Chapter 1: Motherboard & Its Components

Specific Objectives

- To Understand the various components of Motherboard.
- To Know about the different memories in PC & their usage.
- To Understand the selection of different components of PC.

1.1 CPU – Concept like address lines, data lines, internal registers.

1.2 Modes of operation of CPU – Real mode, IA-32 mode, IA-32 Virtual Real Mode.

1.3 Process Technologies, Dual Independent Bus Architecture, Hyper Threading Technologies & its requirement.

1.4 Processor socket & slots.

1.5 Chipset basic, chipset Architecture, North / South bridge & Hub Architecture.

1.6 Latest chipset for PC

1.7 Overview & features of PCI, PCI –X, PCI express, AGP bus.

1.8 Logical memory organization conventional memory, extended memory, expanded memory.

1.9 Overview & features of SDRAM, DDR, DDR2, DDR3.

1.10 Concept of Cache memory:
- L1 Cache, L2 Cache, L3 Cache, Cache Hit & Cache Miss.

1.13 BIOS – Basics & CMOS Set Up.

1.14 Motherboard Selection Criteria.
Central Processing Unit (CPU):

The CPU is the hardware device in a computer that executes all of the instructions from the software.

Composition of a CPU

1. Control Unit
   - Generates control/timing signals
   - Decides which way data is going (in/out)
   - Controls decoding/execution of instructions

2. Arithmetic Logic Unit
   - Execution of instructions
   - Mathematical operations (* / + - etc.)
   - Logical Operations: and/or/xnor etc as well as shift/rotate

3. Registers
   - Small amount of very fast memory
   - Program counter – address of next instruction to be executed
   - Instruction register – Holds instruction while it is decoded
   - Accumulator – holds result of ALU operations
   - Other general purpose registers (e.g. stack pointer)
• **Buses – Masters and Slaves**
  ✓ Active devices attached to the bus that can initiate bus transfers are called **masters**
  ✓ Passive devices that wait for requests are called **slaves**
  ✓ Some devices may act as slaves at some times and masters at others
  ✓ Memory can never be a master device.

> **Modes of operation of CPU**

Processor modes refer to the various ways that the processor creates an operating environment for itself. Specifically, the processor mode controls how the processor sees and manages the system memory and the tasks that use it.

• **Real Mode:**
  ✓ The original IBM PC could only address 1 MB of system memory, and the original versions of DOS created to work on it were designed with this in mind.
  ✓ DOS is by its nature a single-tasking operating system, meaning it can only handle one program running at a time.
  ✓ The decisions made in these early days have carried forward until now, and in each new processor, care had to be taken to be able to put the processor in a mode that would be compatible with the original Intel 8088 chip. This is called **real mode**.
  ✓ When a processor is running in real mode, it acts like an "8088 on steroids". What this means is that it has the advantage of speed, but it otherwise accesses memory with the same restrictions of the original 8088: a limit of 1 MB of addressable RAM, and slow memory access that doesn't take advantage of the full 32-bit processing of modern CPUs.
  ✓ All processors have this real mode available, and in fact the computer normally starts up in real mode.

• **IA-32 (Protected) Mode:**
  ✓ This mode is the native state of the processor.
  ✓ In this mode all instructions and architectural features are available, providing the highest performance and capability. This is the recommended mode for all new applications and operating systems.
  ✓ Among the capabilities of protected mode is the ability to directly execute “real-address mode” 8086 software in a protected, multi-tasking environment.
The advantages of **protected mode** (compared to real mode) are:

- Full access to all of the system's memory. There is no 1 MB limit in protected mode.
- Ability to multitask, meaning having the operating system manage the execution of multiple programs simultaneously.
- Support for virtual memory, which allows the system to use the hard disk to emulate additional system memory when needed.
- Faster (32-bit) access to memory, and faster 32-bit drivers to do I/O transfers.

### IA-32 Virtual Real Mode

The key to the backward compatibility of the Windows 32-bit environment is the third mode in the processor: virtual real mode. **Virtual real** is essentially a virtual real mode 16-bit environment that runs inside 32-bit protected mode. When you run a DOS prompt window inside Windows, you have created a virtual real mode session. Because protected mode enables true multitasking, you can actually have several real mode sessions running, each with its own software running on a **virtual PC**. These can all run simultaneously, even while other 32-bit applications are running.

