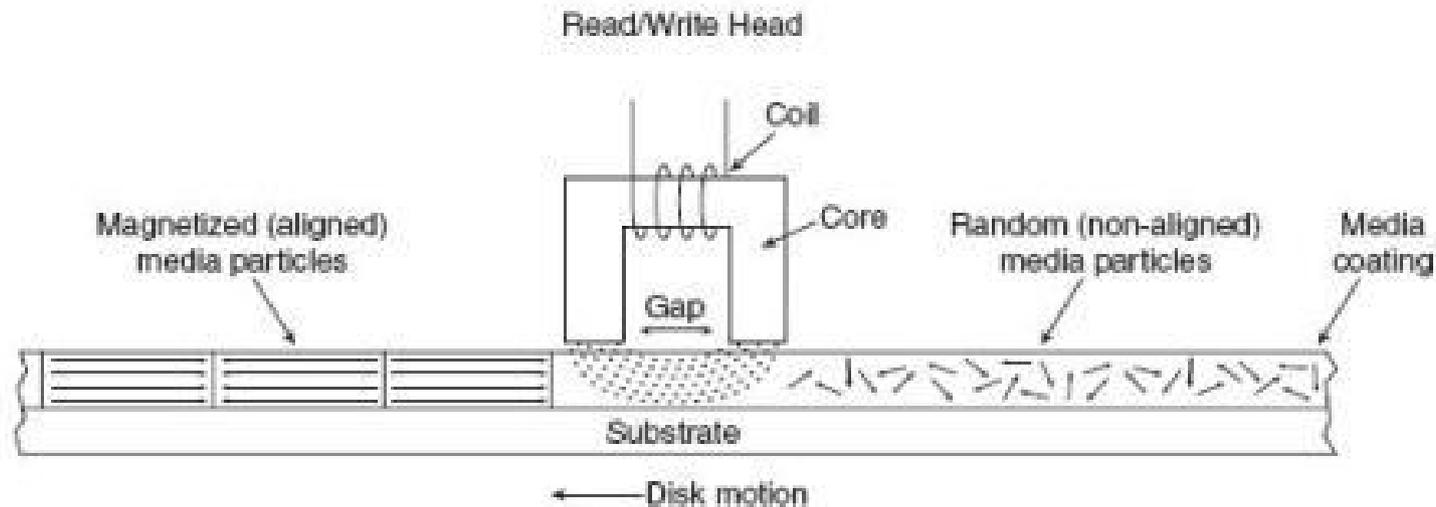
- >> stacked spinning disks (2,3,...12)
- >> aluminum/magnesium alloy or glass-ceramic material, over which magnetic material called medium on one or both sides.
- >> available in 5.25in, 3.5in, 2.5in, 1.8in, 1in and 0.85in.
- >> Currently, 3.5in are used in desktop systems and 2.5in and smaller drives are used in portable and notebook systems.



Inside Hard Disk

Read/Write Heads:

- >> One for each recording surface of disks.
- >> Connected to a single axis.
- >> Use electromagnetism for reading and writing.
- >> Older drives use **Contact Start Stop (CSS)** design for head landing.
- >> Newer drives use **Load/Unload** design for head landing.



Read/Write Heads...

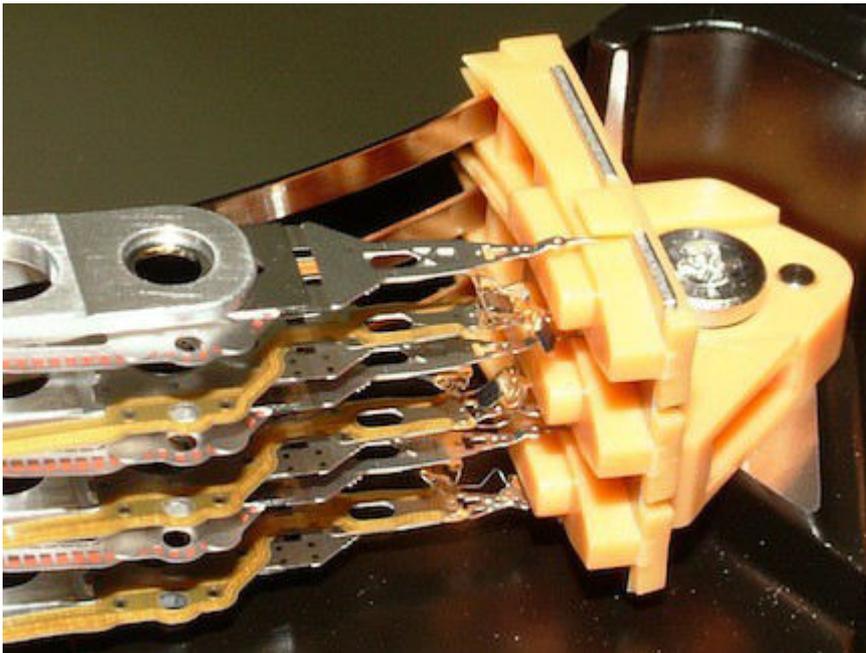


Read/Write Heads – Head Loading mechanisms

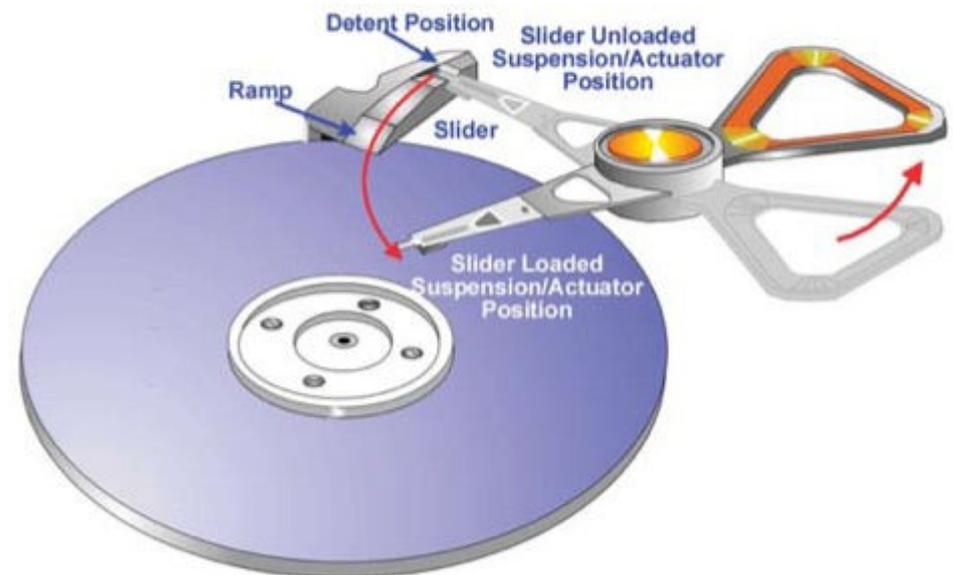


Contact Start Stop (CSS)

Load/Unload

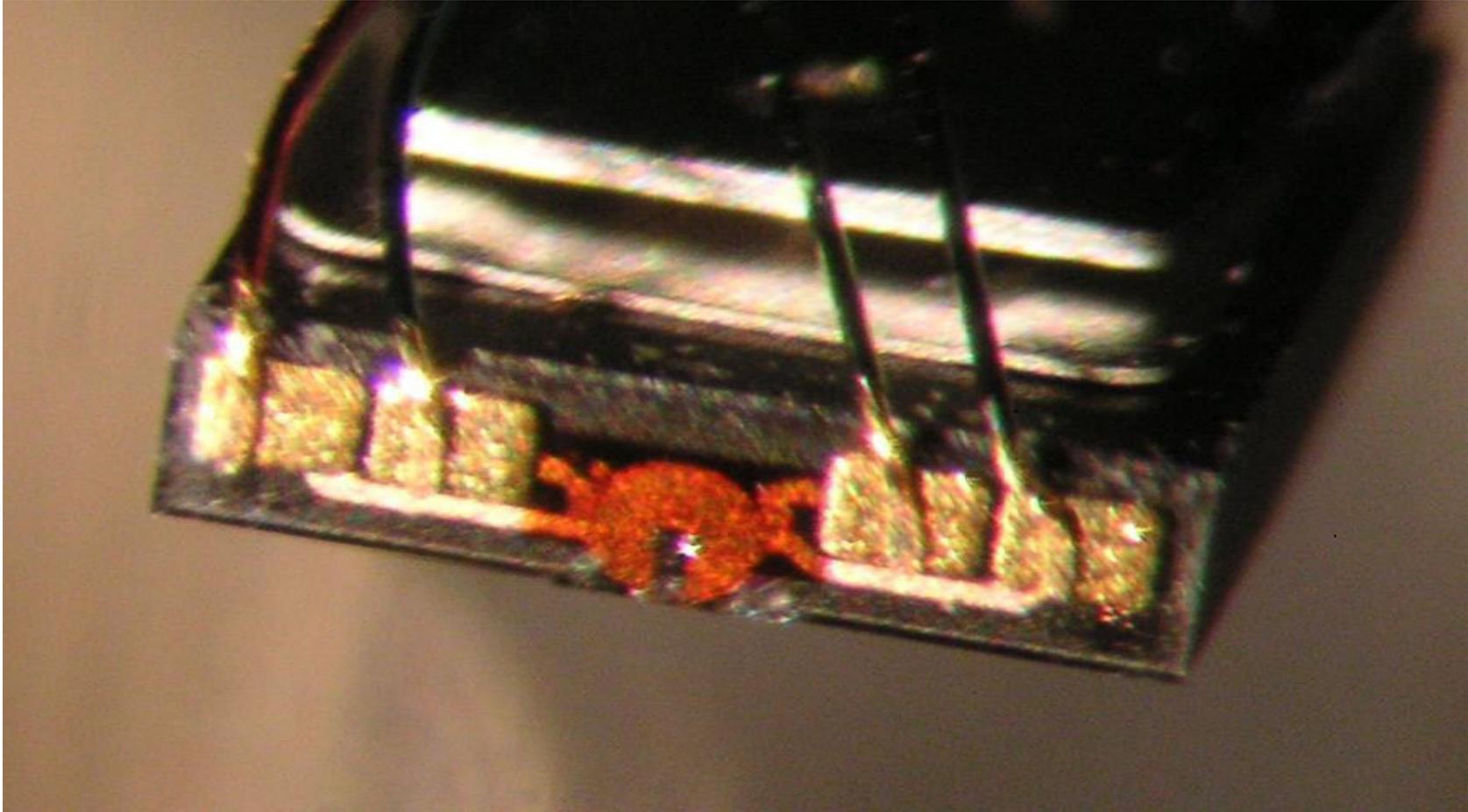


Ramp Load/Unload Dynamics



Read/Write Heads...

- >> Older heads used heavy ferrite cores, which touched the disks and damaged them.
- >> Newer heads are very much lighter and floats over the disks.



Microphotograph of a hard disk head. The size of the front face is about 0.3 mm. One functional part of the head is the round, orange structure in the middle.

Read/Write Heads...

'Ring' writing element



>> Modern read/write heads use Perpendicular magnetic recording (PMR) heads for more dense data recording.

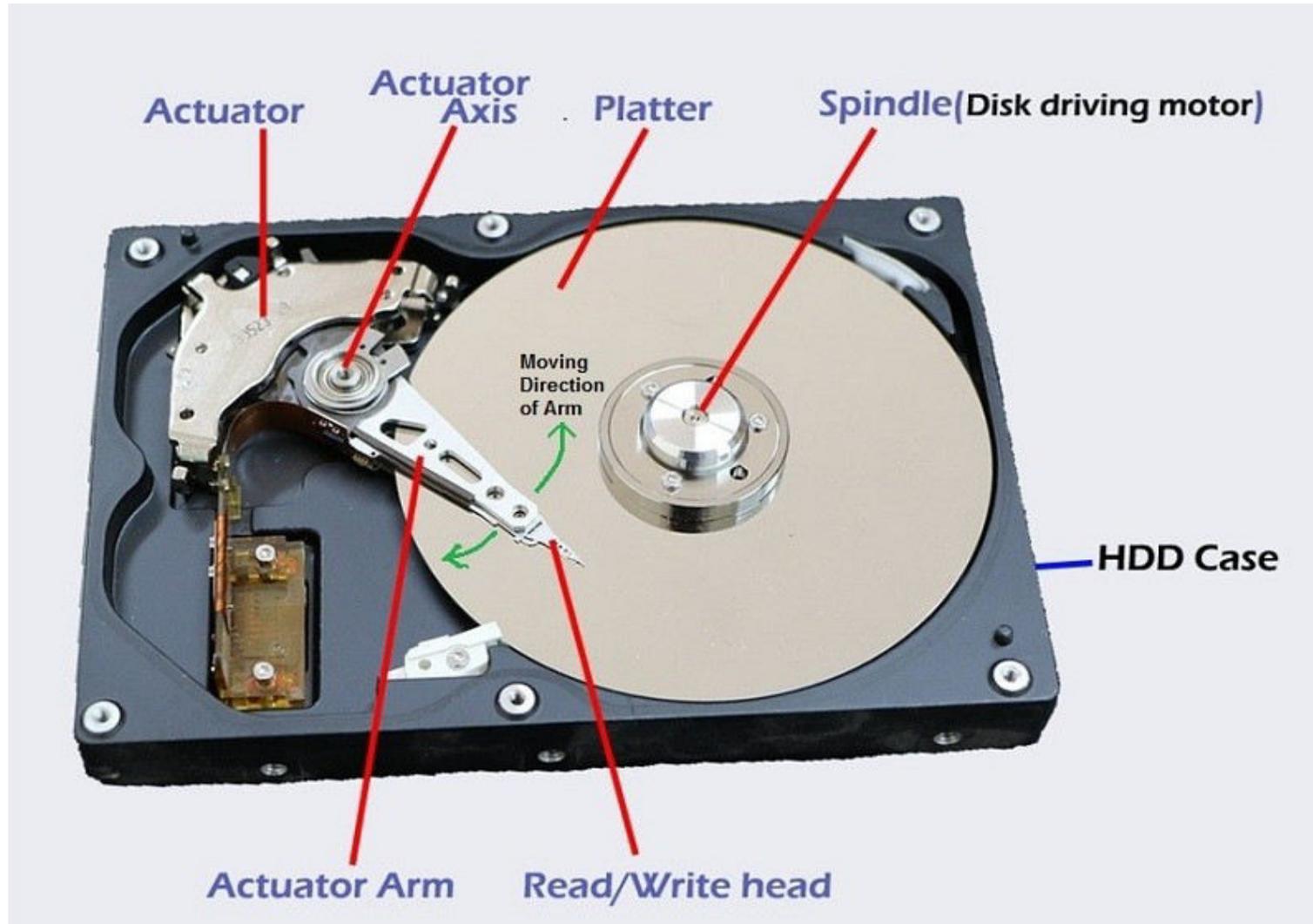
'Monopole' writing element



Head Actuator Mechanisms:

>> It moves the heads across the disk and positions them accurately above the desired location.

>> Consists of actuator, axis and arms.



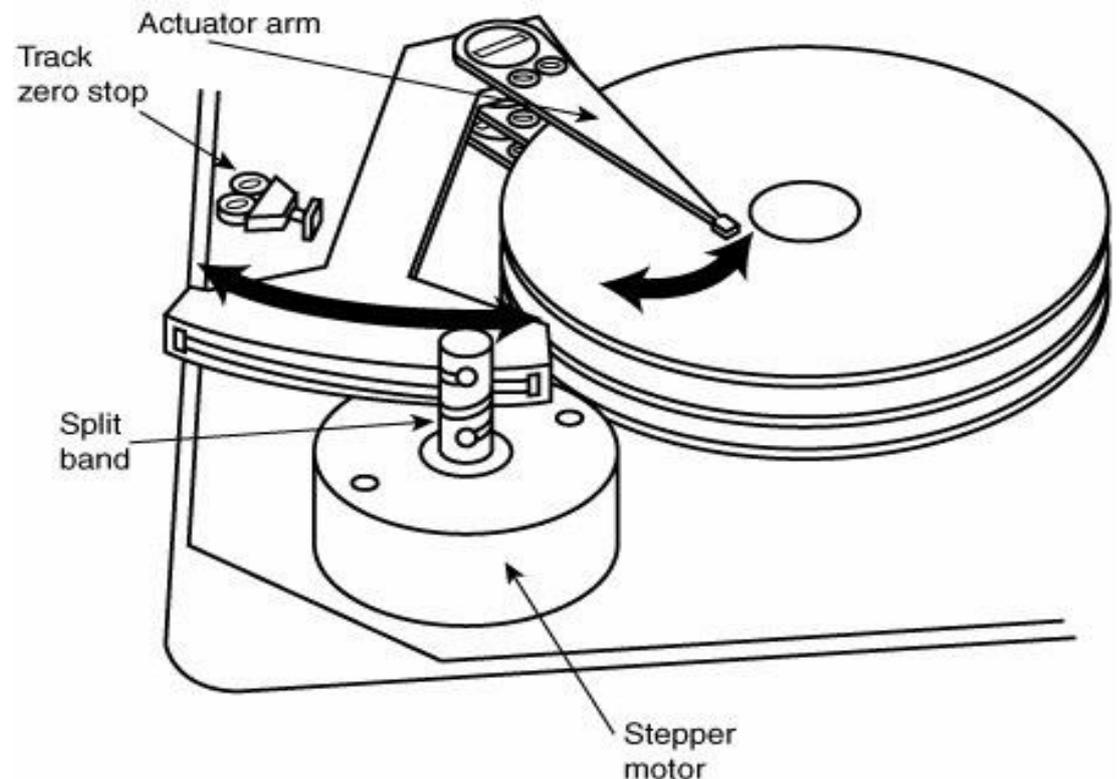
Head Actuator Mechanisms:

>> It moves the heads across the disk and positions them accurately above the desired location.

>> Consists of actuator, axis and arms.

>> The older type called Stepper motor actuators.

- * They cannot stop in between two steps; fails when the disk expands due to heat.
- * Low access speed.
- * Highly position sensitive.
- * No automatic head parking.
- * Low reliability.



Head Actuator Mechanisms:

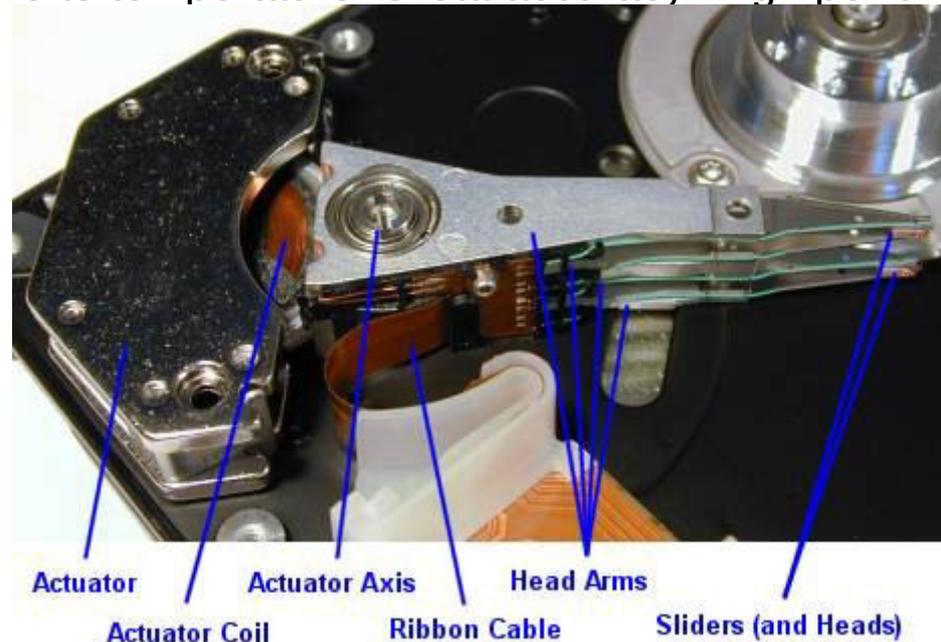
>> Newer type is Voice coil actuators; use electromagnetism just like in audio speakers.

>> An electromagnetic coil is attached at the back end of the actuator and placed near a strong stationary magnet. On energizing the coil, it becomes magnetized and moves accordingly in the permanent magnetic field.

>> No steps so free movement.

>> A guidance mechanism called **Servo** to tell the actuator about the head position and to place the head accurately. This mechanism is also called a **closed loop feedback mechanism** or **servo controlled mechanism**.

>> Not at all sensitive to temperature. Great accuracy. High performance. High reliability.



Spindle Motor:

- >> Spins the platters at a constant speed (3,600 rpm to 15,000 rpm based on HDDs).
- >> Has a control circuit with a feedback mechanism to rotate precisely and accurately.
- >> Seen below the platter stack.
- >> Most motors use a fluid dynamic bearing.
- >> Enables improved speed control, less noise and shock resistant.



>> **Logic Board:** It controls the spindle and the head actuator systems.

>> **Cables and Connectors:** Interface connectors carry the data and command signals between the system and the drive, such as ATA, SATA and SCSI.

>> **Configuration Items:** To configure an HDD for installation in a system, like jumpers.

>> HDDs have two air filters for removing the dust - one is the **recirculating filter**, and the other is a **barometric** or **breather filter**.



