Microprocessors

In this chapter, you will learn how to:
- Identify the core components of a CPU
- Explain the varieties of modern CPUs
- Identify specialty CPUs
- Install and upgrade CPUs

CPU Core Components

- Microprocessor and CPU (Central Processing Unit) mean the same thing
- CPUs are not very smart...just very fast at manipulating 0s and 1s

Man in the Box

- Visualize the CPU as a man in a box. He will gladly perform anything you want him to, but he can’t see or hear anything outside the box. How can we communicate with him?

Talking to the Man

- Suppose we have 16 lights – 8 on the inside and 8 on the outside
  - When an inside light is on, the corresponding outside light is on. We can switch these lights on and off. This communication system is like the external data bus
Talking to the Man

- In reality there are a lot of little wires that flash on or off by applying a voltage or not – represented not as on, on, off, off... but as 1,1,0,0...

External Data Bus

- The external data bus (EDB) is the way the CPU communicates with the outside world
  - Instead of light bulbs the external data bus (EDB) is made up of tiny wires
  - The state of a wire is expressed in a binary format, with 0s and 1s
  - Each discrete setting (series of 0s and 1s representing the state of the wires) of the external data bus is a line of code in a program

Registers

- Inside the box are four tables with 16 light bulbs each for the guy to use (a workplace) – we do not see these from the outside – they are called registers
- The four general purpose registers found in all CPUs are AX, BX, CX, and DX

Codebook

- The man in the box needs one more tool: the codebook
- The first four high-order bits (8,7,6,5) contain commands
  - Called machine language
  - One command is a line of code
  - The complete set of commands for a processor is its instruction set
- The last four low-order bits (4,3,2,1) contain data

Clock

- The CPU does no work until told to – even though all the light bulbs may be ready
- You need a buzzer to tell the guy to go ahead – the time it takes to charge up the buzzer (give it a certain voltage) to make it go off is a clock cycle
Clock

- The crank of the CPU is a special wire called the clock.
- A clock cycle is the time taken by the special wire to charge up.
- The maximum number of clock cycles that can be handled by the CPU is called the clock speed.

System Crystal

- The system crystal defines the speed at which the CPU and the rest of the PC operate.
  - Quartz oscillator, usually soldered to the motherboard.
- Overheating results from overclocking the CPU (running it faster than its maximum clock speed).

Overclocking

- Overclocking is running a CPU at a speed higher than rated.
  - Voids the warranty.
  - Black market exists.

In Summary

- The Man in the Box is the CPU.
- He communicates with the outside world using light bulbs – which in reality is a set of wires called the external data bus.
- He has four tables as his workplace – which in reality are registers or areas in memory inside the CPU.
- The codebook is the instruction set.

Memory

- Memory is a device that holds binary data.
- In early days paper cards were used to read data.
- Later, CPUs used magnetic tapes to read and write data.
- CPUs need a memory device that can transfer data very fast today – RAM to the rescue!

RAM

- RAM is an electronic device that enables a CPU to read and write to storage mediums, and jump between lines of code.
- Data is either transferred by the CPU into RAM or data is stored by the CPU in RAM in byte-sized chunks.

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Northbridge

- The memory controller chip (MCC) or Northbridge is a device that facilitates the flow of data from the RAM to the CPU.

Address Bus

- The address bus enables the CPU to control the Northbridge:
  - Another set of wires in addition to the external data bus
  - Used by the CPU to tell the Northbridge which line of code it wants from RAM.