Note that any program running in a virtual real mode window can access up to only 1MB of memory, which that program will believe is the first and only megabyte of memory in the system. In other words, if you run a **DOS application** in a virtual real window, it will have a 640 KB limitation on memory usage. That is because there is only 1 MB of total RAM in a 16-bit environment, and the upper 384KB is reserved for system use. The virtual real window fully emulates an 8088 environment, so that aside from speed, the software runs as if it were on an original real mode-only PC. Each **virtual machine** gets its own 1 MB address space, an image of the real hardware basic input/output system (BIOS) routines, and emulation of all other registers and features found in real mode.

One interesting thing to note is that all Intel and Intel-compatible (such as AMD and VIA/Cyrix) processors power up in real mode. If you load a 32-bit OS, it automatically switches the processor into 32-bit mode and takes control from there.
Processor Sockets & Slots:

- A CPU socket or CPU slot is a mechanical component(s) that provides mechanical and electrical connections between a microprocessor and a printed circuit board (PCB).
- This allows the CPU to be replaced without soldering.
- A CPU socket is made of plastic, a lever or latch, and metal contacts for each of the pins or lands on the CPU.

Process Technologies: Dual Independent Bus Architecture:

- DIB uses two buses:
  - One from the processor to main memory, and
  - The other from the processor to the L2 cache.
- The processor can access both buses simultaneously, which increases throughput.
### Hyper-Threading Technology:

**Fig:** Hyper-Threading Technology

1. HT Technology enables a single processor to execute 2 separate code streams (called *threads*) concurrently.
2. HT technology allows 1 physical processor to appear as 2 “logical” processors to software (O/S and applications).
   - Each logical processor has its own architecture state with its own set of general-purpose and control registers
   - Some resources are shared (caches, exe units, buses, etc)

#### Chipset Basic, Chipset Architecture, North / South bridge & Hub Architecture:

A **chipset** is a set of electronic components in an integrated circuit that manages the data flow between the processor, memory and peripherals. It is usually found in the motherboard of a computer.
**Fig:** Northbridge & Southbridge Architecture

**Northbridge:**
- MCH – Memory Controller Hub
- Bridges connection from CPU to RAM and Video Bus (AGP/PCI-X)
- Connects to South Bridge
- A Northbridge with integrated video is called a GMCH – Graphics and Memory Controller Hub

**Southbridge:**
- ICH – I/O Controller Hub
- Bridge connection from Memory Controller Hub to slower devices like USB devices, PCI-X, IDE(SATA/PATA), Real Time Clock, BIOS, onboard sound and more
Latest chipset for PC

Intel® H67 Express Chipset Platform Block Diagram

1 Compatible with 2nd generation Intel® Core™ processor family
2 Available with Intel® HD Graphics only
3 All SATA ports capable of 3 Gb/s, 2 ports capable of 6 Gb/s.
Overview & features of PCI, PCI –X, PCI express, AGP bus:

PCI (Peripheral Component Interconnect):

It is high performance Bus that is used to integrate chips, processor, memory subsystems and expansion boards.

Features of PCI bus:

1. **Extremely High-speed data transfer:** 32 bit wide data transfer @33 MHz gives a maximum throughput of 132 mbps. Data transfer @66 MHz with 64 bit wide data is now being offered.

2. **Plug & play facility:** A PCI board inserted in any PCI slot is automatically detected & the required i/o & memory resources are allotted by the system.

3. **New Approach:** It moves peripherals of the i/o bus & places them closer to the system processor bus. Thereby providing faster data transfer between the processor & peripherals.

4. **Processor Independent:** The PCI local bus fulfills the need for the local bus standard that is not directly dependent on the speed & structure of processor bus, and that is both reliable and expandable.

5. **Full multi master capability:** This allows any PCI master to communicate directly with other PCI master slave.

6. **Parity on both data & address line:** This allows implementation of robust systems (Robustness is defined as "the ability of a system to resist change without adapting its initial stable configuration") support for both 5 V & 3.3 V operated logic.

7. Forward & backward compatibility between 66MHz & 33MHz PCI
PCI-X: PCI-X (Peripheral Component Interconnect Extended) is a computer bus technology that increases the frequency of the data bus from 66MHz to 133MHz.