INTERFACES

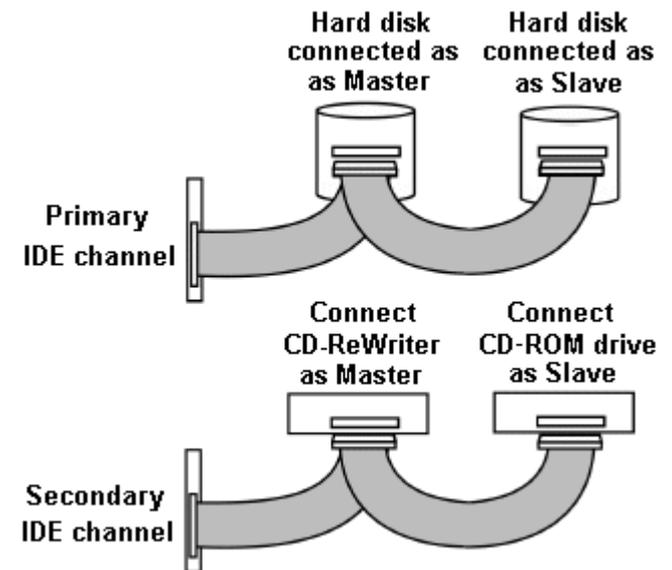
IDE / PATA Drives (Integrated Drive Electronics / Parallel Advanced Technology Attachment) or simply, ATA



INTERFACES

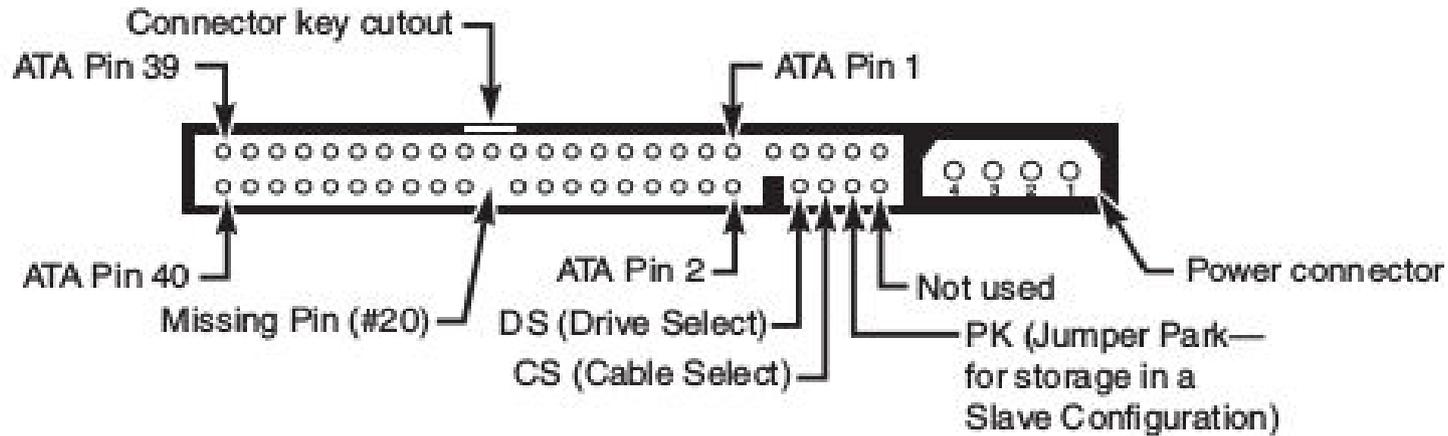
IDE / PATA

- >> Older type.
- >> Drive is integrated with the disk; hence the name IDE.
- >> Transfer 16-bit data in parallel; hence the name Parallel ATA.
- >> Speed at 16/33/66/100/133 MBps.
- >> Use 40 pin connector and cable; pin-20 absent for keying.
- >> Pin 1 will be near the power connector; and usually this conductor is coloured in red.
- >> I/O Cable may be with 40 or 80 conductors. 40- for signalling and data; the other 40 seen in between the former, decreases noise in higher PATA versions.
- >> ATA drive modes: *Master, Slave or Cable Select (CS)*
- >> For identification and priority, Master/Slave is used.
- >> CS is used for automatic selection based on cable.
- >> Selection is done through jumper settings.

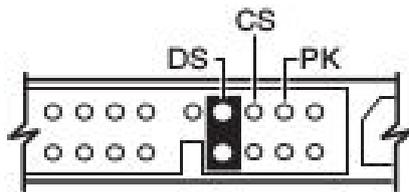


IDE / PATA

>>

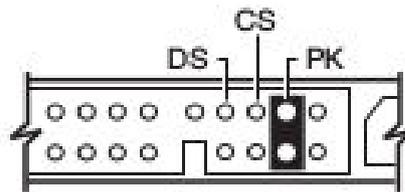


Master Drive Configuration (standard cable)



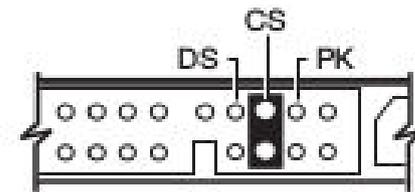
Use the Master Drive Configuration for the first (or only) drive on a standard (non-cable select) cable.

Slave Drive Configuration (standard cable)



Use the Slave Drive Configuration for the second drive on a standard (non-cable select) cable; note that for a Slave Configuration, the jumper can be stored in the PK (Jumper Park) position, removed entirely, or stored on one of the DS Pins in a flag arrangement.

Cable Select Drive Configuration



For Cable Select Drive Configurations, one or both drives are configured the same; the cable automatically determines which is Master or Slave by which connector the drive is plugged into.

IDE / PATA - ATA versions; ATA-1 to ATA-8

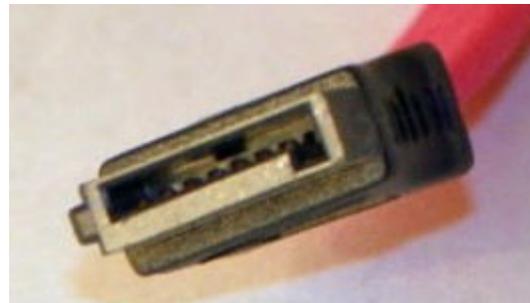
- >> ATA-2 and higher versions are called Enhanced IDE (EIDE) or Fast-ATA.
- >> ATA-3: ATA Packet Interface (ATAPI) was introduced to help deal with IDE devices other than hard disks. Introduced the Self-Monitoring And Reporting Technology (SMART): monitor itself and warn the user during and after boot-up of any failure.
- >> ATA-4: *UltraDMA*, speed up to 33MBps. (UltraDMA/33 or Ultra-ATA/33 or ATA-33)
- >> ATA-5: speed up to 66MBps, (UltraDMA/66 or Ultra-ATA/66 or ATA-66). 80-wire ribbon cable.
- >> ATA-6: speed up to 100MBps, (UltraDMA/100 or Ultra-ATA/100 or ATA-100).
- >> ATA-7: speed up to 133MBps, (UltraDMA/133 or Ultra-ATA/133 or ATA-133). Serial ATA (SATA) started with speed 150MBps.
- >> ATA-8: Compatible with ATA-7. SATA speed up to 300MBps.

SATA Drives (Serial ATA)

- >> Serial data transfer.
- >> 150, 300 and 600 Mbytes/s (1.5, 3 and 6 Gbits/ps) and 8b/10b encoding.
- >> Thin 7 wired cable and maximum 1m with identical ends.
- >> Helps more air flow than when using PATA cable.
- >> Point to point. No master/slave confusion.
- >> Differential voltage signalling (+0.25V and -0.25V), hence no electromagnetic noise.
- >> Ground pins are longer, hence they make contacts first, allowing easy hot-plugging and less chances of damage.

SATA Data Connector Pinout

| Signal Pin | Signal | Description |
|-------------------|---------------|--------------------|
| S1 | Gnd | First mate |
| S2 | A+ | Host Transmit + |
| S3 | A- | Host Transmit - |
| S4 | Gnd | First mate |
| S5 | B- | Host Receive - |
| S6 | B+ | Host Receive + |
| S7 | Gnd | First mate |



Small Computer System Interface (SCSI) Drives

>> a **set of** parallel interface standards for physically connecting and transferring data between computers and peripheral devices especially disk drives.

>> used with RAID, servers, high-performance PCs and storage area networks.

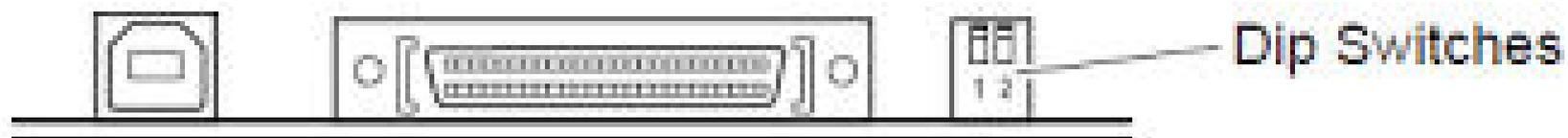
>> SCSI devices can be either internal or external to the computer.

* Internal drives: 8-bit and 16-bit types. 8-bit SCSI-1 and SCSI-2 *internal* devices use a 50-pin SCSI A ribbon cable with a colored stripe (usually blue or red). 16-bit SCSI uses a SCSI P cable, with 68 wires and a 68-pin D-subminiature connector. There is also an 80-pin internal SCA connector ideal for use in hot-swapping environments. Chained connector connecting the devices with one connector connecting to the adapter.

* External drives: SCSI-1 uses a 50-pin Centronics (printer-type) connector. SCSI-2 uses a 25-, 50-, or 68-pin connector. SCSI-3 uses a 68- or 80-pin connector. External cabling is done through *daisy-chaining*. Here each device has two ports on it (in & out).

>> Each device has a unique ID called a SCSI address, SCSI ID, or SCSI device ID.

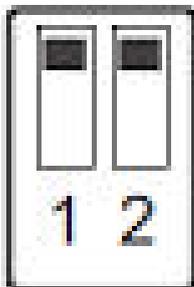
>> These numbers are configured through jumpers, DIP switches or up/down push buttons.



Default Position (SCSI ID=2)

OFF

ON



| SCSI ID | SW1 | SW2 |
|---------|-----|-----|
| 2 | OFF | OFF |
| 3 | ON | OFF |
| 4 | OFF | ON |
| 5 | ON | ON |

Small Computer System Interface (SCSI) Drives...

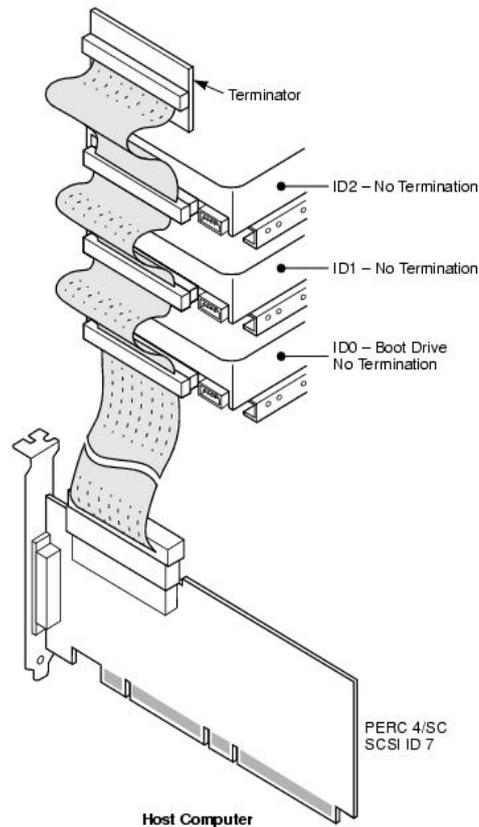
>> When a device need to communicate, it activates its address line and transfers the data.

>> Terminators must be used at the connector ends to avoid signal bouncing.

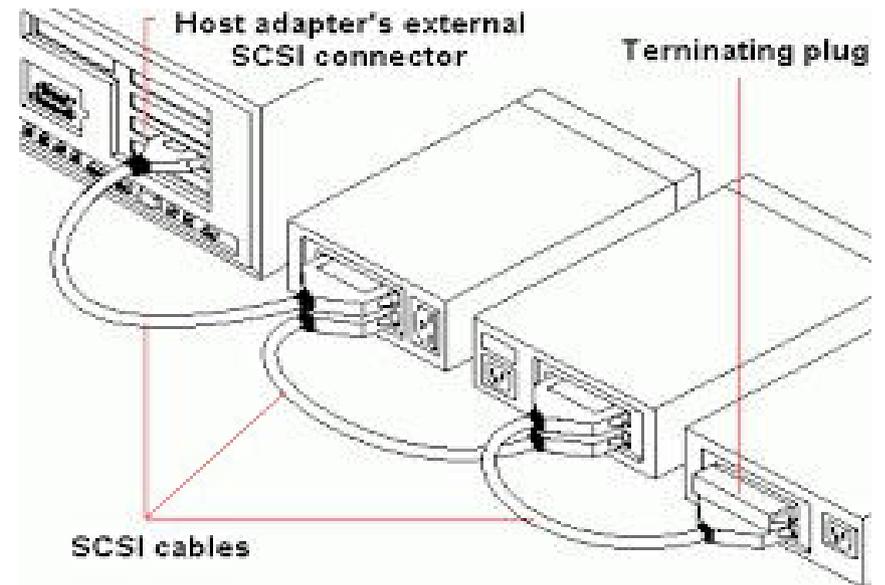
>> *Passive terminators* use resistors.

>> *Active terminators* use voltage regulators; much better than passive ones and are used whenever fast, wide, or Ultra SCSI devices are connected.

Internal Connection



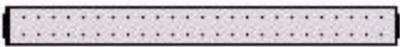
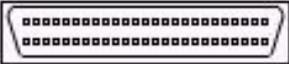
External Connection





SCSI UW Internal Cable (68-Pin) 4 Devices

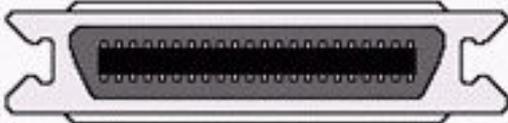
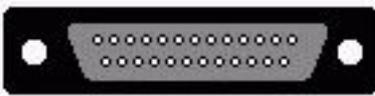
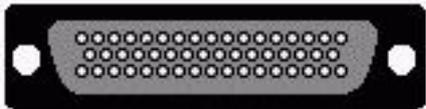
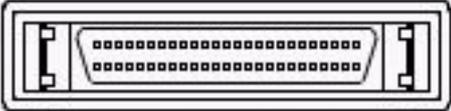
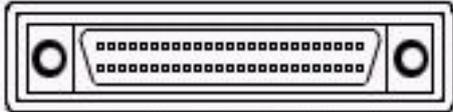
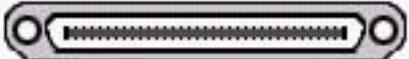
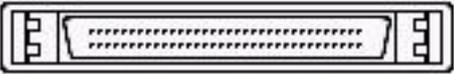
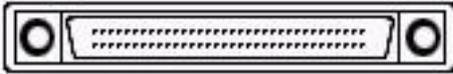
Internal SCSI Connectors

| | | |
|--|---|--|
| <p>1</p>  <p><i>IDC 50-Pin</i></p> | <p>2</p>  <p><i>High Density DB 50-Pin (Internal)</i></p> | <p>3</p>  <p><i>High Density DB 68-Pin (Internal)</i></p> |
| <p>4</p>  <p><i>VHDCI 68-Pin (Internal)</i></p> | <p>5</p>  <p><i>SCA 80-Pin (Internal)</i></p> | |

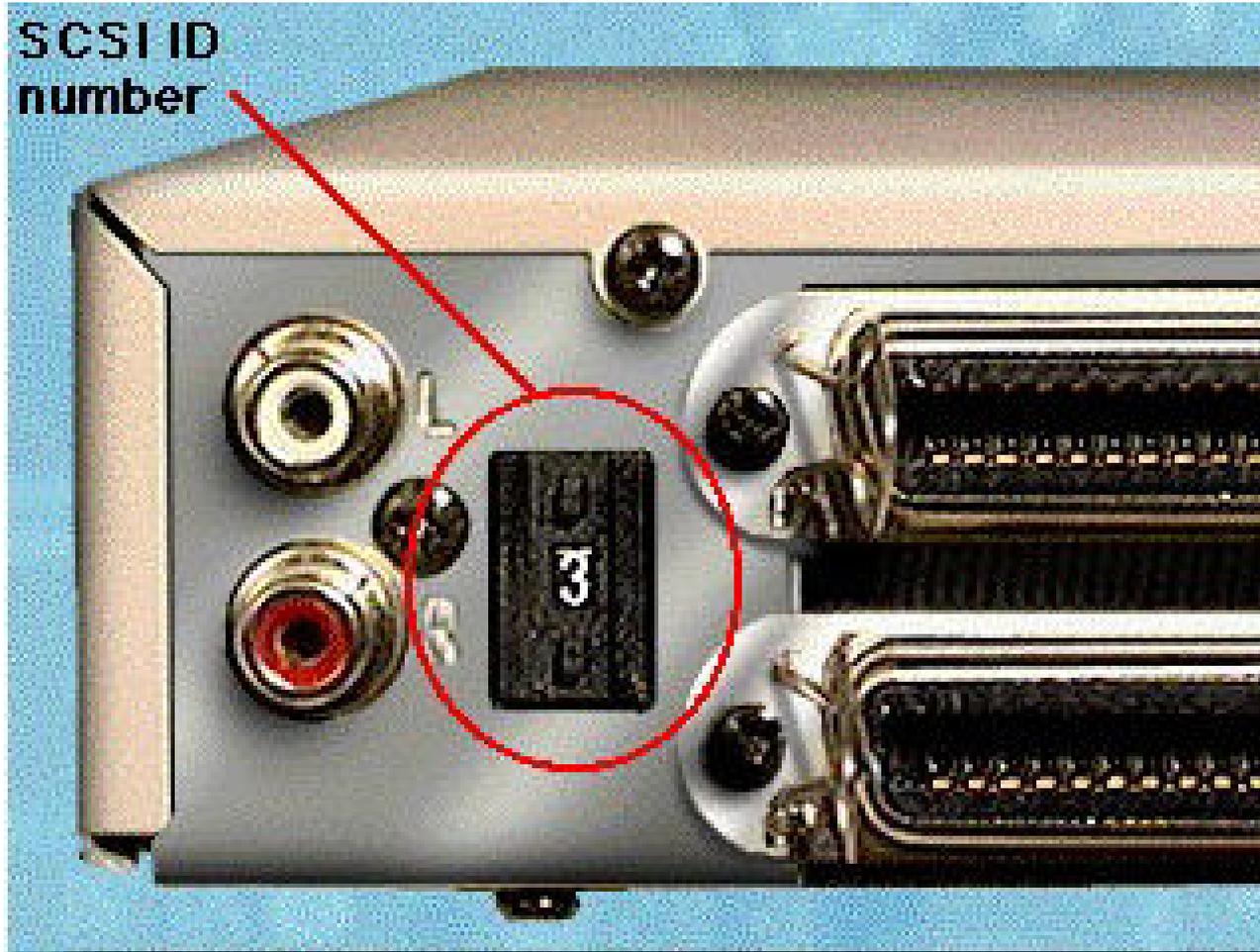


SCSI External cable – 68 pin

External SCSI Connectors

| | | |
|--|--|--|
| <p>1</p>  <p>Centronics 50-Pin</p> | <p>2</p>  <p>DB 25-Pin</p> | <p>3</p>  <p>DB 50-Pin</p> |
| <p>4</p>  <p>High Density DB 50-Pin (Clip Type)</p> | <p>5</p>  <p>High Density DB 50-Pin (Screw Type)</p> | <p>6</p>  <p>VHDCI 68-Pin</p> |
| <p>7</p>  <p>High Density DB 68-Pin (Clip Type)</p> | <p>8</p>  <p>High Density DB 68-Pin (Screw Type)</p> | <p>9</p>  <p>High Density Centronics 50-Pin</p> |
| <p>10</p>  <p>High Density Centronics 60-Pin</p> | <p>11</p>  <p>High Density Centronics 68-Pin</p> | <p>12</p>  <p>HDI30 (Apple/Mac)</p> |

SCSI ID
number

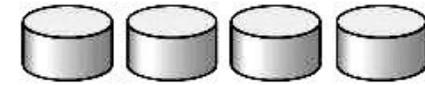


RAID (Redundant Array of Independent / Inexpensive Disks)

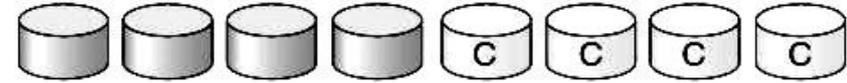
>> Distributing storage for performance and fault tolerance.

>> Seven levels of RAID (0-6) to give fault tolerance (reliability), storage capacity, performance, or a combination of the three.

1. RAID Level 0: Striping
2. RAID Level 1: Mirroring
3. RAID Level 2: Bit-level ECC
4. RAID Level 3: Striped with parity
5. RAID Level 4: Blocked data with parity
6. RAID Level 5: Blocked data with distributed parity
7. RAID Level 6: Blocked data with double distributed parity



(a) RAID 0: non-redundant striping.



(b) RAID 1: mirrored disks.



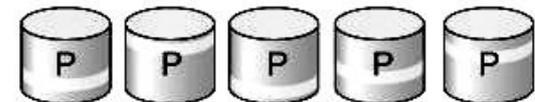
(c) RAID 2: memory-style error-correcting codes.



(d) RAID 3: bit-interleaved parity.



(e) RAID 4: block-interleaved parity.



(f) RAID 5: block-interleaved distributed parity.



(g) RAID 6: P + Q redundancy.