Address Bus

- The number of wires in the address bus determines the maximum amount of RAM the CPU can handle:
  - An 8088 had 20 wires which provided $2^{20}$ combinations (1,048,576)
    - That is, the 8088 has an address space of 1,048,576 bytes
  - Each number represents a different location in RAM:
    - 00000000000000000000 thru 11111111111111111111

Terminology

- | Kilo (K) | $2^{10}$ | 1,024 (about 1,000) | Kilobyte (KB) |
- | Mega (M) | $2^{20}$ | 1,048,576 (about one million) | Megabyte (MB) |
- | Giga (G) | $2^{30}$ | 1,073,741,824 (about one billion) | Gigabyte (GB) |
- | Tera (T) | $2^{40}$ | 1,099,511,627,776 (about one trillion) | Terabyte (TB) |

A single 0 or 1 is a bit (b)
One byte (B) is 8 bits

Modern CPUs

- Factors to describe and compare CPUs:
  - Make
    - Intel, AMD
  - Model
    - 486DX2, Pentium, Pentium Pro, Athlon, Core 2 Duo
  - Speed
    - Measured in MHz or GHz such as 266 MHz or 1.4 GHz
  - How it’s mounted
    - Slotted or socketed
  - The size of CPU cache
  - FSB
  - Word size and data path size
  - Multiprocessing ability and processor specific memory
  - Type of RAM, motherboard, and chipset supported
CPU Speed Rating

- Usually expressed as a frequency
  - The number of clock cycles in a second
- Different ways of labeling processors
  - Pentium series
  - Actual clock speed
  - AMD
    - Pentium equivalent
      - Athlon 3200+, what does this mean?
  - Core 2 Duo
    - Mode number
    - E6300, E6700

Common CPU Packages

- Staggered Pin Grid Array (SPGA)
  - Pins are staggered and more closely packed to keep the overall size of the package small
  - Pentium, Pentium Pro, K5, K6, 6x86

Common CPU Packages

- Single Edge Contact Cartridge (SECC)
  - Take up less space and enable better cooling of the CPU
  - Obsolete – Celeron, Pentium II, Pentium III, Athlon

Common CPU Packages

- LGA (Land Grid Array)
  - No pins on the processor chip
  - Pins in the socket

Common CPU Packages

- ZIF (Zero Insertion Force)

Cache

- Cache means to set aside data in a special, fast storage area
  - Disk cache is moving data between mass storage and RAM
  - RAM cache is moving data between RAM and the CPU
**DRAM**

- **DRAM (Dynamic RAM)** is cheap, small, and relatively fast
  - Each storage bit is a microscopic capacitor and transistor
  - The capacitor holds a charge for about 16 milliseconds and then discharges it

- To prevent loss of data added to RAM, a process called refresh is used to recharge the capacitors
  - Data added to RAM will disappear after 16 milliseconds if not recharged, which is why DRAM is considered volatile RAM
  - A wait state is created when the CPU tries to access the RAM when it is being refreshed

**SRAM**

- **SRAM (static RAM)** is a type of RAM that uses special circuits called flip-flops instead of capacitors that do not need to be refreshed
  - About ten times more expensive than DRAM

- Cache memory (SRAM) is used to temporarily hold data in expectation of what the processor will request next

**External Cache**

- An external cache is also known as L2 cache
- The size of the cache varies from 64K to 4MB
- Integrated into the processor die nowadays

**CPU Voltages**

- The Pentium 60 and 66 MHz needed 5 volts for operations, whereas later Pentiums operated on 3.3 volts only
  - A CPU can run on a lower voltage by reducing transistor size, thereby reducing the overall size of the chip
  - The voltage regulator module (VRM) is a small card that enables a CPU to standardize voltage regulators
Bus Types

- **Frontside bus**
  - Address bus and external data bus are combined together between the CPU, MCC, and RAM

- **Backside bus**
  - Connection between the CPU and L2 cache
  - Remember that L2 cache used to be external cache but is now internal to the CPU housing

Pentium CPU

- **CPU makers have added a large number of improvements over the years**
  - Larger external data buses
  - Larger address buses
  - Faster clock speeds

- **Intel introduced the Pentium CPU in the early 1990s**
  - 32-bit registers
  - Speeds up to 300 MHz
  - Ability to run multiple programs at once
  - Access super-fast cache RAM
  - Processes two or more lines of code at the same time

Multiprocessing

- **Multiprocessing** is running two programs at the same time

- **Pentium processors have a 32-wire address bus that can address up to 2^32 or about four gigabytes of memory**
  - Actually CPUs do not run two programs at once. They simply switch back-and-forth between them so that it looks like they are doing two things at once.