Features of PCI-X bus:

1. Upto 133MHz bus speed
2. 64 bit bandwidth
3. 1 Gbps throughput
5. Split transaction allows & indicator device to make only one data request & release the bus, instead of constantly needing to poll the bus for response.
6. Byte count that enables indicators to specify in advanced, the specific number of bytes requested, eliminating the inefficiency of involving a high risk of loss pre fetches.

PCI-Express (Peripheral Component Interconnect Express (PCIe)):

It is a scalable Input/output (I/O) serial bus technology that largely replaced earlier PCI slots on motherboards.

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Diagram: PCI Express Physical Link Diagram

Features of PCI Express

- **Point-to-Point connection:** PCI Express is a point-to-point connection, which means it does not share bandwidth but communicates directly with devices via a switch that directs data flow.

- **Hot Swapping & Plugging:** This allows for "hot swapping" or "hot plugging," which means cards in PCIe slots can be changed without shutting down the computer.

- **Less Power Consumption:** It consumes less power than previous PCI technology.

- **Scalable:** One of the most promising features of PCI-Express is that it is scalable, which means greater bandwidth can be achieved through adding more "lanes."
Advantages of PCI-E over PCI-X:

- **Interface**: PCI Express is a serial interface format, unlike PCI and PCI-X, which are parallel interface formats.

- **High Speed**: The 32-bit PCI bus has a maximum speed of 33 MHz, which allows a maximum of 133 MB of data to pass through the bus per second. Different PCI Express specifications allow different rates of data transfer, anywhere from 400 MB to 8000 MB of data per second and beyond.

- **Point to Point Communication**: PCI Express is designed to support chip-to-chip connections, board-to-board connections, and hot pluggable devices.

- **Superior Performance and Scalability**: Another advantage of PCI Express over PCI and PCI-X is the amount of bandwidth the former can support while using significantly fewer pins and traces. The PCI Express Specification defines the initial signaling rate for PCI Express as 2.5 gigahertz. This means that each Lane can carry 2.5 gigabits of data simultaneously in each direction using only eight traces.

- **Full Compatibility with the PCI Software Model**: PCI Express uses the same load/store I/O architecture as PCI and PCI-X. This similarity makes PCI Express fully compatible with the PCI software model.

  - **AGP (Advanced Graphics Port)**: The Accelerated Graphics Port (often shortened to AGP) is a high-speed point-to-point channel for attaching a video card to a computer's motherboard, primarily to assist in the acceleration of 3D computer graphics.

  **Features of AGP bus**:

  - Probably the most important feature of AGP is DME (direct memory execute). This gives AGP chips the capability to access main memory directly for the complex operations of texture mapping.
  
  - AGP provides the graphics card with two methods of directly accessing texture maps in system memory: pipelining and sideband addressing.
  
  - AGP makes multiple requests for data during a bus or memory access, while PCI makes one request, and does not make another until the data it requested has been transferred.
  
  - AGP doesn't share bandwidth with other devices, whereas the PCI bus does share bandwidth.
Comparison between AGP & PCI:

- AGP is a port (it only connects two nodes) while PCI is a bus.
- AGP can access the system memory via complex operations while PCI can only access the memory inside the actual card.
- AGP also doesn't share bandwidth with other local devices while PCI does.
- AGP does not replace the PCI bus, it is a dedicated connection that can be used only by the graphics subsystem.
- AGP transaction are multiples of 8 bytes in length and are aligned on 8 byte boundaries, while PCI transactions must be multiples of 4 bytes and are aligned on 4 byte boundaries.

➢ Logical memory organization:

Conventional Memory (or Base RAM):

![Conventional Memory Diagram]

**Fig: Conventional Memory**

1. The first 640Kb of system memory is called as the conventional memory.
2. This area is used for standard DOS programs along with many drivers, memory resident programs.

**Upper Memory Area:** This is 384Kb of above conventional memory. It is specially reserved for use by system devices & special use such as ROM shadowing & drivers.