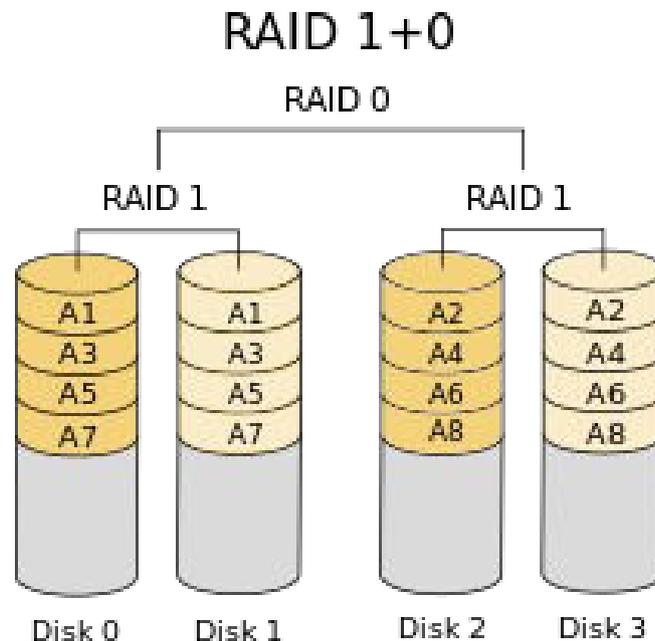
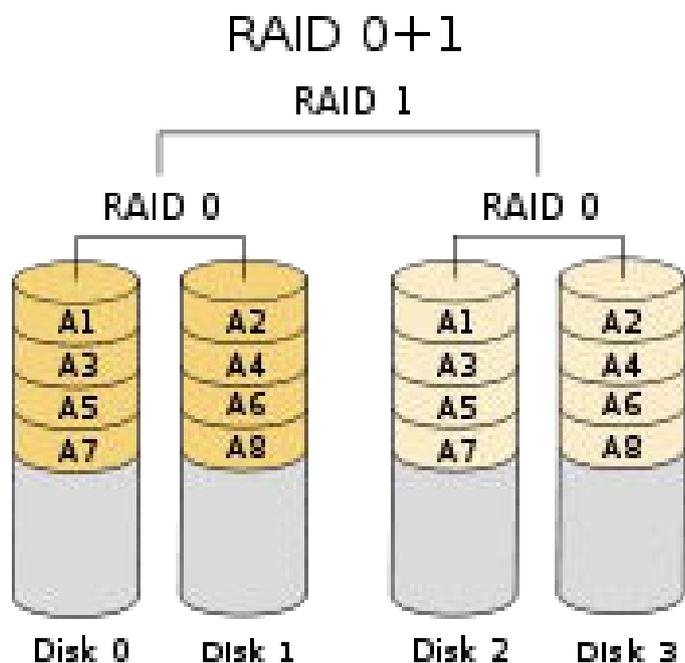
RAID (Redundant Array of Independent / Inexpensive Disks)...

>> Nested RAID levels can be created by combining several forms of RAID.

>> Most common such combinations are;

1. RAID Level 01: Mirrored stripes—Drives are first combined in striped RAID 0 sets; then the RAID 0 sets are mirrored in a RAID 1 configuration.

2. RAID Level 10: Striped mirrors—Drives are first combined in mirrored RAID 1 sets; then the RAID 1 sets are striped in a RAID 0 configuration.



Removable storage and media

Tape Backup Devices

- >> Older form.
- >> Sequential storage and much slower.
- >> Used for data collection, backup and archiving.
- >> If kept for longer duration, it must be periodically recopied or traversed.
- >> In internal and external attachment forms.

Flash memory

- >> Non volatile forms of memory; data written by using electricity, hence the term 'flash'.
- >> Priimarily used as storage medium in small devices such as routers, switches etc.
- >> Types include SD and other memory cards, flash/pen drives etc.
- >> The dlash memory cards used in older digital camera like devices are MultiMedia Cards (MMC).
- >> Later SD Cards (Secure Digital) were developed by SD Association (SDA) for most of the portable devices.
- >> SD Cards have three form factors: *standard SD*, *miniSD* and *microSD*.
- >> Smaller cards can be used in bigger interfaces using adapters.

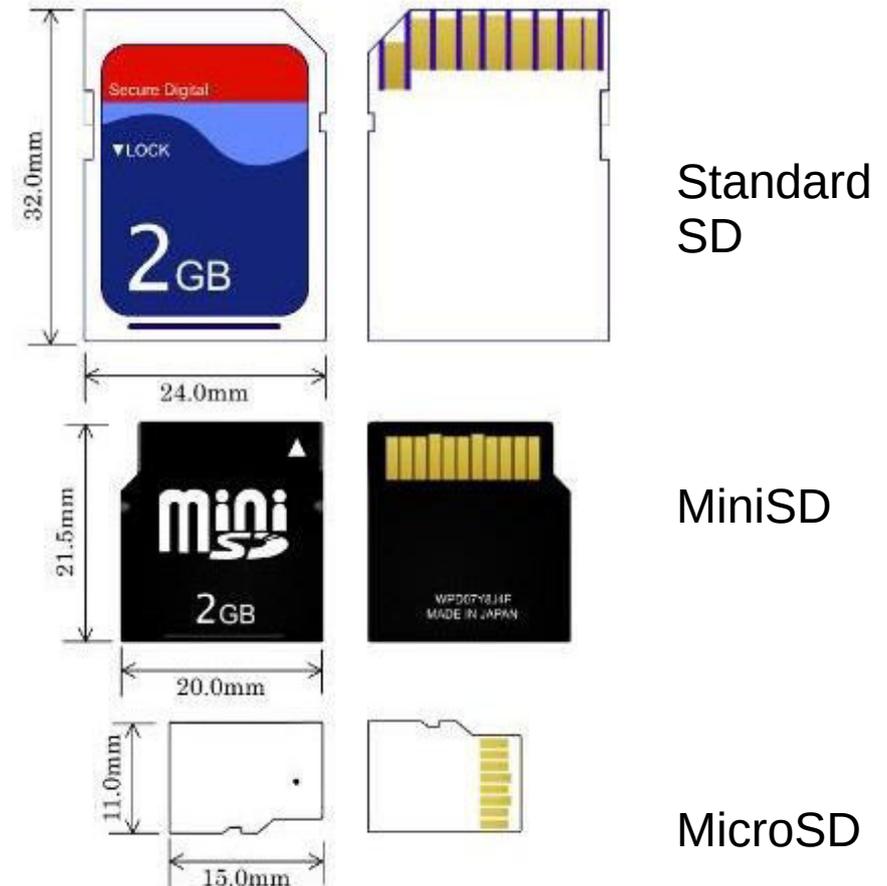
SD Cards...

>> Four types based on size:

1. The original Standard-Capacity (SD or SDSC – upto 2GB)
2. The High-Capacity (SDHC above 2GB upto 32GB)
3. The eXtended-Capacity (SDXC – above 32GB upto 2TB)
4. The SDIO, which combines input/output functions with data storage.



| | Mark | Minimum Serial Data | SD Bus Mode |
|-----------------|------|---------------------|-----------------|
| UHS Speed Class | | 30MB/s | UHS-II UHS-I |
| | | 10MB/s | |
| Speed Class | | 10MB/s | High Speed |
| | | 6MB/s | Normal Speed |
| | | 4MB/s | |
| | | 2MB/s | |



Externally attached drives

>> Major attachment interface is USB.

>> External HDDs and Optical drives are common. If additional power is needed, it is done through another USB cable or external power supplies.

>> External SATA (eSATA) disk drives performs similar to SATA, but need external power supply.

Solid State Drives

>> have no moving parts but use the same solid-state memory technology found in the other forms of flash memory.

>> limited to a finite number of write and erase operations.

>> SSDs read contents more quickly, can consume less power and produce less heat, and are more reliable and less susceptible to damage from physical shock and heat production than their magnetic counterparts.

>> Two types: volatile DRAM-based and non-volatile flash-based.

>> Flash-based SSDs are made with NAND memory, use less power, and no power backup needed.

>> DRAM-based SSDs are faster than Flash based ones, and upgradable, but need backup power.

>> Flash-based SSDs can be made faster by including a small amount of DRAM as cache.

Optical Storage Drives

>> Read and write data using light (laser).

>> The disk is made of an optically transparent polycarbonate wafer, 120mm in diameter and 1.2mm thick, with a 15mm hole in the center.

>> Compact Disk (CD), Digital Versatile Disk (DVD) and Blue-ray Disk (BD).

>> Each one has its ROM, Recordable and Re-recordable versions.

>> The drives for each new type of disk is backward compatible with older disks.

CD:

>> CD may be CD-ROM (read-only), CD-R (Recordable) or CD-RW (ReWritable).

>> General size of a CD is 700MB; but 800MB and 900MB are also standards.

>> Speed varies from 1X to 52X (1 x 150KBytes/s to 52 x 150kBytes/s) but for CD-RW the speed is very low.

>> CD-ROM: Information are written on the CD in the factory itself. Cannot be changed.

Used for software/application distribution.

>> CD-R: Can be recorded once. Also called WORM (Write Once Read Many).

>> CD-RW: can be burned again and again just like burning many CDs and is expensive than CD-R.

>> It has only a single physical track, from inside and spiraling outward and when viewed from the reading side (the bottom), the disk rotates counterclockwise.

>> In CD-ROM along the track, there are raised bumps, called **pits**, and flat areas between the pits, called **lands**. The other surface is coated with a reflective layer. Above it, an acrylic coating and then the label is printed.

>> In blank CD-Rs the pits and lands are replaced by raised **pre-grooves**.

>> WRITING: A powerful 780nm laser burns the pre-grooves to make it less reflective. This burned area is considered as a bit (say 1). For the other bit (say 0) no burning occurs.

>> READING: A less powerful 780nm laser is pointed to the track and a sensor receives the reflected beam. Based on the beam-intensity, a 0 or 1 is recognised.

DVD:

>> Use a narrow 650nm red laser.

>> DVD has a standard capacity of 4.7GB.

>> A dual layer DVD (DVD DL) has 9.4GB capacity (but only 8.5GB is usable).

>> A dual layer dual sided DVD can store 17.1GB of data.

>> DVD Varieties: DVD-ROM, DVD+R (DVD-R), DVD+RW (DVD-RW), DVD-R DL (DVD+R DL) and DVD-RAM (to be written to and erased just like a hard or floppy disk).

BD:

>> Use a very narrow violet laser (405nm).

>> A basic single side BD (BD SS) can store 25GB of data, a dual layer (BD DL) disk can store 50GB and a dual layer dual side BD (BD DL, DS) can store 100GB of data.

>> The 1X transfer rate for Blu-ray is 4.5MBps. (2X is the commonly used speed).

>> It also has ROM, Recordable and ReWritable versions.

Optical Disks and their capacities

| Disc Format | Capacity |
|--------------------------------------|------------------------------------|
| CD SS (includes recordable versions) | 650MB, 700MB , 800MB, 900MB |
| DVD-R/RW SS, SL | 4.71GB (4.7GB) |
| DVD+R/RW SS, SL | 4.70GB (4.7GB) |
| DVD-R, DVD+R DS, SL | 9.4GB |
| DVD-R SS, DL | 8.54GB (8.5GB) |
| DVD+R SS, DL | 8.55GB (8.5GB) |
| DVD+R DS, DL | 17.1GB |
| BD-R/RE SS, SL | 25GB |
| BD-R/RE SS, DL | 50GB |
| BD-R/RE DS, DL | 100GB |

SS: single-sided; DS: double-sided; SL: single-layer; DL: dual-layer

Module III

Expansion Cards

>> Circuit boards to expand the capabilities of a computer

>> Must match with the bus (PCI card on PCI slot, etc)

>> Four most common type cards: Video, Multimedia, I/O, Communication

>> **Video Adapters (Graphics Cards):**

- Enhance the video capabilities and qualities.
- Some cards contain processors for extreme graphics and speed.
- PCI, AGP and PCIe slots are commonly used for video cards.

>> **Multimedia cards:** Include sound card, TV tuner cards and video capture cards.

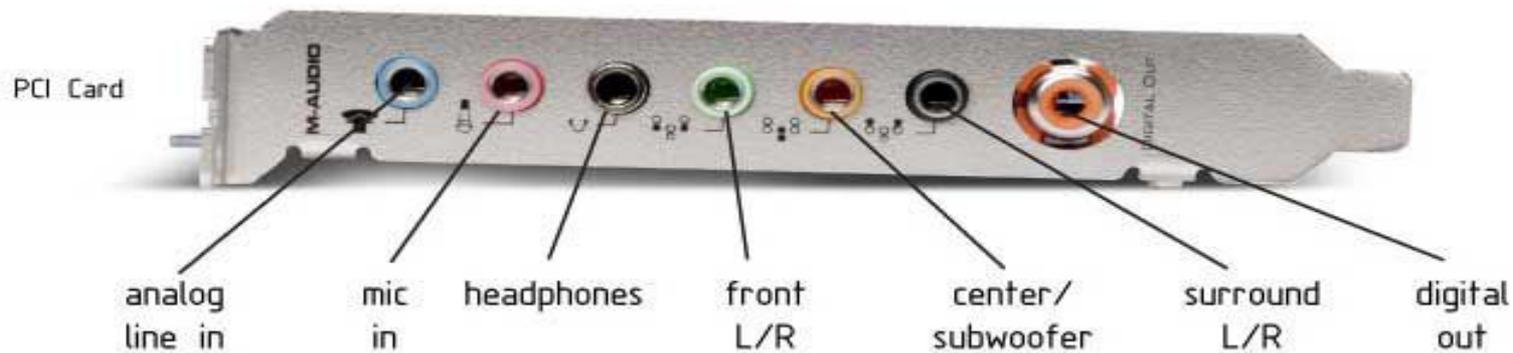
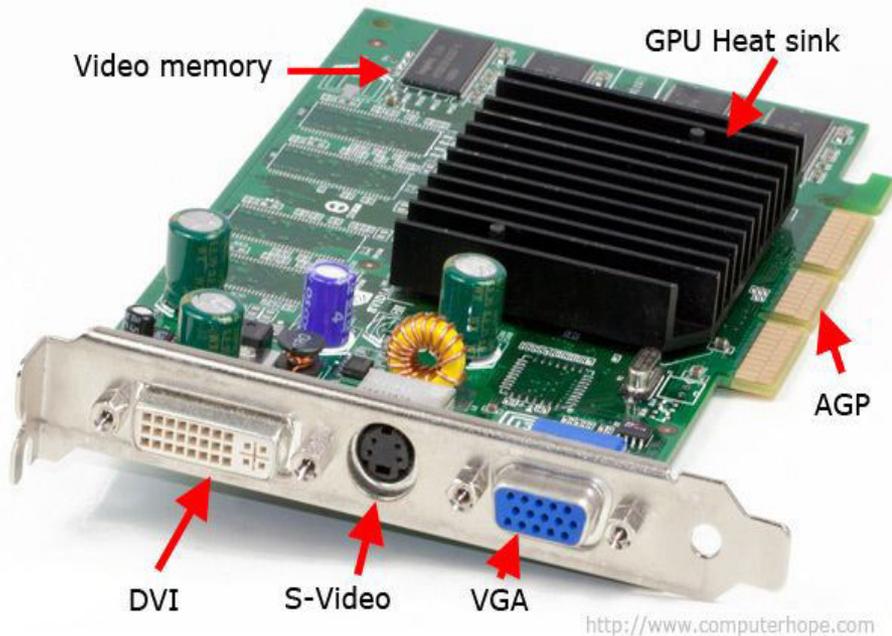
● Sound cards:

- In old systems, sound cards provide the basic sound facilities (headphone output, Auxiliary output and microphone input) and sometimes game ports too.
- In newer systems, basic sound capabilities are on board and enhanced sound is provided by special sound cards.

● TV Tuner cards:

- Connect to a broadcast signal such as cable television
- Can be internal or external.
- Act as video capture card as well.
- Comes with softwares to process the video streams.

Internal computer video expansion card



Sound Card



TV Tuner Card – PCI Interface



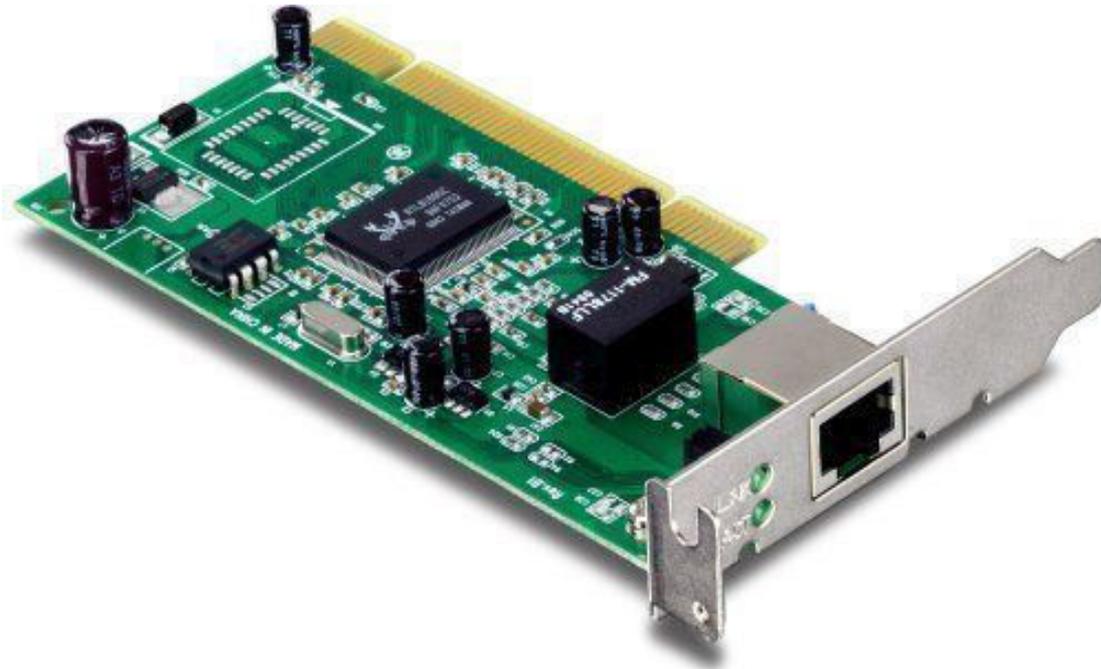
Parallel I/O card



I/O card for additional USB ports

Expansion Cards...

- >> I/O Cards: Serial and parallel ports, drive interfaces and SCSI interfaces.
- >> Communication cards: To communicate with the external networks. NIC, Modem.

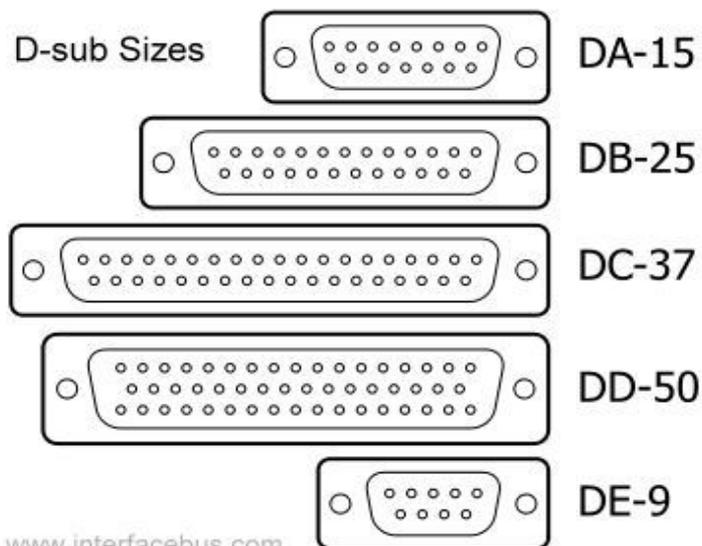


Characteristics of Connectors (ports)

D-subminiature Connectors (D-sub connectors):

- >> D shape to ensure correct orientation; no other keying
- >> Have two or three rows of pins (or holes).
- >> Represented by DXn where X ranges from A to E based on size and 'n' is the number of pins.

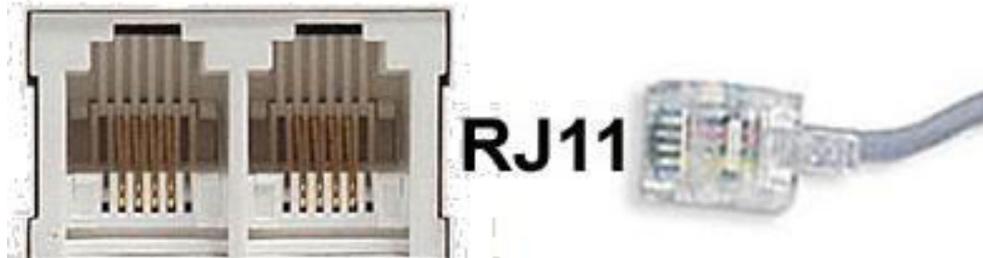
| Connector | Gender | Use |
|-----------|--------|--|
| DE9 | Male | Serial port |
| DB25 | Female | Parallel port |
| DA15 | Female | Game port or MIDI port |
| DE15 | Female | Video port (has three rows of five pins instead of two rows) |



Characteristics of Connectors (ports)...

RJ-Series:

- >> RJ: Registered Jack
- >> RJ-45: for Ethernet networks that use twisted-pair cabling.
- >> RJ-11: used most often on cables in telephones and in modems.