Clock Doubling

- **Clock doubling** is used to enhance the CPU speed
  - Running the internals of a CPU at one speed, and the external data bus at another slower speed
  - All CPUs use multipliers
  - Pentiums use variable multipliers

Dual Pipeline

- **A pipeline** is a series of steps taken by the CPU to process a command

- **Dual pipelining** is the process of processing more than one command at a time through the use of separate sets of circuitry
  - Dual pipelining in a Pentium is achieved through the U (main pipeline that can do anything) and V pipeline (handles only simple commands)

The Pentium CPU

- **The first Pentium processor (1993)** had a 64-bit external data bus that was split internally as two dual-pipelined 32-bit data buses
  - Enabled the CPU to process two separate lines of code simultaneously
  - Capable of branch prediction allowing the CPU to anticipate program branches

- **Superscalar**
**Clock Doubling**

- Pentium CPUs do not have built-in multipliers (clock doubling or more to run the internals of a CPU faster than the external data bus)
  - Set with the help of jumpers or switches present in the motherboard
  - Clock speed and multiplier can be adjusted via the CMOS setup program

**Pentium Socket Types**

- Most Pentium processors use the Staggered Pin Grid Array (SPGA) package
  - Enables higher pin density and smaller case
  - Socket 5 and Socket 7 were the two standard sockets for lower-powered Pentiums

**Pentium Pro**

- Pentium Pro is also known as the P6
  - Bus and register size is similar to Pentium
  - Quad pipelining
    - Pentium was dual-pipelined and could only run two processes simultaneously
    - Dynamic processing
    - While waiting for information from DRAM, the CPU could process other commands
  - On-chip L2 cache

**Pentium Class CPUs**

- MMX (Multimedia Extensions)
  - Designed for graphical applications
  - All new CPUs have MMX enabled
- Split voltage
  - Two different voltages are required for different chips on the motherboard
  - Super Socket 7 motherboards required
- Increased clocks and multipliers
- Improved processing
- Pentium II
  - Faster Pentium Pro with MMX

**Pentium Competitors**

- AMD Athlon
  - 9 pipelines, dynamic branch prediction, 200 or 266 MHz system bus
  - CPU and chipset perform two calculations on every clock cycle
  - Must use a motherboard with Slot A
- AMD Duron
  - AMD’s competitor to Intel’s Celeron for the low-end PC

**AMD K6 series**

- Requires a Super Socket 7 motherboard
  - K6, K6-2, K6-2+, K6-III

**Celeron**

- Offshoot of Pentium II’s for the low-end PC

**Pentium III**

- Intel’s answer to 3DNow! by AMD
More Processors

- Intel Xeon processors
  - Series of powerful Slot 1 CPUs
  - Massive L2 caches
- Intel Pentium 4
  - 20-step pipeline that enhances its core processing function
  - Four data transfers per clock cycle
- AMD Athlon XP
  - Enhanced version of the Athlon core processor

More Processors

- Hyperthreading
  - One processor that can handle two threads at the same time
  - Have problem with certain applications
- Dual Core
  - Two processors in a dye
- Core 2 Duo
  - Energy efficient

64-Bit Processors

- 64-bit processing refers to a 64-bit registers
  - We already had 64-bit external data buses
- Intel Itanium processors
  - Itanium was Intel’s first 64-bit chip
  - Itanium II is made for the PC
- AMD Opteron processor
  - Runs both 32-bit and 64-bit code

Mobile Processors

- Mobile processors
  - For laptops
  - Overcome the problems of heat and size

Mobile Processors

- Laptops require CPUs that are smaller, use less power, and run cooler
  - AMD and Intel make mobile versions of all of their CPUs
  - Intel introduced the mobile module that includes the processor and support chips to conserve space
- System Management Mode (SMM) is used to reduce power consumption on laptops
Processor Modes

- All Intel 32 bit and later processors can run in several modes.
- Processor modes refer to the various operating environments and effect the instructions and capabilities of the chip.
- The processor mode controls how the processor sees and manages the system memory and the tasks that use it.