**High Memory Area:** First 64Kb of 2nd Mb used in real mode. It is used for DOS.
Expanded Memory:

- An expanded memory specification (EMS) was a technique introduced in about 1984 for expanding the conventional or main memory beyond 1 MB in IBM XT compatible computers.
- The process was known as bank switching and involved expanding memory beyond that which was directly addressed by the processor.
- EMS was designed for disk operating system (DOS) software programs requiring the additional memory.
- It was designed to overcome 1 Mb of addressing limitations of first generation 8088 & 8086 PC.
- Expanded memory cannot accessible by processor instead it is access with high memory area 64 Kb segment on board combine with special switching & mapping hardware.

Extended Memory:
• All above the 1 Mb is called extended memory.
• Extended memory refers to any amount of memory that is available for use over the main memory that is inherent in most DOS systems
• In most cases, this means that any memory over the 1 megabyte (MB) that is supported by DOS would be considered extended memory.
• This is all above the high memory area until the end of system memory.
• Memory of this type is supported by the use of certain types of microprocessors that allow loading and access to the extended memory.
• It is best for windows & multitasking operating system.

➤ Overview & features of SDRAM, DDR, DDR2, DDR3

RAM (Random Access Memory) is where data is stored that's being accessed by the CPU.

Types of RAM:

1. Static RAM:

Static Random Access Memory (Static RAM or SRAM) is a type of RAM that holds data in a static form, that is, as long as the memory has power. Unlike dynamic RAM, it does not need to be refreshed. SRAM stores a bit of data on four transistors using two cross-coupled inverters.

Static RAM is faster and less volatile than dynamic RAM, but it requires more power and is more expensive.

2. Dynamic RAM:

DRAM stores each bit in a storage cell consisting of a capacitor and a transistor. Capacitors tend to lose their charge rather quickly; thus, the need for recharging or refreshing.

Types of DRAM:

1. FPM (Fast Page Mode): It was traditional RAM for PC. It was mounted in single inline memory module (SIMM) of 2MB, 4MB, 8MB, 16MB, 32MB.
2. EDO (Extended Data Out): It is faster than FPM RAM. EDO have improvement in performance 2% to 5% compared with FPM.
3. ECC (Error Correcting Code): It is special error correcting RAM used in server.
4. SDRAM (Synchronous Dynamic RAM): SDRAM replaced DRAM, FPM, and EDO. SDRAM is an improvement because it synchronizes data transfer between the CPU and memory. SDRAM allows the CPU to process data while another process is being queued.
Features of SDRAM:

- All SDRAM chips for desktop PC have 168 pins
- Speed of SDRAM is 100 MHz & 133 MHz
- Available in sizes 32MB, 64MB, 128MB, 256MB, 512MB, & 1GB
- Operating Voltage 3.3 V
- Architecture used Synchronous
- Operating Max Temperature is 85°C
- It pre-fetches 1 bit at a time.

**DDR (Double Data Rate SDRAM):** also called DDR1 SDRAM.

DDR SDRAM (double data rate SDRAM) is synchronous dynamic RAM (SDRAM) that can theoretically improve memory clock speed to at least 200 MHz.

Features of DDR SDRAM:

- All DDR RAM Chips have 184 pins.
- DDR RAM comes in different speeds *i.e.* 100Mhz, 133MHz, 166MHz, 200MHz
- DDR is twice as fast as SDRAM
- Operating Voltage 2.5 V
- Architecture used is Source Synchronous (it refers to the technique of having the transmitting device send a clock signal along with the data signals.)
- Operating Max Temperature – 85°C
- It Pre-fetches 2 bit at a time

**DDR2 (Double Data Rate 2 SDRAM):**

Features of DDR2:

- The DDR2 RAM chip has 240 pins
- DDR2 operate at data rates of 400MHz, 533MHz, 667MHz, & above
- Higher Bandwidth
- Lower power 1.8V
- Architecture used source synchronous
- It pre-fetches 4 bits at a time
- Operating Max Temperature – 95°C

**DDR3 (Double Data Rate 3 RAM):**

Features of DDR3:

- Introduction to asynchronous RESET pin.
• Support system level same delay compensation.
• On DIMM (dual in-line memory module) mirror friendly DRAM pin out.
• Introduction of CWL (CAS Write Latency) per Speed bin.
• On-die I/O calibration engine.
• READ & WRITE calibration.
• It works on very low power \textit{i.e.} 1.5V
• DDR3 operate at data rates of 800MHz, 1066MHz, 1333MHZ, 1600MHz, & above.
• It pre-fetches 8 bits at a time.