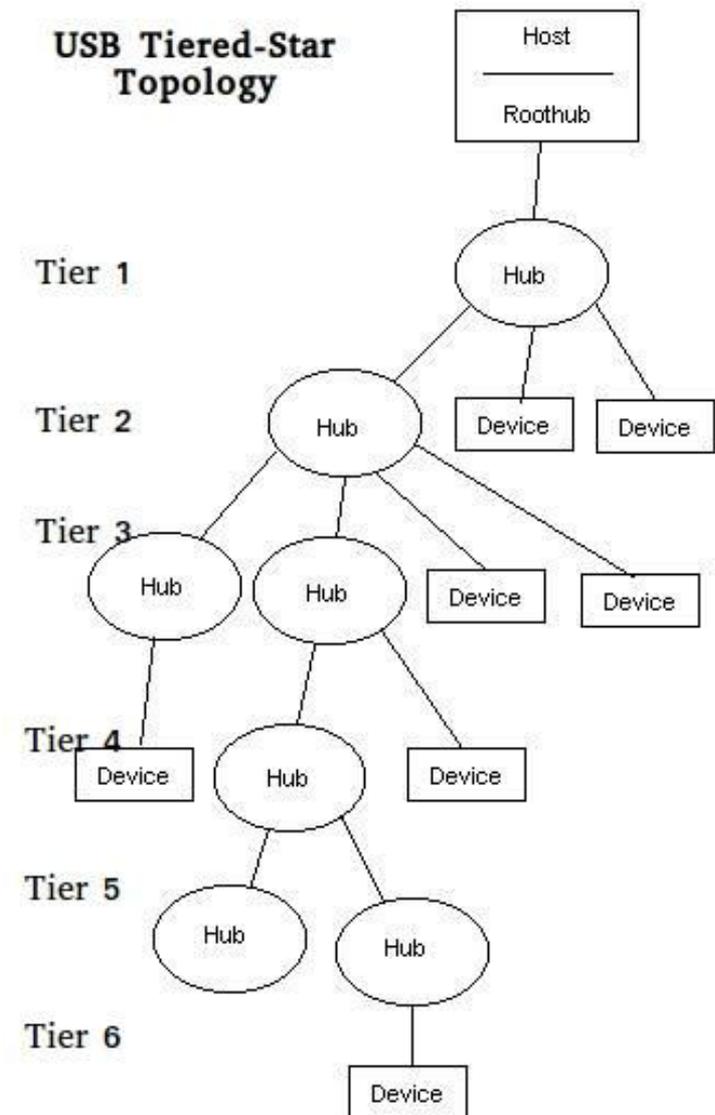


Characteristics of Connectors (ports)...

Universal Serial Bus (USB) port:

- >> Most common port today.
- >> A single USB port can handle upto 127 devices, but shares a common bus.
- >> Supports Plug-n-Play.
- >> Uses 'tiered star topology' with maximum number of levels limited to six.

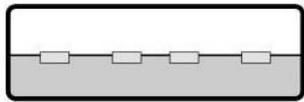
| Release name | Release date | Maximum transfer rate |
|--------------|---------------|-------------------------|
| USB 1.0 | January 1996 | Low Speed (1.5 Mbit/s) |
| USB 1.1 | August 1998 | Full Speed (12 Mbit/s) |
| USB 2.0 | April 2000 | High Speed (480 Mbit/s) |
| USB 3.0 | November 2008 | SuperSpeed (5 Gbit/s) |



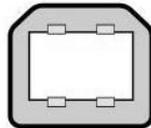
Characteristics of Connectors (ports)...

Universal Serial Bus (USB) port:

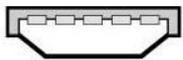
USB 1.1 - 2.0



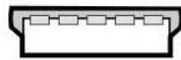
A



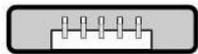
B



Mini-A



Mini-B

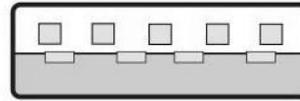


Micro-A

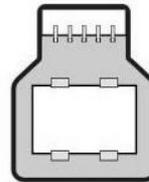


Micro-B

USB 3.0



A



B



Micro-B



Type-C

USB Icons:



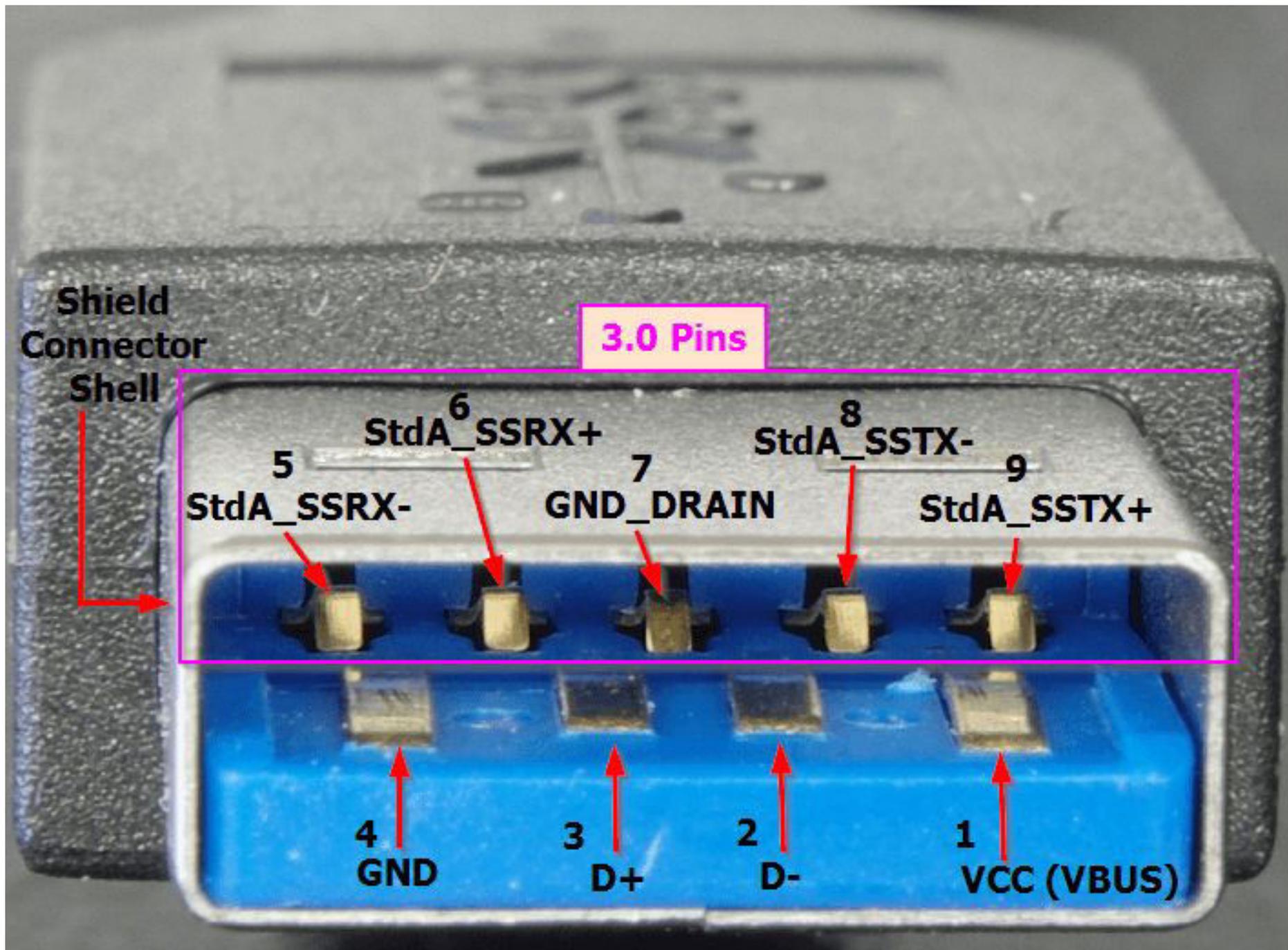
Supports USB 1.x



Supports USB 2.0 and 1.x



SuperSpeed USB 3.0 cable icon.



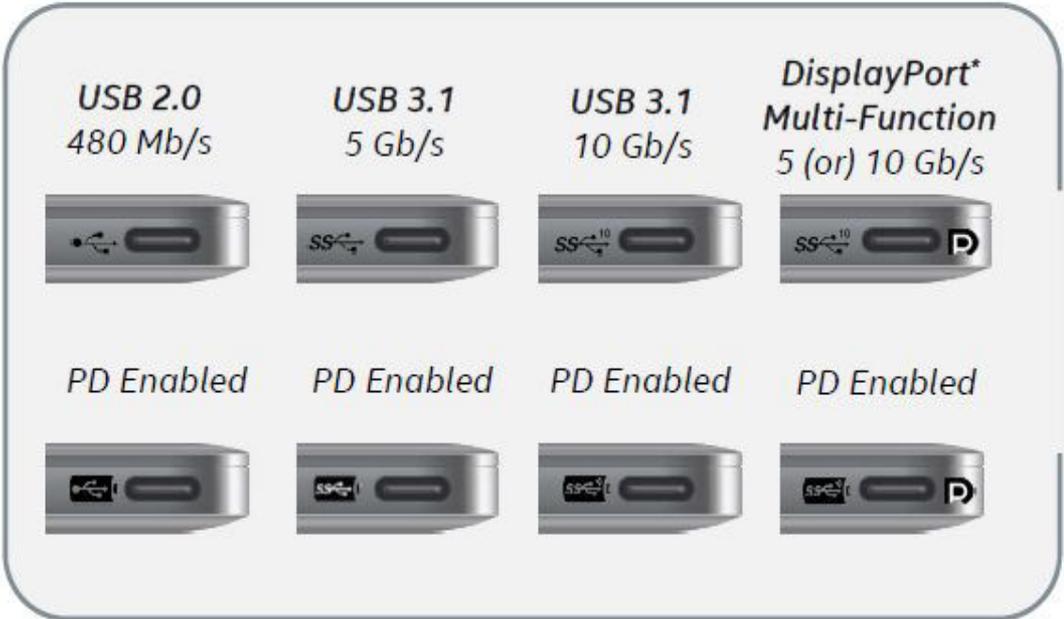
Common peripheral cables and interfaces...

Serial Interfaces: USB

- >> USB 1.0 (1.5Mbps), USB 1.1 (12Mbps), USB 2.0 (480Mbps) and USB 3.0 (5Gbps).
- >> Have types A, B and C
- >> The 24 pin Type-C is a symmetrical connector standard.
- >> A standard cable has Type A on one side and Type B on the other side.
- >> USB hub can be connected to the existing USB port to extend the number of ports.

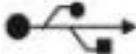
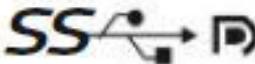
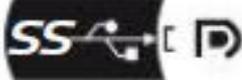
| Specification | Maximum Cable Length | Total Cable with 5 Hubs |
|---------------|----------------------|-------------------------|
| USB 1.0 / 1.1 | 3m | 18m |
| USB 2.0 | 5m | 30m |
| USB 3.0 | 3m | 18m |





40 Gb/s and PD Enabled

Thunderbolt™ 3 the USB-C that does it all

| | | USB 2.0 High Speed 480 MBit/s | USB 3.1 Gen 1 (formerly USB 3.0) Super Speed 5 GBit/s | USB 3.1 Gen 2 (formerly USB 3.1) Super Speed Plus 10 GBit/s |
|---|------------------------|---|---|---|
| Without Power Delivery | Without DisplayPort |  |  |  |
| | With DisplayPort | |  |  |
| With Power Delivery | Without DisplayPort |  |  |  |
| | With DisplayPort | |  |  |
| Thunderbolt 3 With Power Delivery and DisplayPort | | | |  |

Common peripheral cables and interfaces...

Serial Interfaces: USB 2.0 and 3.0 differences

Shielding: In USB 3.0 each pair in the cable assembly be shielded to withstand the electromagnetic interference (EMI) inherent with transmissions at higher frequencies.

Connectors: Although all connectors are compatible with all receptacles, to attain SuperSpeed performance, SuperSpeed connectors with five additional pins must be used on cables and receptacles. These 5 pins sit farther back and are accessible only to compatible interfaces.

Bursting & streaming: USB 3.0 supports continuous bursting & streaming, but USB 2.0 does not.

Duplex: USB 2.0 is a half-duplex technology, but USB 3.0 supports duplex communications.

Media access method: USB 2.0 peripheral devices must wait until polled by the host before transmitting data. USB 3.0 endpoints use an asynchronous transmission mechanism, similar to that of Ethernet, where data is transmitted at will.

Host control: The host (computer system) is the only device in the USB 2.0 specification that can control power management. The endpoints are the only devices that can participate in error detection and recovery as well as flow control. USB 3.0 endpoints can all control when they enter low-power mode to conserve power. Error handling and flow control are performed on each link in USB 3.0, not just at the endpoints.

Power : USB 2.0 provides a maximum of 100 milliamperes (mA) of current at low power and 500mA at high power. USB 3.0 provides 150mA and 900mA.

Characteristics of Connectors (ports)...

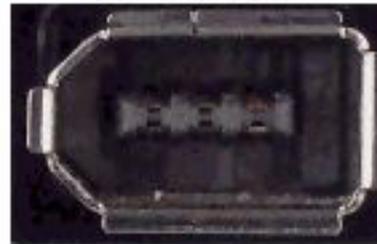
IEEE 1394 (FireWire) Port

- >> Developed by Apple.
- >> Serial bus for high-speed communications and real-time data transfer.
- >> peer-to-peer network mode with synchronous clock (hence called **isochronous**).
- >> 400Mbps to 3.2Gbps and higherspeed.
- >> Major use by digital video editing tools.
- >> Higher power output, reducing the need for external power to devices such as security cameras.

IEEE 1394(AKA Firewire, I-Link)



6-pin

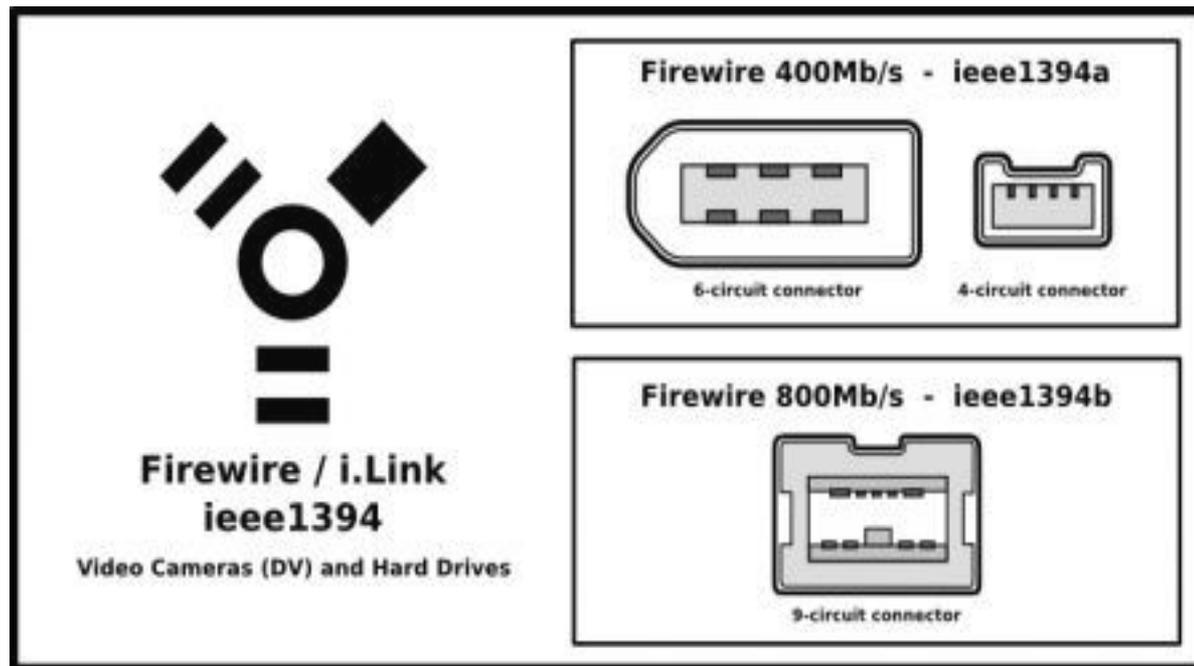


4-pin



Serial Interfaces: FireWire (IEEE 1394)

- >> It can provide 1.5A at up to 30VDC (ie, 45W); no need of external power to the connecting device.
- >> Two variants; FireWire 400 and FireWire 800.
- >> FireWire 400: Speed 400 Mbps. Works in half duplex. Supports 63 devices. Cable 4.5m
- >> FireWire 800 (IEEE 1394b): Speed 800 Mbps. Works in duplex. Supports 63 devices. Cable 4.5m with copper wire and 100m with optical fibre cables (speed upto 3200 Mbps).
- >> IEEE 1394c uses Cat 5e cables and RJ45 pins.



Characteristics of Connectors (ports)...

Infrared Port

- >> Used to communicate via infrared radiation.
- >> Mostly found on older computers.
- >> Very slow. Line-of-sight communication. Short distance.

Audio/Video Jacks:

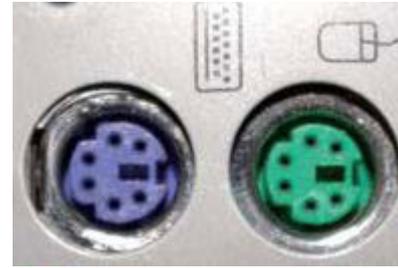
- >> RCA jacks and connectors are used to transmit video and audio information.
- >> On a video card, a yellow coloured jack is used for composite video.



Characteristics of Connectors (ports)...

PS/2 (Keyboard and Mouse)

>> 6-pin mini-DIN connector



Centronics Port

>> Primarily used in parallel printer connections and SCSI interfaces.

>> The centronics cable is connected to the printer at the centronics port and the other end of the cable to the parallel port of the computer.

>> Developed by the Centronics printer company.



Common peripheral cables and interfaces

Parallel Interfaces

- >> DB25 female connector on the computer.
- >> transfers data 8 bits at a time.
- >> faster than the original serial ports (RS232).
- >> generally used for printer communication.
- >> Three major types:

1. Standard Parallel Ports (SPP):

Transfer data in one direction only (from computer).

Found on the original IBM PC, XT, and AT.

150KBps speed at maximum 10 feet distance.

2. Bidirectional Parallel Ports (BPP):

Transmit and receive data.

Used for external CD-ROM drives and external parallel port backup drives.

3. Enhanced Parallel Ports (EPP or IEEE 1284):

Act as an extension to the main bus with the ability to send memory addresses as well as data.

Speed 600 KBps to 1.5 MBps.

- >> Enhanced Capabilities Port (ECP) can transfer data at 2MBps using DMA and buffering.

Parallel Port (DB25)



ComputerHope.com

Common peripheral cables and interfaces...

Serial Interfaces

>> Three main types:

1. Standard serial (RS-232)
2. Universal Serial Bus (USB)
3. FireWire (IEEE 1394).

>> Standard Serial (RS-232)

Present from the original IBM PC

They have either a DE9 or DB25 male port.

Maximum speed of 57Kbps and a maximum cable length of 50 feet.

Serial cables are of two types: **Standard** and **Null-modem**.

Standard serial cables connects a computer with a modem or printer.

Null-modem cable connects two computers directly without a modem.



Video Display Cables and Connectors

VGA (Video Graphics Array):

>> An analog standard introduced by IBM.

>> It has a 15 pin (3 rows) D-sub connector (DE-15) and cable.

>> The original VGA modes allowed for a maximum graphics resolution of 640×480 in only 16 (4-bit) colors. Today the minimum resolution and color depth (number of colors) is 1024×768 and 32-bit color.

VGA cable



VGA connector



Video Display Cables and Connectors

Digital Visual (or Video) Interface (DVI):

>> A digital standard but support analog standard too.

>> Three types:

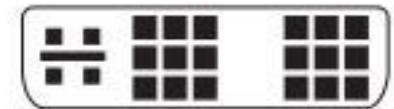
DVI-A: Analog. Source and display device must be analog.

DVI-D: Digital. Source and display device must be digital.

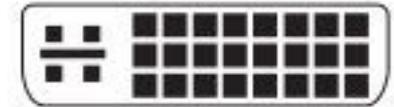
DVI-I: Combination of analog/digital. Source and display device must same type.

>> The DVI-D and DVI-I connectors come in two varieties: single link and dual link.

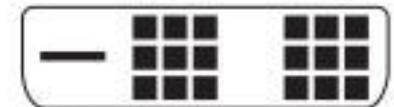
>> DVI-A and DVI-I are superior to VGA. Travel longer distances than VGA and are pin compatible to VGA using passive adapters.