Three different modes of possible operation are:
- Real mode (16 bit software)
- Protected mode (32 bit software)
- Virtual real mode (16 bit programs within a 32 bit environment)

Real Mode

The original IBM PC included an 8088 processor that could execute 16 bit instructions using 16 bit internal registers and could address 1MB of memory using 20 address lines.

Later processors such as the 286 could also run the same 16 bit instructions as the 8088. The 16 bit instruction mode of the 8088 and 286 has become known as real mode.

All software running in real mode must use only 16 bit instructions and work within the 20 bit (1MB) memory architecture.

Software of this type is usually single-tasking.

No built-in protection exists to keep one program from overwriting another program.

Protected Mode

386 : 32 bit processor.

a 32 bit operating system and 32 bit application were required.

This new 32 bit mode was referred to as protected mode.

It helps make the system more crash-proof.

In addition, a crashed program can be terminated, while the rest of the system continues to run unaffected. This is often referred to as multitasking. Finally, Intel built a backward-compatible real mode into the 386.

Virtual Real Mode

The key to the backward compatibility: virtual real mode.

Virtual real mode 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.

Real Mode-vs-Protected Mode (Swapping)

The 286 was the first chip to physically address 16 MB of actual memory. In Real mode the 286 acts essentially the same as an 8088/86 and can run older software with no modifications. Real mode means that the chip can address the first 1024 bytes (1 MB) of “conventional memory”.

As software began requiring more memory, the 286 introduced a way for software to access 1 GB of memory by “swapping” code held in RAM to a hard disk. This enabled the software to use the freed up memory and to think that it can utilize up to 1 GB of RAM while not knowing about the swapping.

Virtual Memory Operations

In these operations, the system treats an area of hard disk space as an extension of RAM. It can shift data from RAM to the disk and back again to simulate large areas of RAM, up to 1GB.

This allowed the CPU to run multiple programs at once in “virtual memory.”
Math Coprocessors
(Floating Point Units)

The floating point unit (FPU) contained in the processor, which was formerly a separate external math coprocessor in the 386 and before.

Math chips can perform high level mathematical operations – long division, trigonometric functions, roots, and logarithms – at 10 to 100 times the speed of the corresponding main processor.

The operations performed by the math chip are all operations that use noninteger numbers (digits after the decimal point).

Historically, the Intel processor FPUs have dramatically outperformed those from AMD and Cyrix.

Installing CPUs

Why Replace a CPU?

• Cost
  – Chances are you’ll need to replace the motherboard as well as the CPU – is it worth it?

• Cooling
  – Faster CPUs will probably need better cooling

• Performance
  – Faster CPUs may not be the best answer to speeding up your PC
    • Many times what you really need is more RAM

The Right CPU

• Consult your motherboard manual
  – You need a CPU that will fit in the socket or slot you have on your motherboard

• Buying a CPU
  – Most stores will not accept returns
  – Retail-boxed CPUs are genuine and come with a fan
  – There are a lot of illegal CPUs on the market

CPU Installation Guidelines

• Don’t touch the pins
• Match the notch and dot printed on the corners of the CPU...it must line up
  – Incorrectly installing your CPU may destroy the CPU and/or motherboard!

CPU Installation Guidelines

• Install a fan on top of the CPU after the CPU has been inserted into the socket
  – Use a heat sink compound
Plugging in the CPU Fan

Inserting a Slot I / Slot A CPU

- Install the CPU mount
  - Usually requires removing the motherboard
- Add a small amount of heat sink compound before mounting the fan
- Slide the CPU straight down – notches will make it impossible to install incorrectly
- Plug in the CPU fan’s power

Modern CPUs need to be kept cool

- OEM fans are included in retail-boxed CPUs
- Liquid cooling works by running a liquid (usually water) through a metal block that sits on top of your CPU to absorb heat

The Art of Cooling