➢ Concept of Cache memory:

\textit{“The cache is a very high speed and very expensive piece of memory, which is used to speed up the memory retrieval process.”}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{cache_memory.png}
\caption{Cache Memory}
\end{figure}

• Recently used instructions and data are kept in a very fast memory so that the CPU does not have to access the main memory every time it requires access to data.
• Cache memory is random access memory (RAM) that a computer microprocessor can access more quickly than it can access regular RAM.
• As the microprocessor processes data, it looks first in the cache memory and if it finds the data there (from a previous reading of data), it does not have to do the more time-consuming reading of data from larger memory.
• \textbf{Cache} is a smaller, faster, memory which stores copies of data from most frequently used main memory location.
• \textbf{Cache memory} is a high speed memory buffer that processor need allows processor to retrieve data faster than it will come from main memory.
• The advantage of cache memory is that CPU does not have to use the motherboard bus for data transfer.

➢ Types of Cache Memory:

\textbf{L1 (Level 1 or Internal or Primary) Cache:}

Level 1 cache, often called primary cache, is a static memory integrated with processor core that is used to store information recently accessed by a processor. Level 1 cache is often abbreviated as L1 cache. The purpose of level 1 cache is to improve data access speed in cases when the CPU accesses the same data multiple times. For this reason access time of level 1 cache
is always faster than access time of system memory. The processor may have additional level 2 and level 3 caches, albeit those caches are always slower then the L1 cache.

The L1 cache typically ranges in size from 8KB to 64KB and uses the high-speed SRAM (static RAM) instead of the slower and cheaper DRAM (dynamic RAM) used for main memory.

L2 (Level2 or External or Secondary) Cache:

Level 2 cache, also called secondary cache, is a memory that is used to store recently accessed information. The goal of having the level 2 cache is to reduce data access time in cases when the same data was already accessed before. In modern microprocessors that incorporate data prefetching feature the level 2 cache may also be used to buffer program instructions and data that the processor is about to request from memory. This also reduces data access time. Please note that the level 2 cache is secondary to the CPU - it is not as fast as the level 1 cache, although it is usually much larger. All data that is requested from level 2 cache is copied to level 1 cache. Requested data stays in the secondary cache if it's an inclusive cache, and is removed from secondary cache if it's an exclusive cache.

L2 cache comes between L1 and RAM(processor-L1-L2-RAM) and is bigger than the primary cache (typically 64KB to 4MB).

L3 Cache:

L3 cache is not found nowadays as its function is replaced by L2 cache. L3 caches are found on the motherboard rather than the processor. It is kept between RAM and L2 cache.

Cache Hit: A request to read from memory which can satisfied from the cache without using the main memory.

Cache Miss: A request to read from memory which cannot be satisfied from the cache, for which the main memory has to be consulted.

The percentage time cache hit is called as Cache Hit Ratio

➢ BIOS – Basics & CMOS Set Up:

Definition: Basic Input/output System, the BIOS, ROM BIOS, or System BIOS is a chip located on all motherboards that contain instructions and setup for how your system should boot and how it operates.

The main function of BIOS in a computer is to offer a small library of basic input/output functions that are used to run and manage computer peripherals.

Some common tasks/functions that the BIOS perform include:

- A power-on self-test (POST) for all of the different hardware components in the system
to make sure everything is working properly

- Activating other BIOS chips on different cards installed in the computer - For example, SCSI and graphics cards often have their own BIOS chips.
- Providing a set of low-level routines that the operating system uses to interface to different hardware devices - It is these routines that give the BIOS its name. They manage things like the keyboard, the screen, and the serial and parallel ports, especially when the computer is booting.
- Managing a collection of settings for the hard disks, clock, etc.

The BIOS is special software that interfaces the major hardware components of your computer with the operating system. It is usually stored on a Flash memory chip on the motherboard, but sometimes the chip is another type of ROM.