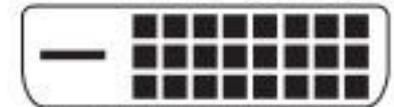
DVI-I (Single Link)



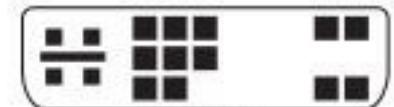
DVI-I (Dual Link)



DVI-D (Single Link)



DVI-D (Dual Link)



DVI-A



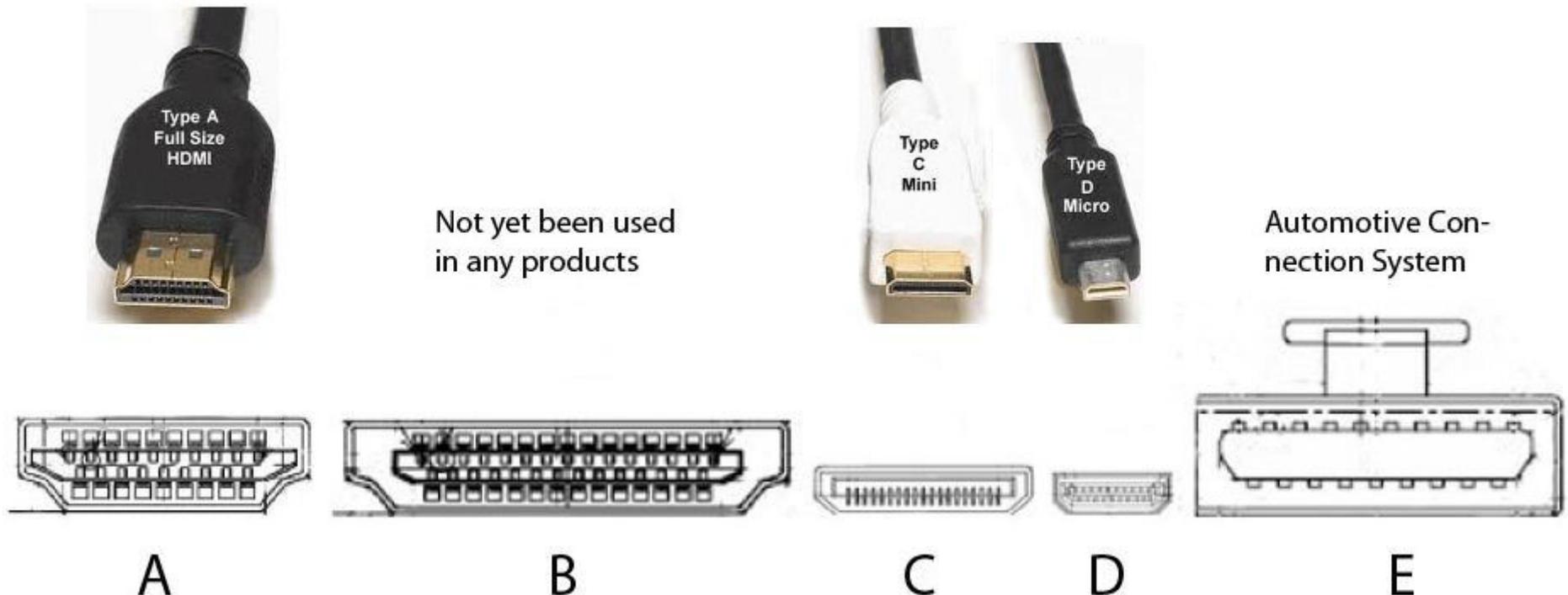
Video Display Cables and Connectors

High-Definition Multimedia Interface (HDMI):

>> A digital video technology that includes high-quality high-resolution uncompressed **video and audio**.

>> Also supports an optional Consumer Electronics Control (CEC) feature that allows all the connected devices to be controlled by a single remote control.

>> Different types: Type A, Type B, Type C (mini HDMI), Type D (micro HDMI) and Type E.



Video Display Cables and Connectors

Component Video:

>> Analog uncompressed video.

>> Transmitting the primary colour components (Red, Blue and Green) through separate wires (with similarly coloured RCA/BNC codes).

>> The brightness (greyscale) part of the signal (called Luma 'Y') is subtracted from Red and Blue ($P_r = R - Y$ and $P_b = B - Y$) and the green wire carries the Luma too.

>> This technology is also called YPbPr.

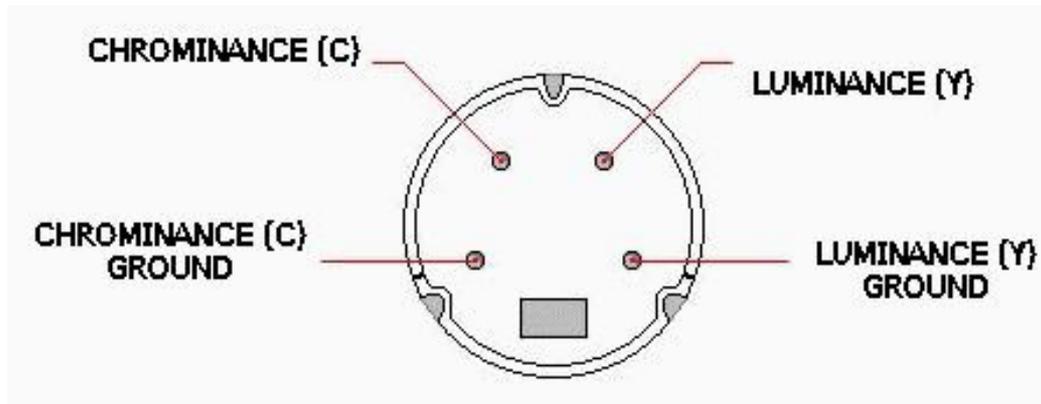
>> A digital version of this is called YCbCr.



Video Display Cables and Connectors

S-video (Separate Video)

- >> Transmits colour (chrominance) and brightness (luminance) separately.
- >> Use 7-pin mini-DIN and 4-pin mini-DIN connectors.
- >> 4-pin male connector is compatible with a 7-pin female connector.



Video Display Cables and Connectors

Composite Video:

- >> It combines all luma and chroma leads into one.
- >> It is the bottom type for analog signal; used in most of the T and DVD purposes.
- >> Less quality but great cost efficiency.
- >> Seen as yellow RCA connector.



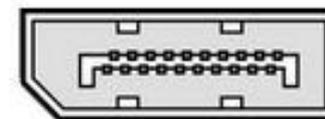
DisplayPort:

- >> By Video Electronics Standards Association (VESA)
- >> Uses less power than other digital interfaces and VGA.
- >> it can also carry audio, USB, and other forms of data.
- >> HDMI and DVI cables can be connected to DisplayPort using passive adapters.
- >> Cable can be 3m; but with cable-power it can be 33m.
- >> Intel and Apple combined DisplayPort and PCIe technologies to form a Thunderbolt Interface.
- >> Thunderbolt cable can be 3m long.
- >> Thunderbolt 1 and 2 use the same connector as Mini DisplayPort (MDP), whereas Thunderbolt 3 uses USB-C.
- >> It has the same label as the Lightning-bolt port.



DisplayPort

Video and Audio Port for
Home Theater Systems



MiniDP



Thunderbolt 1 and 2



Thunderbolt 3

Video Display Cables and Connectors

Coaxial:

- >> Coaxial cables are used to transfer video signals.
- >> Connectors are RCA, BNC and F connectors.

F Connector



Input Devices: Mouse

>> A hand-fitting device.

>> A motion-detection mechanism translates its physical two-dimensional movement into onscreen cursor motion.

>> Many variations exist, including trackballs, tablets, touchpads and pointing sticks.

>> Invented by Douglas Engelbart; but made the part of computer by Apple in its Macintosh.

>> First there was ball mouse, later came optical mouse.

>> Today wireless mechanism is used.

>> Today's mouse has two buttons, and a scroll wheel which acts as a third button.

>> On laptops, Touch pads (flat panels below the spacebar) and pointing sticks (eraser-like protrusions in the middle of the keyboard; seen in IBM Thinkpad series).

>> There are trackball which has a protruding rotating-ball and buttons on the top of the device to use in a tight space.



Pointing Sticks



Trackball

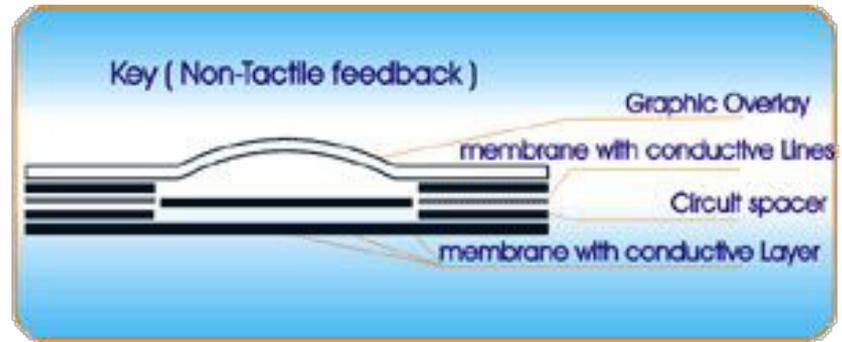
Input Devices: Keyboard

- >> Most common input device.
- >> QWERTY keyboard is widely used.
- >> Different types of keyboard technologies such as dome-switch, membrane type, scissor switch, mechanical switch, capacitive keyboards, etc.
- >> Mechanical switches and membrane type switches are commonly used in keyboards.
- >> Key switches generate typical codes of signal when they are depressed and these signals are sent to the PC.





Mechanical Keyboard key



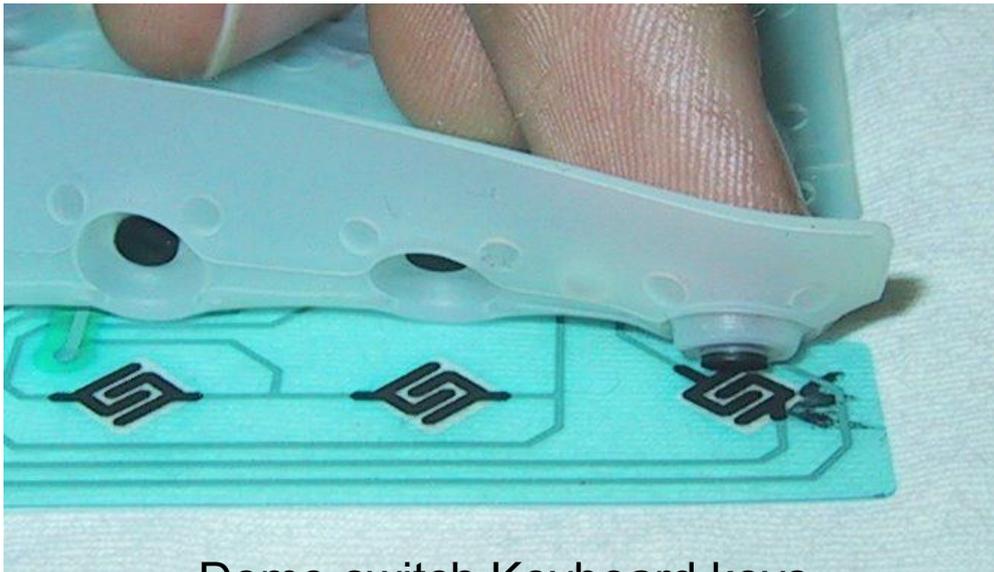
Membrane Keyboard key



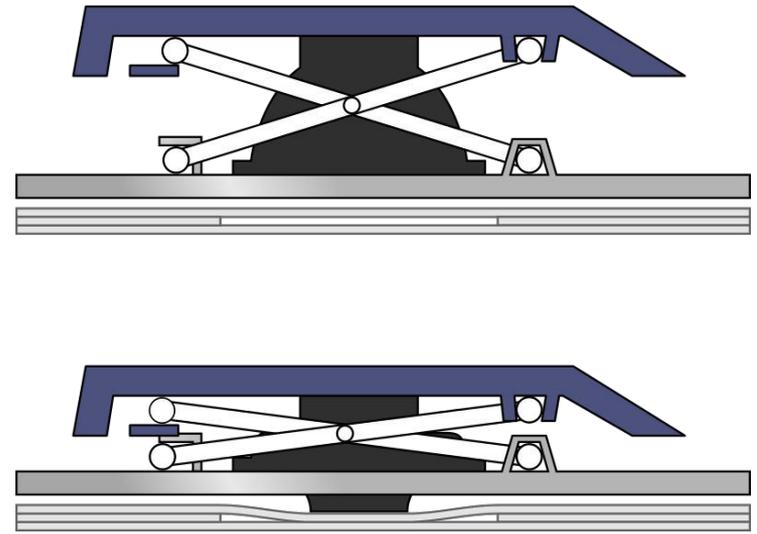
Mechanical Keyboard



Flexible membrane keyboard



Dome-switch Keyboard keys



Scissor-switch keyboard key



Dome-switch Keyboard



Scissor-switch keyboard

Input Devices: Scanner

>> Scans images/documents and sends as digital information to computer.

>> First used SCSI interface, now USB.

>> Working: The document is highlighted using an illumination method, lead the reflected light through a set of mirrors and colour filters to a lens which focuses the light into charge coupled devices (CCD), which converts the captured information into digital form. Here either the document or the head moves to scan the entire document.

>> Three types of scanners:

(a) Flat Bed scanner: The document is placed above a flat surface, the head moves from one end to the other.

(b) Sheet Fed scanner: Head remains stationary and the image is moved in front of the head. It occupies less space and it is less expensive.

(c) Hand Held scanner: Scan-head and the image will not move. The user moves the scanner above the image two-three times to get the full image. Quality low and depends on the skill of the user.



Input Devices: Barcode Reader

>> Commonly used in retail and other industrial sectors that manage inventory.

>> Use LEDs or lasers as light sources and can scan one- or two-dimensional barcodes.

>> Interfaces: RS232 or USB.

>> Commonly used to read product's identification number, a website's URL, a phone number, etc.



Digitizer (Digitizing Tablet)

>> Reproduce incredibly good artwork in digital form.

>> Place the analog artwork on top of a sensor and use a stylus to trace the artwork after choosing an onscreen “crayon” or “pen”.



Biometric Devices

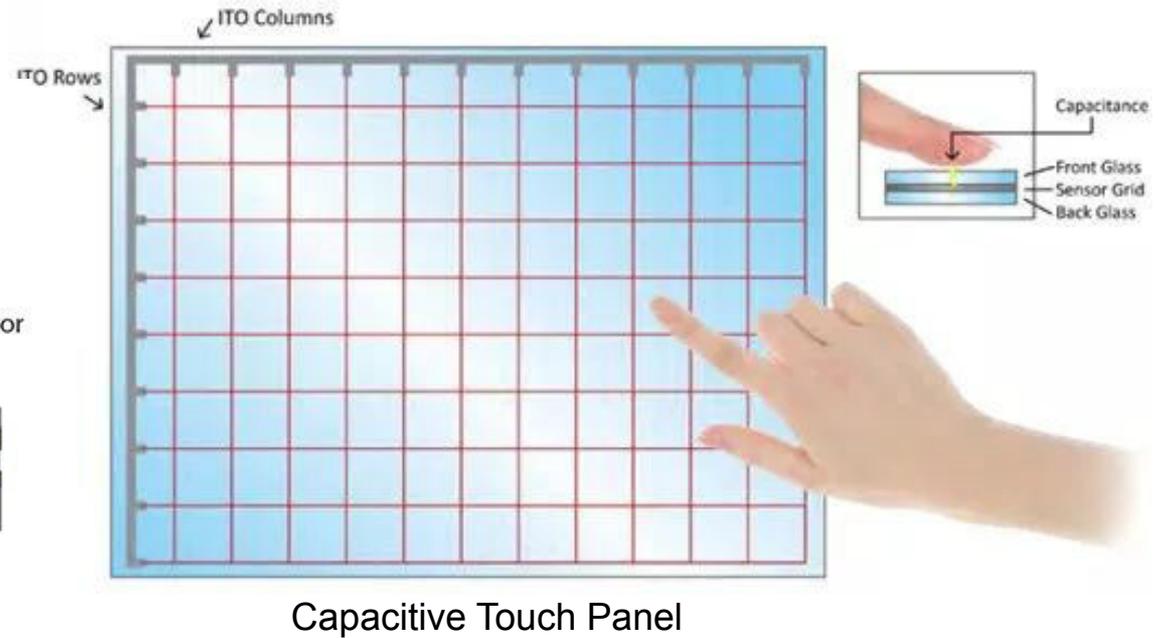
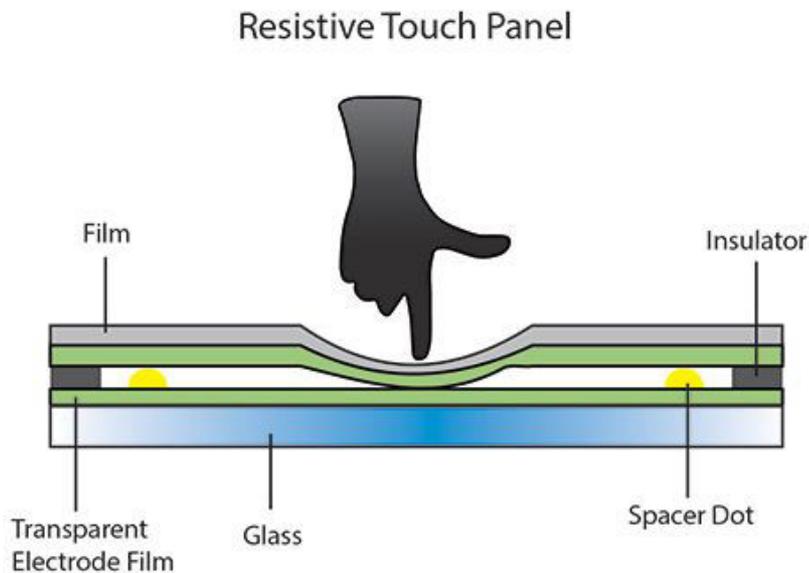
>> Fingerprint scanners, retinal and iris scanners, voice recognition devices, etc.

>> So powerful authentication mechanism that it is used to authenticate the user of a computer.



Input Devices: Touch Screen

- >> input device and output device.
- >> A touch sensitive layer is placed on the top an electronic display.
- >> User can give single- or multi-touch instructions with fingers or stylus.
- >> Used in some laptops, mobile phones, ATMs atc.
- >> Two types: resistive and capacitive touch screens.
- >> Capacitive interfaces are generally smoother to the touch than resistive interfaces.
- >> Capacitive touch screens can be controlled by the pad of the finger or a special stylus that mimics this soft part of the fingertip.
- >> Resistive interfaces usually have to be controlled by the fingernail or a plastic or metal stylus.



Input Devices: Gamepads and Joysticks

>> Used in computer games.

>> Connecting interfaces can be DA15 game port, the DB25/DE9 serial port, and the USB port.

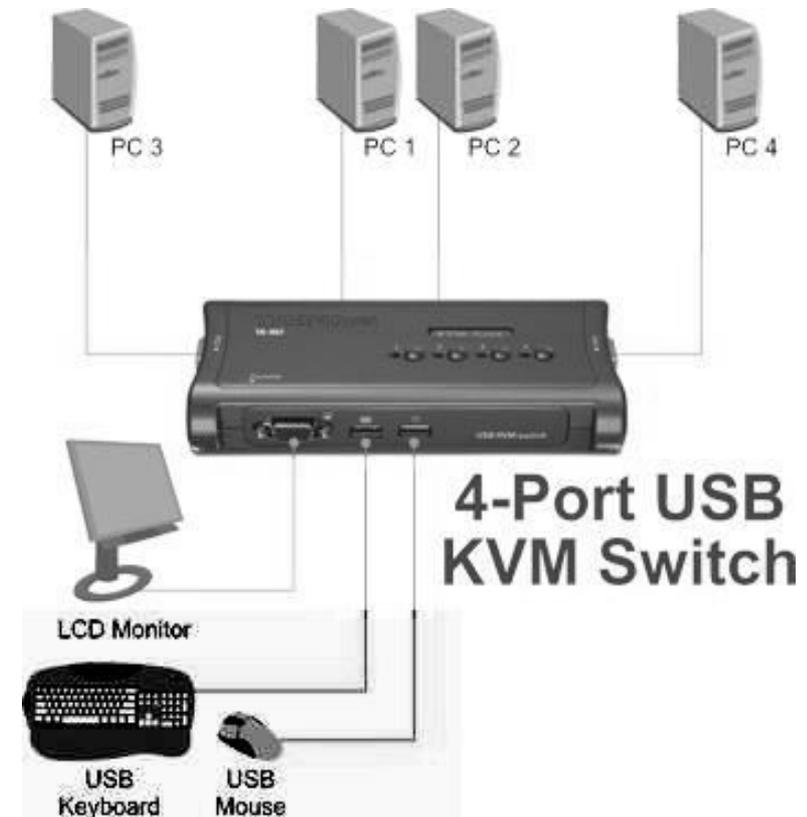


KVM Switch

>> It is not an input device, but it allows to switch between sets of input devices such as Keyboard, Video, and Mouse.

>> It allows to have multiple systems attached to the same keyboard, monitor, and mouse.

>> You can use these three devices with only one system at a time.



Multimedia Input Devices

Multimedia Input Devices:

Webcams

MIDI Devices (Musical Instrument Digital Interface)

Digital Cameras and Camcorders

Output Devices

The major output devices are printers, speakers and display devices.

>> Printers:

Impact printers – Dot matrix printer

Non-impact printers – Laser printer, inkjet printer

>> Speakers

Understanding Display Types and Settings: Video Display Types

The different VDU types are;

- 1) CRT
- 2) Liquid crystal display
- 3) LED displays
- 4) Plasma
- 5) OLED
- 6) Projection systems

CRT (Cathode Ray Tube) Displays

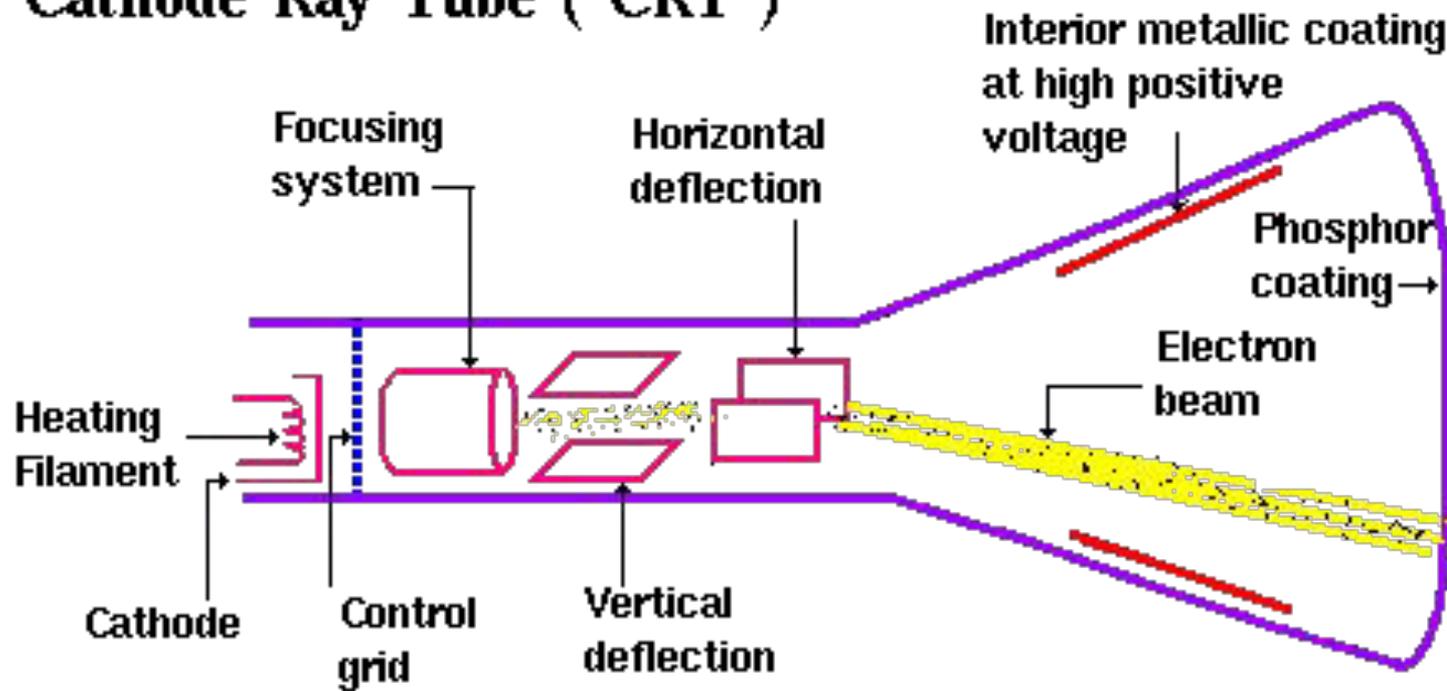
>> Old type of monitors

>> An electron gun shoots a beam of electrons toward the back side of the monitor screen from left to right, line by line, from top to bottom (the process is called scanning).

>> That surface is coated with phosphor particles which emits light based on the intensity with which the electrons strike.

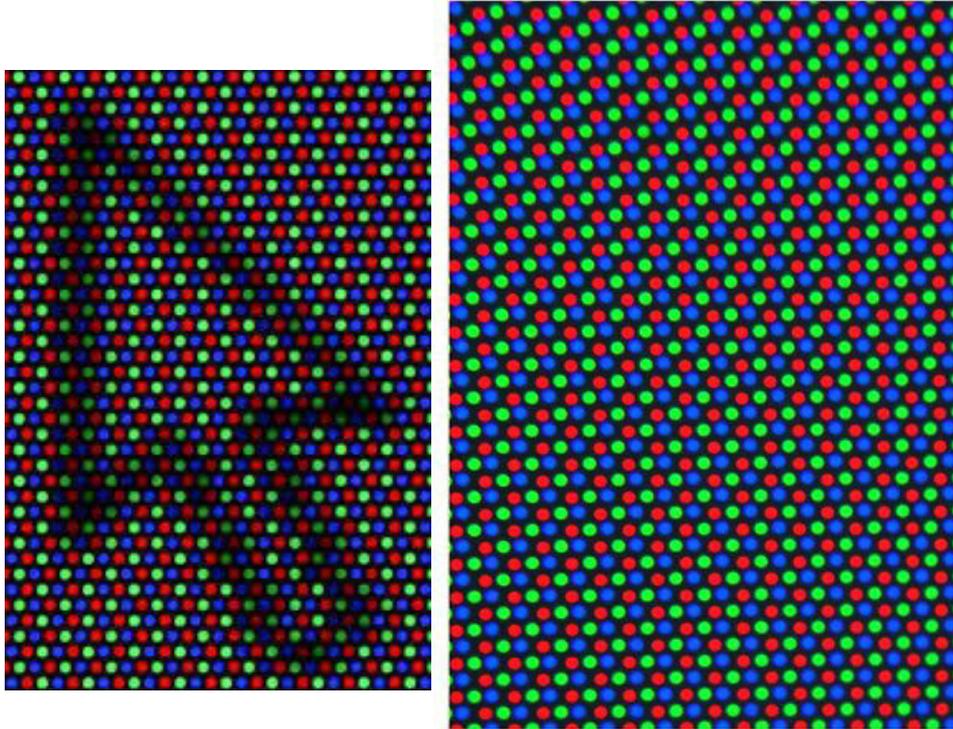
>> Color CRTs often use three guns, one each for red, green, and blue image components and the phosphor dots contains three subdots each with that particular coloured filter.

Cathode Ray Tube (CRT)



CRT (Cathode Ray Tube) Displays

>> The glow of the phosphors decay quickly, hence the scanning is repeated quickly (say 60 times/second) to sustain the glow.



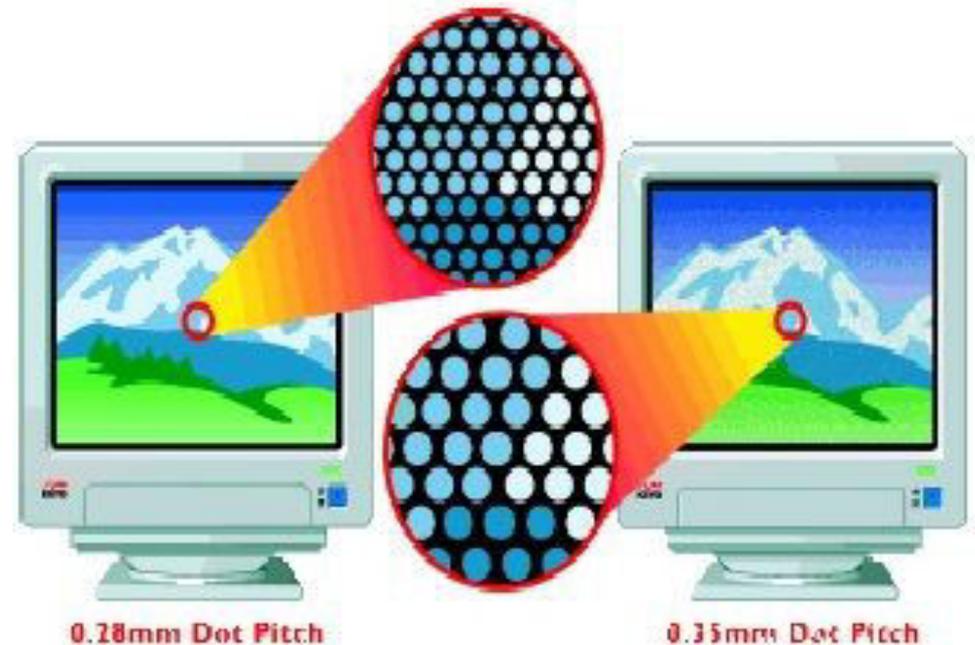
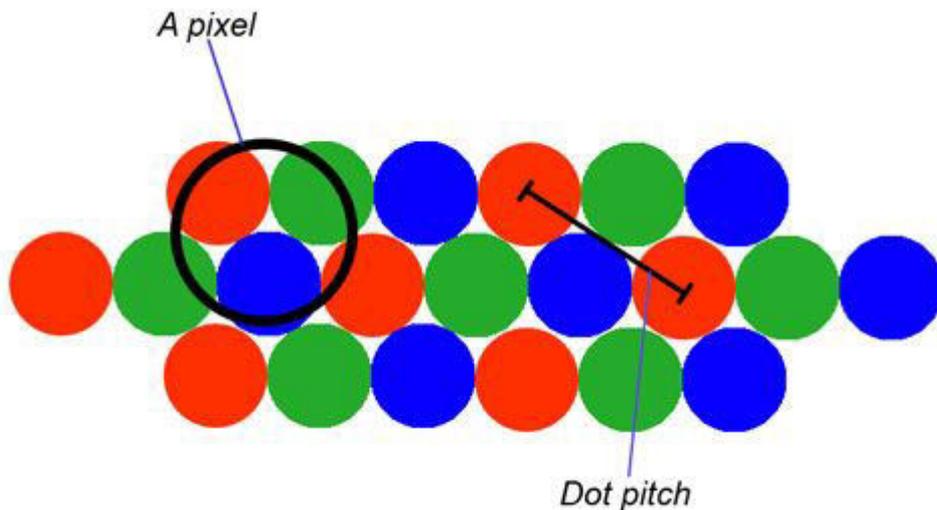
17" PC CRT Display

>> Two ways to measure a CRT monitor's image quality: dot pitch and resolution.

CRT (Cathode Ray Tube) Displays

Dot pitch (Pixel Pitch):

- >> Measurement between the same coloured spot in two vertically adjacent dot trios.
- >> It tells how “sharp” the picture can be.
- >> The lower the measurement in millimeters, the sharper the image can be.
- >> An average dot pitch is 0.28mm to 0.32mm.
- >> It is a physical characteristic of a monitor.



Dot Pitch of a Monitor (Closer the Dots, Sharper the Image)

CRT (Cathode Ray Tube) Displays

Resolution:

>> It is defined by how many software picture elements (pixels) are used to draw the screen.

>> High resolution means more information can be displayed in the same screen area.

>> disadvantage is that the same objects and text displayed at a higher resolution appear smaller and might be harder to see.

>> eg: 1024X768 means 1024 pixels across and 768 pixels down.

Colour Depth (bit depth)

The number of bits used to indicate the color of a single pixel.

There are different colour depths, from old days, such as 1 bit, 2 bit, 4 bit, 8 bit, 16 bit, 24 bit, 32 bit etc.



32 bit.png
4,294,967,296 colors
98 KB



8 bit.png
256 colors
37 KB (-62%)



4 bit.png
16 colors
13 KB (-87%)



2 bit.png
4 colors
6 KB (-94%)

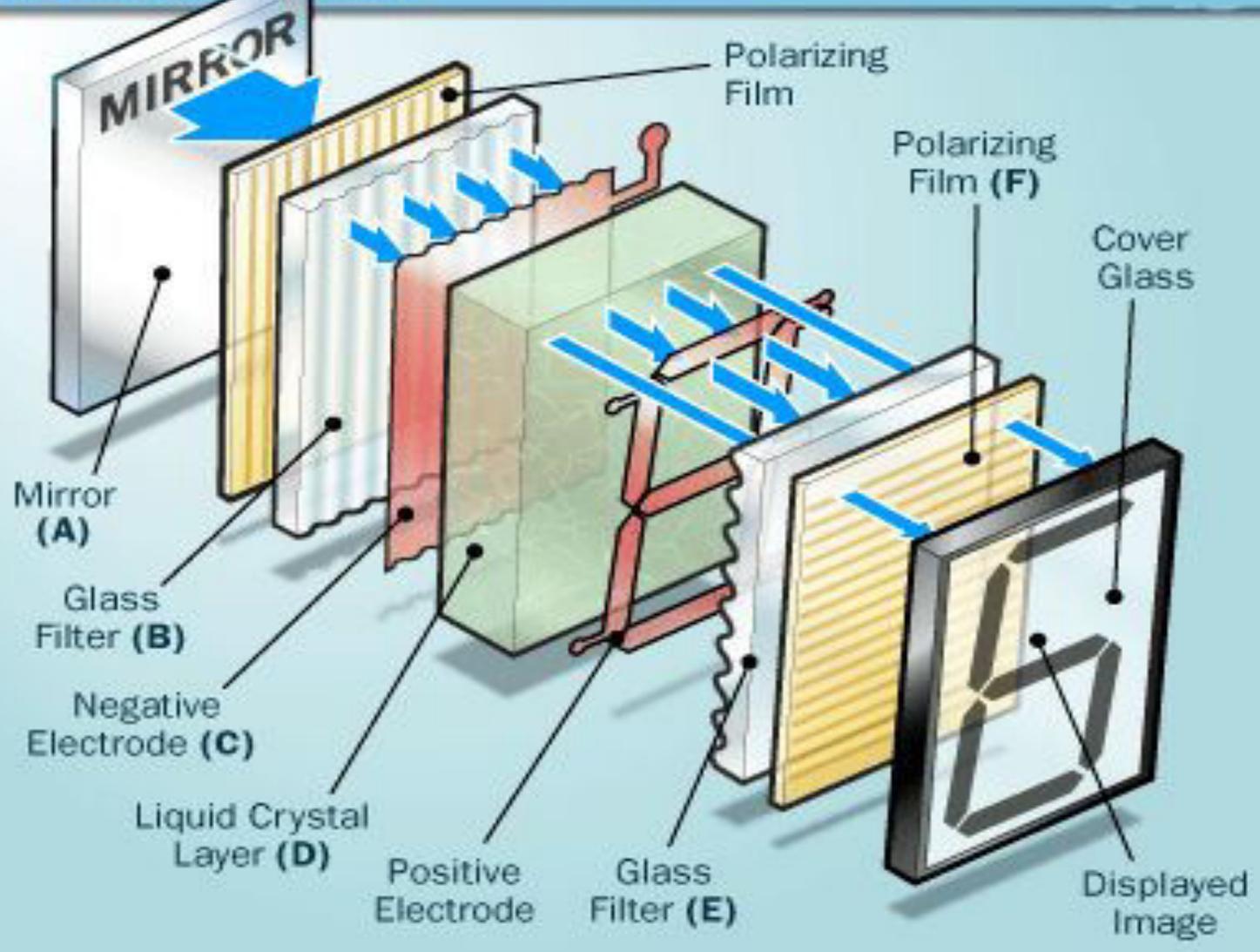


1 bit.png
2 colors
4 KB (-96%)

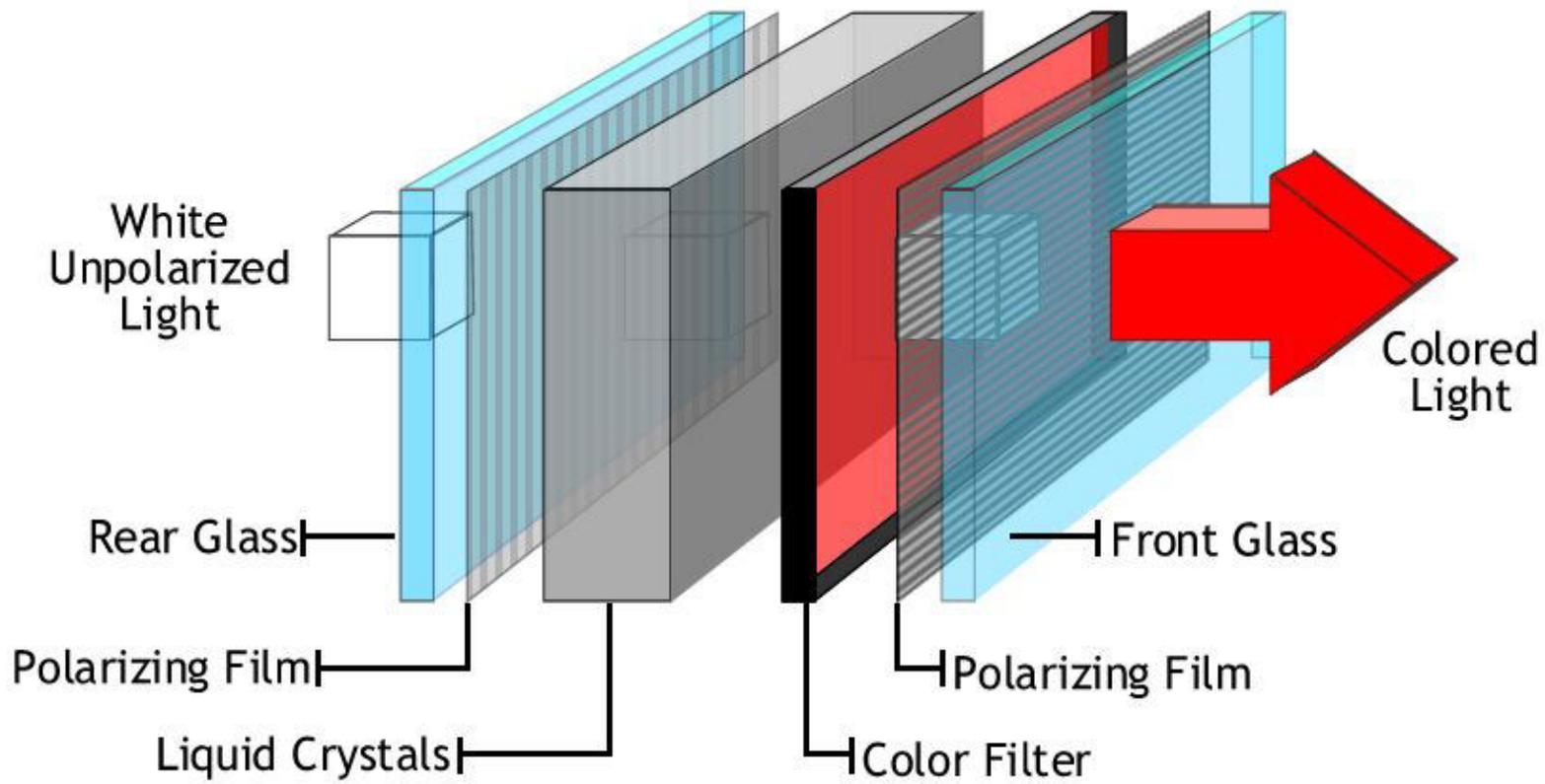
Liquid Crystal Display (LCD)

- A flat display technology for displays in digital watches and calculator to laptops.
- LCD screen is made of two sheets of a flexible polarizing material placed at right angle to each other and a layer of liquid crystal solution between the two.
- Passing electricity through the liquid crystal will change its polarization; and thus pass or block light coming from back to front.
- When light is blocked, that part seems black, and when light is passed that part seems bright.
- Calculators use reflections of the outside light as backlight.
- Most of the electronics LCD displays use fluorescent/LED light as back-light.
- Colour LCDs have three sub-pixels (RGB) for each pixel. These sub-pixels show colour because of the presence of colour filters with it.
- LCD monitors use fluorescent light for backlighting.
- Transistors are used to control the current flow through the liquid crystal.
- LCD Monitors are available in either *analog* (VGA) or *digital* interfaces (DVI).
- An LCD is available as a passive-matrix, active matrix or dual-scan.

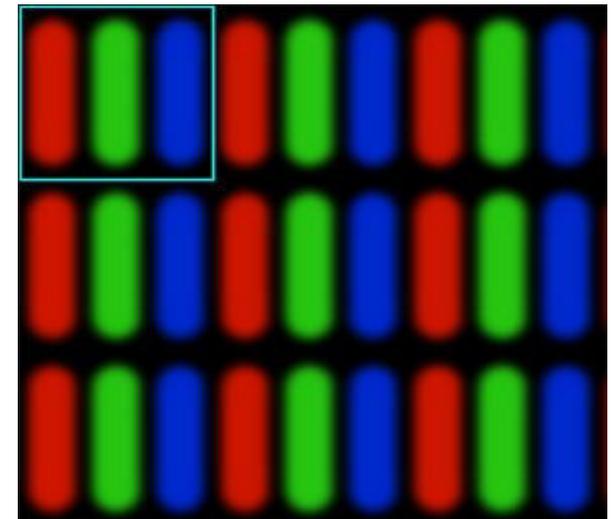
How LCDs Work



Calculator LCD parts



© Lon Koenig



LCD monitor subpixels

Liquid Crystal Display (LCD): Passive Matrix LCD

- Has a row of transistors running on the top of the screen (x-axes) as well as the left of the screen (y-axes).
- The number of transistors are defined by the maximum resolution of the monitor (say 800x600).
- For colour monitor, there will be separate transistors for each subpixel (RGB).
- To control each pixel, corresponding x and y transistors are used.
- If any transistor fails, the row or column of pixels will be unusable.
- The screen needs constant refreshing.
- Angles of visibility and response times are lower.
- Less contrast.
- Low response time to ON and OFF the transistor and hence low refresh rate. These bring a 'ghost effect' for moving objects.

Liquid Crystal Display (LCD): Active Matrix LCD (AMLCD)

- A transistor for **each RGB subpixel** of a pixel and turns ON/OFF by selecting corresponding row and column.
- Does not need constant refreshing as the transistor holds electricity until the next image frame appears.
- Brighter screen and colourful display than passive-matrix display.
- Great viewing angle and faster screen updates than passive matrix display.
- But more expensive and consumes more power.
- Since these displays use very thin film of transistors, these displays are also called **Thin Film Transistor (TFT) LCDs**.

Dual Scan LCD:

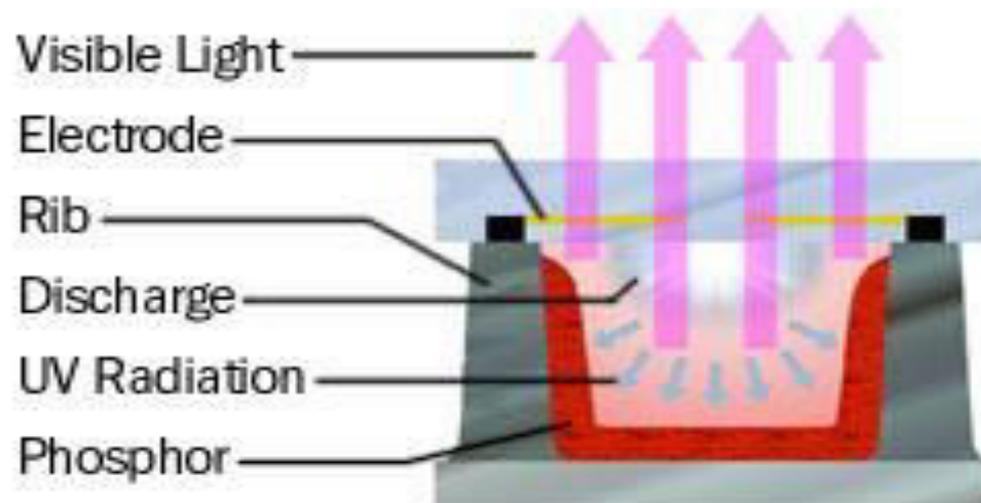
- It is a passive LCD technology in which a screen is divided into two sections which are simultaneously refreshed giving faster refresh rate than traditional passive matrix screens.
- Low power consumption compared to Active Matrix LCDs.
- but less sharpness, brightness and poor display quality.
- Such screens are unsuitable for viewing movies.