When you turn on your computer, the BIOS does several things. This is its usual sequence:

1. Check the CMOS Setup for custom settings
2. Load the interrupt handlers and device drivers
3. Initialize registers and power management
4. Perform the power-on self-test (POST)
5. Display system settings
6. Determine which devices are bootable
7. Initiate the bootstrap sequence

The CMOS setup utility is used to setup the hardware configuration of your computer's motherboard. It's the same function as the BIOS utility. It has things like disk boot order, RAM settings, and system clock settings (so your computer knows what time it is).

“There are some differences between a warm and cold booting. A warm boot is what happens when a computer is running and it is restarted. A cold boot is when the computer is already off and the power is turned on.”

To boot (also "to boot up") a computer is to load an operating system into the computer's main memory or random access memory (RAM).

A bootstrap is the process of starting up a computer. It also refers to the program that initializes the operating system (OS) during start-up.
Motherboard & Its Components

- **Motherboard Selection Criteria (Knowing What to Look For)**

  It helps to think like an engineer when you make your selection. Consider every aspect and detail of the motherboards in question. For instance, you should consider both present usage as well as any future uses and upgrades. Technical support at a professional (as opposed to a user) level is extremely important.

  The following list includes some of the most important criteria to consider when selecting a motherboard:

  ✓ **Motherboard chipset:**

    The motherboard chipset is the backbone of a system and is perhaps the single most important part you’ll consider. Compare the features of the available chipsets to ensure that the board will do what you want. For example, some chipsets include support for faster memory, PCIe 2.x cards, SATA 3Gbps drives, and optional RAID capabilities. I spend the most time deciding on my next chipset because it affects and influences virtually every other component in the system.

  ✓ **Processor socket:**

    The processor socket on a motherboard dictates the specific processor makes and models you will be able to install. In most cases you will have a given processor in mind, so choose a motherboard with a socket that supports the processor you wish to use. The main sockets in use today on new systems include Socket AM2 and AM3 for AMD processors, and Sockets LGA775, LGA1156, and LGA1366 for Intel processors. Also check the motherboard specifications for what specific processors are supported by a given motherboard.

  ✓ **Memory:**

    The type and amount of memory compatible with a system depends on the motherboard you choose. Most motherboards today support either DDR2 or DDR3 memory, in single, dual, or triple-channel operation. The number of memory sockets, supported speeds, and other variables also depend on the motherboard, so check the board specifications to see exactly what is supported.

  ✓ **Form factor:**

    The form factor indicates the size and shape of the board, and must be compatible with the chassis or case and power supply. For maximum flexibility, performance, reliability, and ease of use, I recommend motherboards based on the ATX and microATX form factors. Larger form
factors such as ATX offer more slots and room for additional integrated components and features. Smaller variations on ATX are also available, but in the end you need to be sure that the motherboard is compatible with the case and power supply you have chosen.

✓ **Bus slots:**

Current systems offer one to five or more PCI and PCI Express slots (depending on the form factor). Some boards have more than one PCIe x16 (video card) slots, which you may want if you are running multiple video cards in an SLI or CrossFire arrangement. Make sure the board you choose has the number and types of slots you require.

✓ **Onboard ATA interfaces:**

All motherboards on the market have included onboard Serial and Parallel ATA interfaces for some time now, but not all are equal. Look for boards that include at least four to six SATA connectors, with support for 3Gbps operation as well as optional RAID functionality (if desired).

✓ **Other built-in interfaces:**

Ideally, a motherboard should contain as many built-in standard controllers and interfaces as possible. Most boards feature integrated USB, sound, and LAN (look for those offering gigabit Ethernet), whereas others also have integrated video, FireWire, eSATA, dual LAN adapters, and more.

✓ **Documentation:**

Good technical documentation is important. Documents should be easy to download from the manufacturer’s site, and should include information on any and all jumpers and switches found on the board, connector pinouts for all connectors, specifications for other plug-in components, and any other applicable technical information. Most vendors provide this information in electronic form (using the Adobe Reader PDF format) on their websites, so you can preview the information available for a given motherboard before you buy.

✓ **Technical support:**

Good online technical support goes beyond documentation. It includes easily downloadable driver and BIOS updates, FAQs, updated tables of processor and memory compatibility, and utility programs to help you monitor the condition of your system. In addition to these online support features, make sure the vendor can be contacted through email and by phone.