LED (Light Emitting Diode) Displays

- They are LCD displays with LED backlight.
- Separate LEDs for each pixel, hence more intelligent backlighting and hence more quality images.
- Since LED used DC voltage, it is easy for use with portable systems like laptop computers which run on DC.

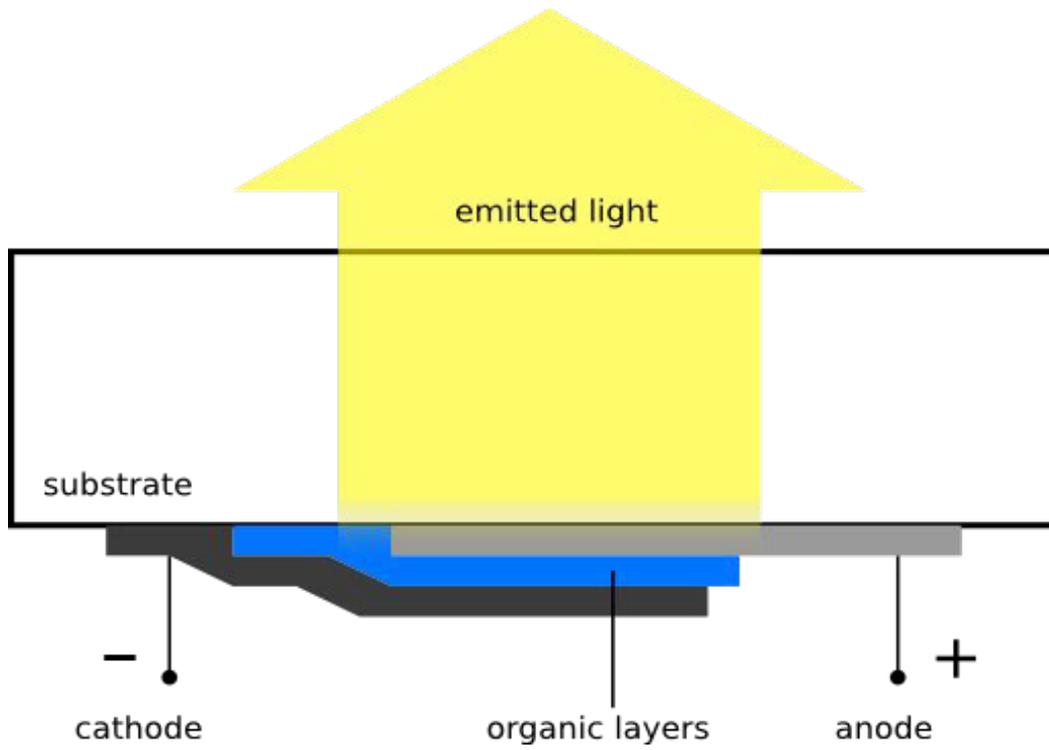
Plasma Display Panels (PDP)

- plasma refers to a cloud of ionized (charged) particles—atoms and molecules with electrons in an unstable state. They emit energy to achieve stable state. This energy hits phosphor particles and emits light.
- Plasma display panels (PDPs) create just such a cloud from an inert gas, such as neon, by placing electrodes in front of and behind sealed chambers full of the gas and vaporized mercury. The chamber is coated inside with phosphor particles.
- Subpixels are provided with RGB filters.
- Does not need backlighting.
- Due to pressurised gas, they are not used in high altitude areas like aircrafts.
- Quality degrades over time.



OLED (Organic Light Emitting Diode) Displays

- An Organic light-emitting (electroluminescent) compound is placed in between two electrodes.
- When electricity passes between the electrodes through this compound, it emits light.
- In OLED displays, such very small forms are used for each subpixel (RGB colour with filters) with one opaque electrode at the back and one thin transparent electrode at the front.
- The opaque back electrode allows a rich black display when the OLED cell is not lit.
- Advantages:
 - No backlighting needed.
 - Less power consumption than LED LCD
 - In darker surroundings, OLED displays produce better images than do LCD panels.
- Disadvantages:
 - When the images progress towards all white, the power consumption increases and goes over that of LED displays.
 - Costly than LCD -LED displays.
- Two types: Active Matrix OLED (AMOLED) and Passive Matrix OLED (PMOLED). AMOLED has better quality than PMOLED but needs more electrodes.
- The electrodes can be made flexible; resulting in **flexible displays**.



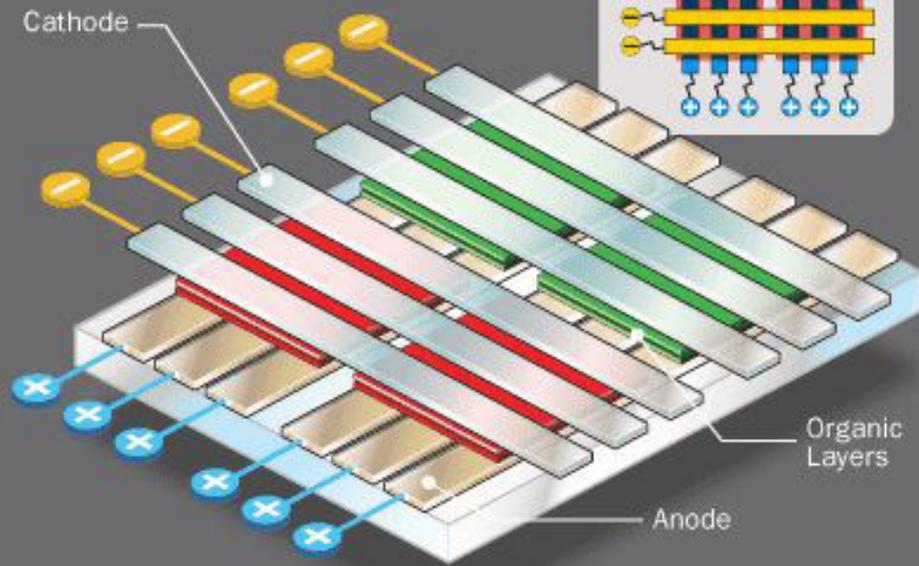
OLED working



Flexible OLED panels

OLED Passive Matrix

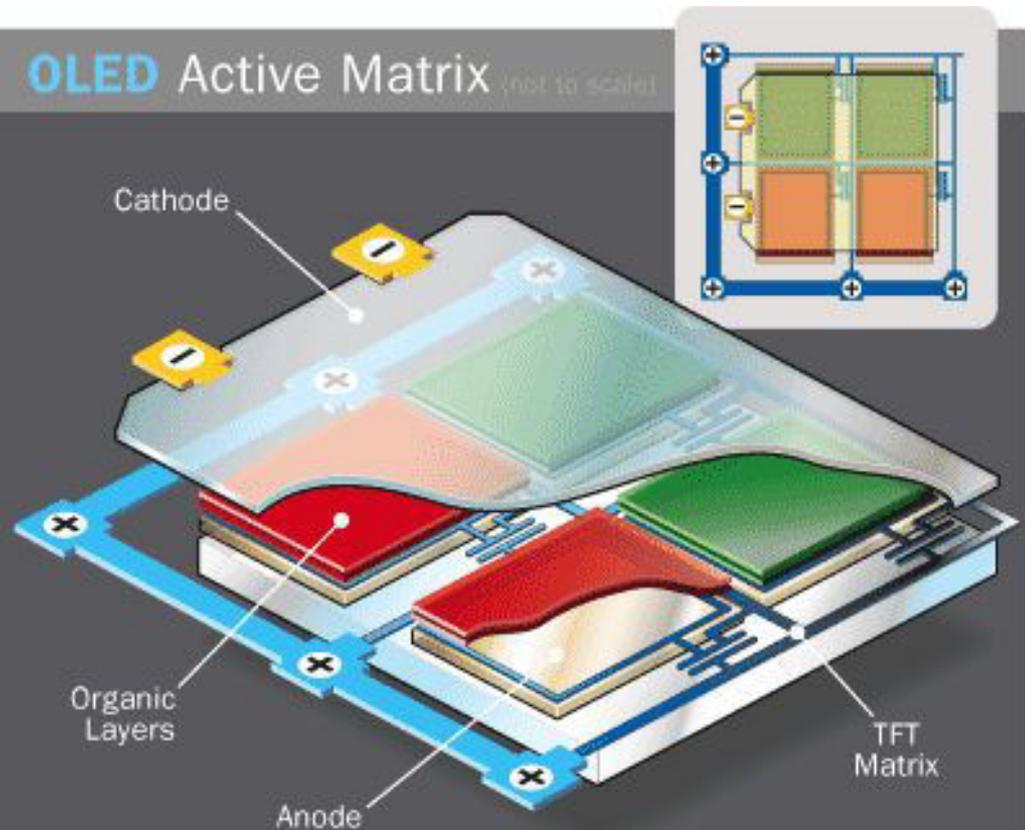
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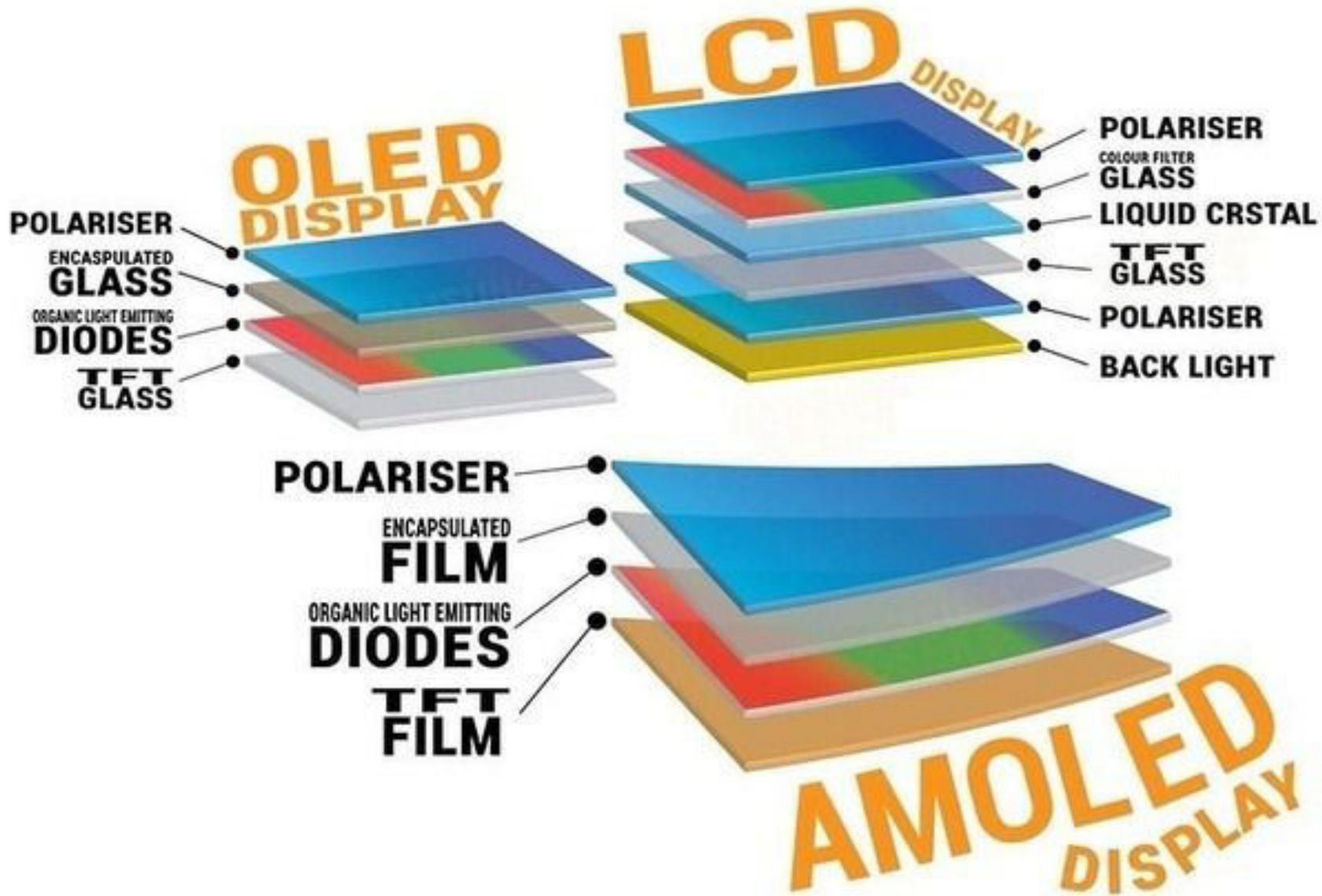
©2005 HowStuffWorks

OLED Active Matrix

(not to scale)



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Projection Systems (Projectors)

- Condensed video systems that projects the images onto external screens.
- Can be used as desk-mount or ceiling-mount systems.
- Rear-projection systems are also available which projects the images from the back side of the screen.
- Mainly two types of projectors: DLP (digital light processing), and LCD (liquid crystal display).

Video Settings

Refresh Rate

- It is the vertical scan frequency.
- Specifies how many times in one second the scanning beam of electrons redraws the screen in CRTs.
- Measured in Hertz.
- For small CRT monitors 60Hz to 72Hz, but for larger CRT monitors, it may be 85Hz or higher; it is based on the decay rate of phosphor light-emission
- For LCD, there is no pixel decay, but affects the flow of frames.
- Refresh rate selected must be supported by both the display device and the display adapter.

Video Settings

Resolution

- Number of horizontal dots (pixels) by the number of vertical dots that make up the rows and columns of the display. For example, 640x480 (VGA), 1920x1080 (HD 1080).
- With more pixels, the image can be viewed in greater detail.

Multiple Displays

- For some applications, two monitors on the same computer.
- The adapter must support both displays simultaneously.

Degauss

- In CRT, external magnetic field can affect the image production.
- Degaussing is used to neutralize that effect.
- Not used in LCDs.

Understanding Video Standards and Technologies

- Major differences occurs in two areas:
 1. The highest resolution supported
 2. The maximum number of colors in their palette.
- Both are directly related to the amount of memory on the adapter or used by the adapter.
- Based on evolution, there are five groups of video standards:
 1. Monochrome
 2. CGA (Color Graphics Adapter)
 3. EGA (Enhanced Graphics Adapter)
 4. VGA (Video Graphics Array)
 5. DVI, HDMI, and other modern digital video
- The amount of memory used to implement the pre-VGA adapters was fixed
- Hence the resolution and number of colors supported by these cards was fixed as well.
- Newer standards can change the amount of video memory.

Understanding Video Standards and Technologies

- **Monochrome:**
 - First video technology and the adapter was called Monochrome Display Adapter (MDA).
 - Fine for DOS.
 - Supported text only and the resolution was 720x350.
- **CGA (Color Graphics Adapter):**
 - First colour adapter.
 - CGA displays 16-color text in resolutions of 320x200 (40 columns) and 640x200 (80 columns), but it displays 320x200 graphics with only four colors.
- **EGA (Enhanced Graphics Adapter):**
 - By IBM.
 - EGA could display 16 colors out of a palette of 64.
- **VGA (Video Graphics Array):**
 - By IBM with its PS/2 series computers.
 - VGA uses 6 bits to specify each color, instead of the 8 that is the standard today.
 - 256KB of video memory on board and could display 16 colors at 640x480, 640x350, and 320x200 pixels.

Advanced Video Resolutions and Concepts

- Advancements after the VGA adapter occurred only in the memory and firmware of the adapter, not the connector or its fundamental analog functionality.
- SVGA (Super VGA):
 - By Video Electronics Standards Association (VESA). it could support 16 colors at a resolution of 800x600 (the VESA standard), but it soon expanded to support 1024x768 pixels with 256 colors.
- XGA (Extended Graphics Array):
 - By IBM, but it was available only as a Micro Channel Architecture (MCA) expansion board.
 - XGA could support 256 colors at 1024x768 pixels or 65,536 colors at 800x600 pixels.

Non Adjustable Characteristics

- **Native Resolution**

- One of the peculiarities of LCD, plasma, OLED, and other flat-panel displays is that they have a single fixed resolution, known as the **native resolution**.
- Trying to display a resolution other than the native resolution *may* result in a distortion of the image on the screen.

- **Contrast Ratio**

- Measure of the ratio of the luminance of the brightest color to that of the darkest color the screen is capable of producing.
- A display with a low contrast ratio won't show a "true black" very well the other colors will look washed out when you have a light source nearby.
- Lower contrast ratio mean that you'll have a harder time viewing images from the side as compared with being directly in front of the display.
- Ratios for smaller LCD monitors and televisions typically start out around 500:1
- Common ratios for larger units range from 20,000:1 to 100,000:1

Custom Configuration PCs and Workstations

- **Graphic and CAD/CAM Design Workstations**

- To create high-quality copy consisting of professional text and graphical images.
- This output is used in advertising, marketing, and other forms of specialized documentation.
- Used in the design of engineering and architectural documentation, including blueprints in both two and three dimensions.
- Need-
 - i. CPU enhancements
 - ii. Video enhancements
 - iii. Maximized RAM

- **Audio/Video Editing Workstations**

- Need-
 - i. Video enhancements
 - ii. Specialized audio
 - iii. Specialized drives

- **Virtualization Workstations**

- Need-
 - i. CPU enhancements
 - ii. Maximized RAM

Custom Configuration PCs and Workstations

- **Gaming PCs**
 - Need-
 - i. CPU enhancements
 - ii. Video enhancements
 - iii. Specialized audio
 - iv. Enhanced cooling

- **Home Theater PCs (HTPC)**
 - Need-
 - i. Video enhancements
 - ii. Specialized audio
 - iii. Special chassis
 - iv. TV tuner requirement

- **Home Server PCs**
 - Need-
 - i. Media streaming capabilities
 - ii. File sharing services
 - iii. Print sharing services
 - iv. Gigabit NIC
 - v. RAID array

Standard Thick Clients

- Must meet only the basic standards that any system running a particular operating system and particular applications.
- The operating system requires a certain amount of RAM for its installation and a certain amount of hard drive space.

Thin Clients

- Especially small so that the bulk of the data processing occurs on the server.
- Thin client resembles a dumb terminal, only displaying graphical user interface output to the monitor and relaying input from the mouse and keyboard back to the server.

Printers

- Electromechanical devices to put information from the computer onto paper.
- Two major classifications
 - Impact printers (Eg: Dot matrix printers)
 - Non-impact printers (Eg: inkjet or bubble-jet, laser printers)

Impact Printers

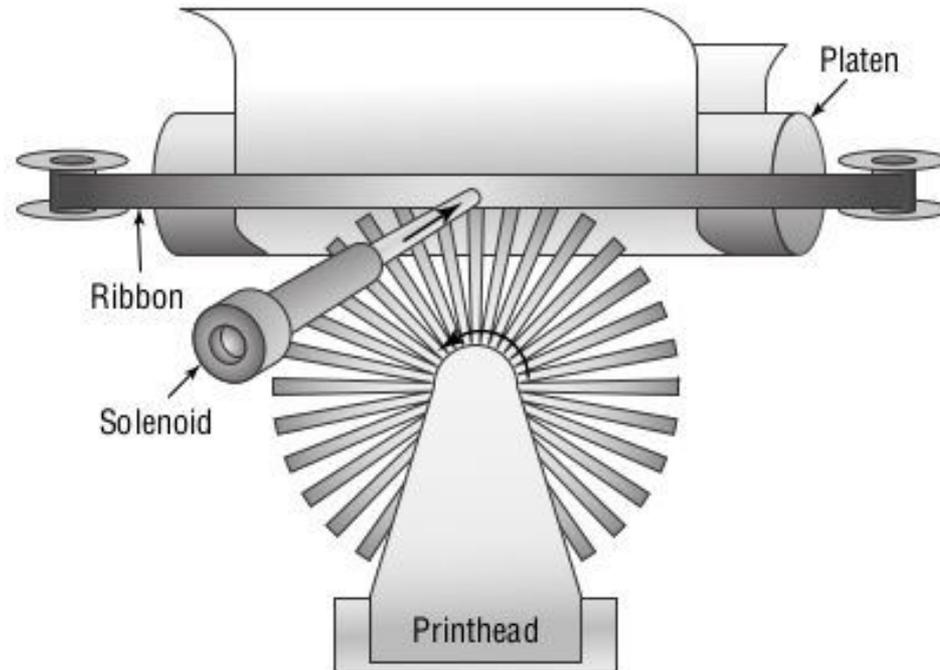
- Use some form of impact and an inked ribbon to make an imprint on the paper.
- Use a paper feed mechanism called a tractor feed that requires special paper.
- Two major types of impact printers: daisy wheel and dot matrix.

Non Impact Printers

- Does not operate by striking a head against a ribbon.
- Very less noise compared to impact printers.
- Examples: Laser and inkjet printers.

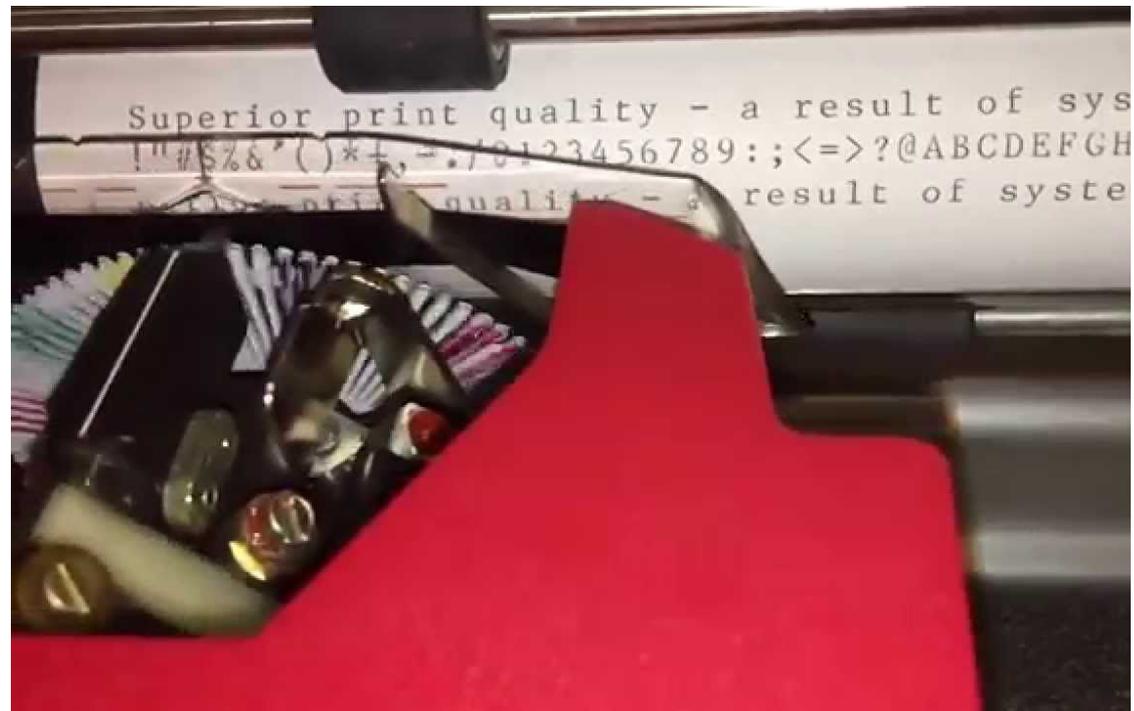
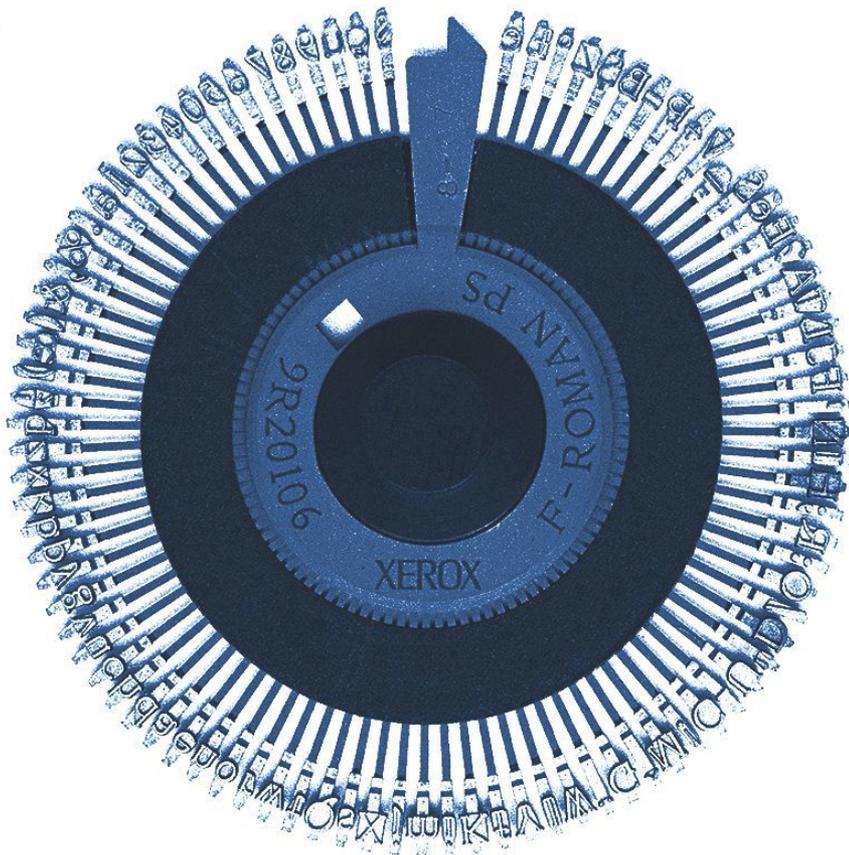
Daisy-wheel Printers

- One of the oldest technologies.
- Contains a wheel with raised letters and symbols on each “petal”.
- When the printer needs to print a character, it sends a signal to the print head mechanism that contains the wheel.
- The print head rotates the daisy wheel until the required character is in place.
- An electromechanical hammer (called a solenoid) then strikes the back of the petal containing the character.
- The character pushes up against an inked ribbon that ultimately strikes the paper, making the impression of the requested character.



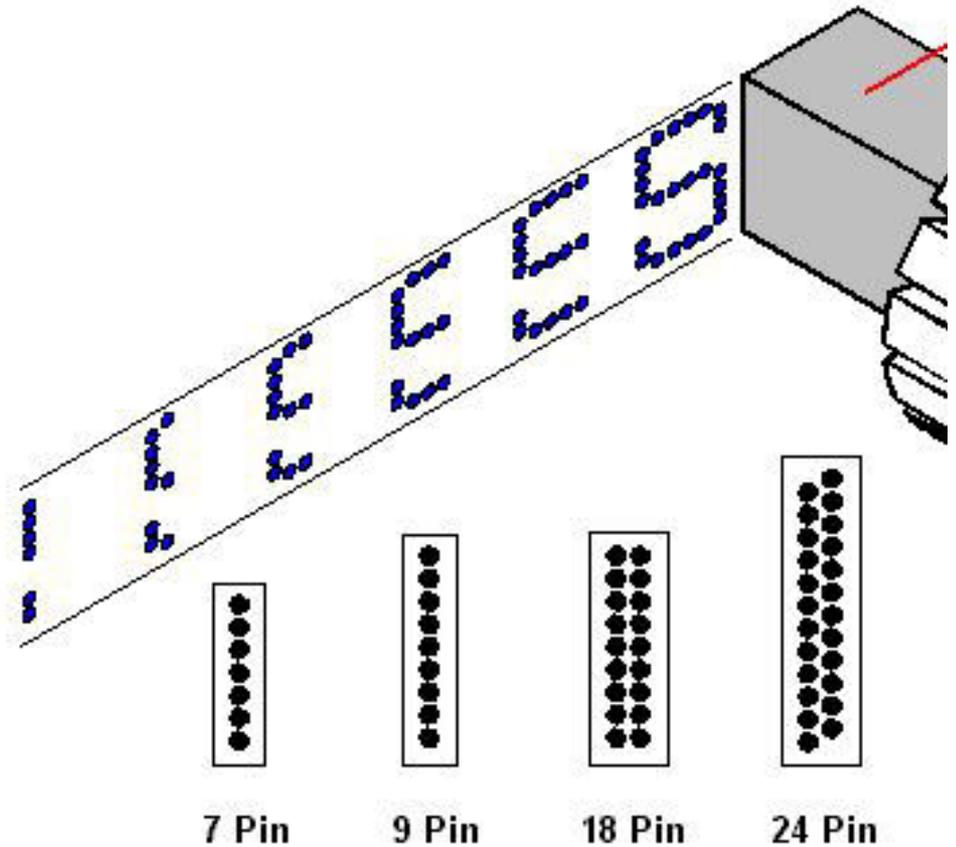
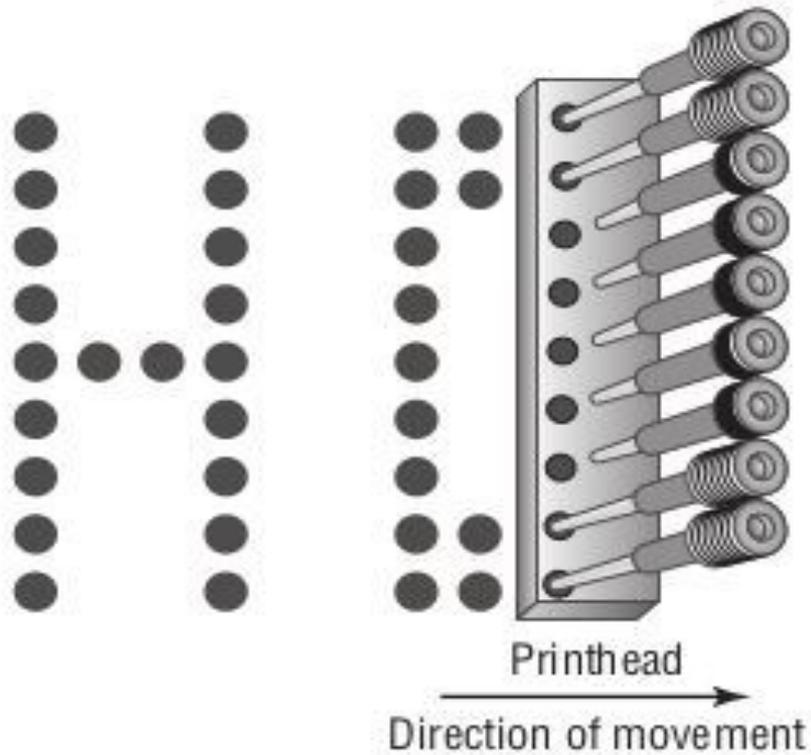
Daisy-wheel Printers

- Speed is rated by the number of characters per second (cps) they can print.
- Disadvantages
 - Print only two to four characters per second.
 - Makes a lot of noise when printing.
- Advantages
 - Can print on multipart forms (like carbonless receipts).
 - Relatively inexpensive



Dot-matrix Printers

- Works just like daisy-wheel printer
- But instead of character-imprinted wheel, the print head contains a row of pins.
- These pins are triggered in patterns that form letters and numbers as the print head moves across the paper.



Dot-matrix Printers

- The pins in the print head are wrapped with coils of wire to create a solenoid and are held in the rest position by a combination of a small magnet and a spring.
- To trigger a particular pin, the printer controller sends a signal to the print head, which energizes the wires around the appropriate print wire.
- This turns the print wire into an electromagnet, which repels the print pin, forcing it against the ink ribbon and making a dot on the paper.
- The arrangement of the dots in columns and rows creates the letters and numbers.

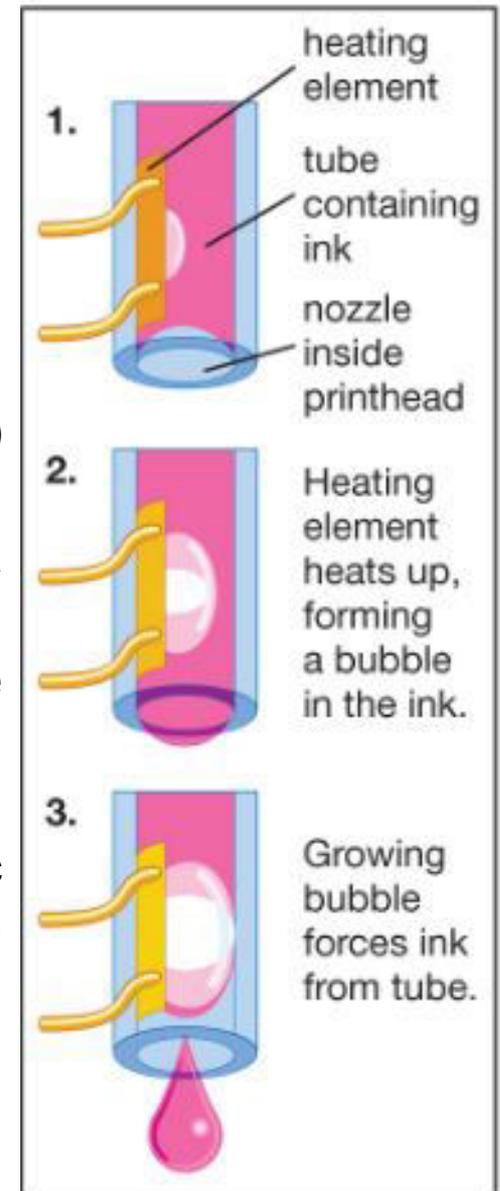
- Disadvantages
 - Less quality than daisy-wheel printers
 - Noisy, but less noise than daisy-wheel
 - Letter quality depends on the number of pins in the head (9 to 24 pins).
- Advantages
 - Faster than daisy-wheel (nearly 72 cps)
 - Use multipart forms

Inkjet (Bubble-Jet)

- Spray ink on the page precisely to form the text or image.
- Parts:
 - Print head/ink cartridge
 - Head carriage, belt, and stepper motor
 - Paper-feed mechanism
 - Control, interface, and power circuitry

● Print Head/Ink Cartridge

- Print head contains many small nozzles (usually 100 to 200) that spray the ink.
- Print head is part of the ink cartridge, which contains a reservoir of ink.
- Most color bubble-jet printers include multiple print heads, one for each of the CMYK (cyan, magenta, yellow, and black) print inks.
- When a particular chamber needs to spray ink, an electric signal is sent to the heating element, energizing it. The elements heat up quickly, causing the ink to vaporize. Because of the expanding ink vapor, the ink is pushed out the pinhole.
- The print cartridge must be replaced as the ink supply runs out.



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Inkjet (Bubble-Jet)

- **Head Carriage, Belt, and Stepper Motor**

- The print head carriage is the component that moves back and forth during printing.
- Connected to printhead and ink reservoir.
- The stepper motor and belt make the print head carriage move.

- **Paper-Feed Mechanism**

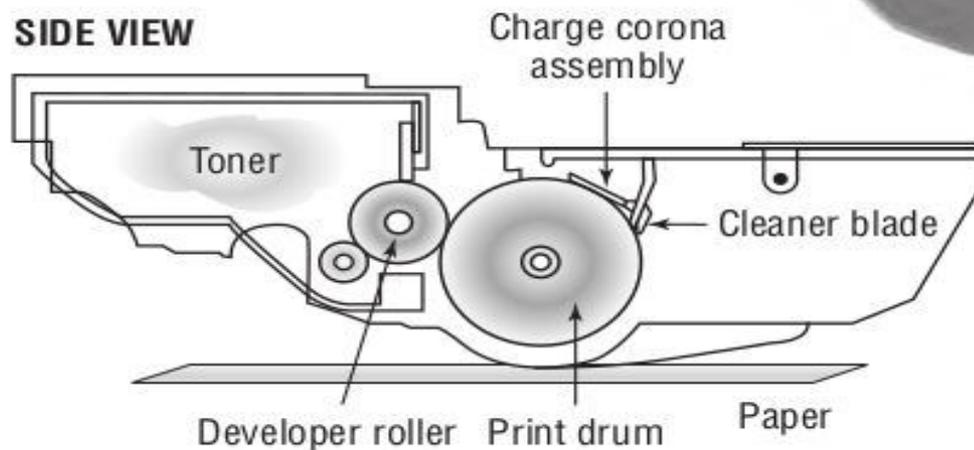
- The paper-feed mechanism picks up paper from the paper drawer and feeds it into the printer.

Inkjet (Bubble-Jet)

- **Control, Interface, and Power Circuitry**
 - **Control circuitry:**
 - Contains all the circuitry to run the stepper motors.
 - Monitoring the health of the printer and reporting that information back to the PC.
 - **Interface circuitry (port):**
 - Makes the physical connection to whatever signal is coming from the computer
 - Connects the physical interface to the control circuitry.
 - Converts the signals from the interface into the datastream that the printer uses.
 - **Power circuitry:**
 - Converts 110V/220V AC into the voltages the bubble-jet printer uses, usually 12V and 5V, and distribute those voltages to the other printer circuits and devices that need it.

Laser Printers

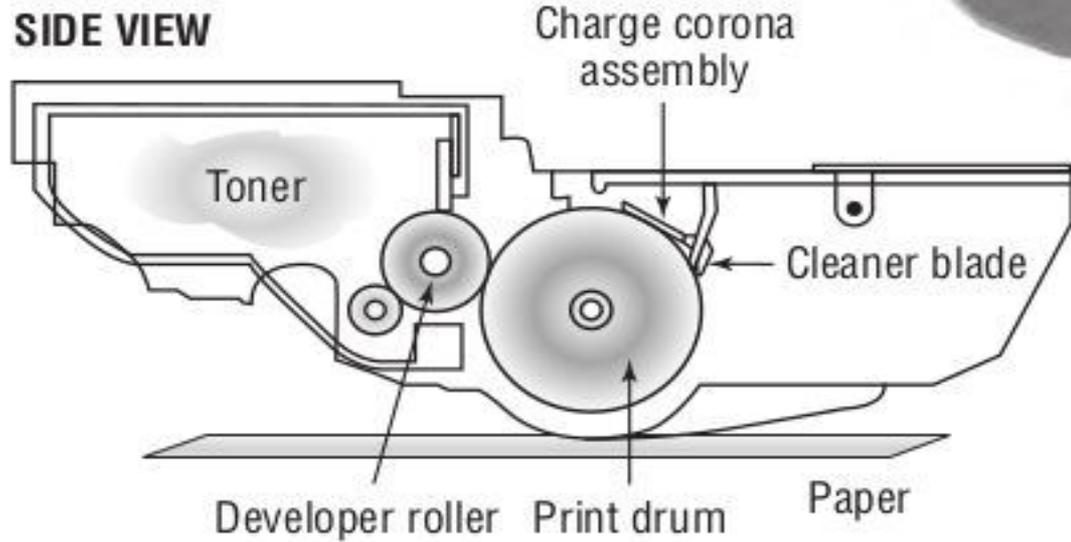
- Use the electrophotographic (EP) printing
- Basic Components:
 - a. the toner cartridge
 - b. laser scanner
 - c. high-voltage power supply
 - d. DC power supply
 - e. paper transport assembly
 - f. transfer corona
 - g. fusing assembly
 - h. printer controller circuitry
 - i. ozone filter



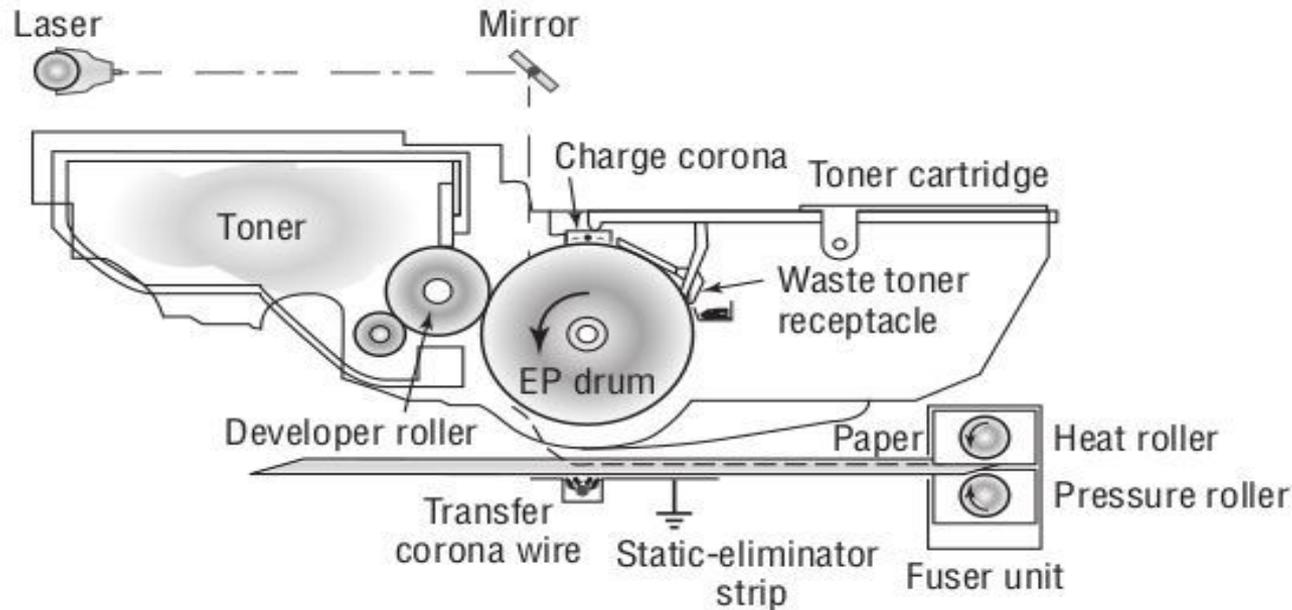
Toner cartridge

Laser Printers

- The Toner Cartridge



EP Print Process



The printer uses a rubber scraper to clean the photosensitive drum. Then the printer places a uniform -600VDC charge on the photosensitive drum by means of a charging corona. The laser “paints” an image onto the photosensitive drum, discharging the image areas to a much lower voltage (-100VDC). The developing roller in the toner cartridge has charged (-600VDC) toner stuck to it. As it rolls the toner toward the photosensitive drum, the toner is attracted to (and sticks to) the areas of the photosensitive drum that the laser has discharged. The image is then transferred from the drum to the paper at its line of contact by means of the transfer corona wire (or corona roller) with a $+600\text{VDC}$ charge. The static-eliminator strip removes the high, positive charge from the paper, and the paper, now holding the image, moves on. The paper then enters the fuser, where a fuser roller and the pressure roller make the image permanent. The paper exits the printer, and the printer begins printing the next page or returns to its ready state.

Laser Printer

Laser scanning diagram

