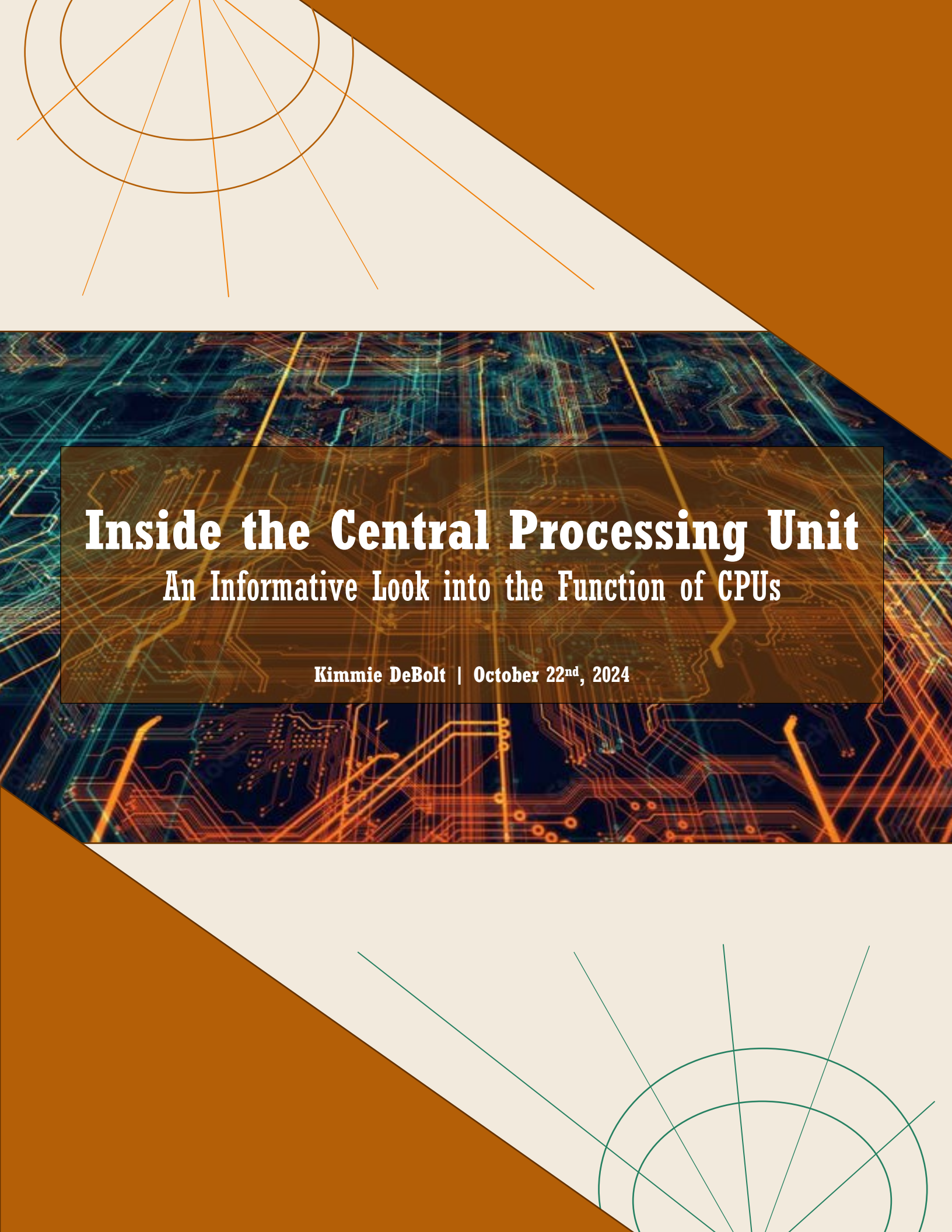




Inside the Central Processing Unit

An Informative Look into the Function of CPUs

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Audience & Scope

The goal of this technical document is to relay information surrounding the function and inner workings of a **central processing unit** (Figure 1). Explanation will be provided for each component that exists within the CPU. Further explanation regarding the importance of a central processing unit and its interactions with other parts of a computer will also be provided.

The content of this document will be particularly relevant to those who seek to understand the magic of computers and technology. As well as how the input of a user comes alive through a machine, all thanks to the central processing unit. The audience will naturally include those interested in any element of computer science such as professionals and students of the field.

Introduction

A central processing unit is the main processing component of a computer. CPUs can be traced back to the late 1950s. The first commercial CPU came about in 1971 and was marketed by Intel. In modern times many tech companies offer their own versions such as Apple's silicon chip, AMD's Ryzen, and Intel's Core i9.

Without it, all the wonderful things we accomplish with "smart" technology would become a lot more difficult. CPUs are found in most of electronic devices including, computers, tablets, smartphones, smartwatches, televisions, thermostats, and many other smart household appliances. Their functions range from big to small, whether controlling the launch of a rocket-ship into the atmosphere, or simply computing an equation input into a calculator.

What's Inside of a CPU?

A CPU consists of a small chip that is sealed within a metal container. This chip contains the processor. The metal container is then mounted on top of a **printed circuit board**. Some optional physical attributes include PCB pins, wires, and metallic pads. It is then placed into a socket on the **motherboard**.

The **logical components** (Figure 2) of a CPU include the arithmetic logic unit, an accumulator, caches, a control unit, a CPU clock, a memory management unit, and registers. These components all function through the circuitry of the CPU. They are facilitated and conveyed via electrical signals that are processed by the CPU. Hence the name "central processing unit".

Central Processing Unit – The CPU is also referred to as the main or core processor. A machine's operating system and applications run by utilizing the electric circuitry found here.



Figure 1. A CPU mounted on a PCB [1]

Printed Circuit Board – Also referred to as a PCB, this board is used to provide electrical interconnections via copper traces that have been soldered to a material that is electrically insulated.

Motherboard – The motherboard refers to the main PCB in a computer. It connects all the components together.

Logical Component – The logical components in computing refer to an abstract of a physical component.

How Does A CPU Operate?

The CPU receives electrical information which is converted into **binary**. As soon as the machine is powered up, the binary received is translated into data via the instruction cycle. This instruction cycle is typically defined by the following steps: fetch, decode, and execute but for more advanced machines these steps can be further defined. We'll explore in more detail below.

Every CPU: therefore, every computer, is operating within a certain set of instructions. This is also known as Instruction Set Architecture (ISA). If you want to speak to them, you must speak their language! Enter stage: **machine language**. For the sake of simplicity, first look at how the components of a CPU can process an equation.

Through some form of input method by the user, the equation is provided and received as binary. All clicks, button presses, and selections are converted into binary data. The CPU uses the **control unit** and references this data in its machine language as instruction to perform addition. The CPU then fetches the instructions that are stored in its memory, decodes them, and executes them all according to the binary data it received.

In this case, the CPU would utilize its **Arithmetic Logic Unit** to perform the math. Any numbers are stored in the **registers**, and the ALU will locate them there. CPUs can have several registers, such as the instruction register, where the instructions are stored. The A and B register are typically associated with the ALU. Once the ALU processes the equation the result is stored in the register specified as the destination (by the CU) or the accumulator.

Memory

A CPU processes data at speeds the human mind is incapable of. It can be difficult to wrap one's head around it at times, even for seasoned professionals. One large difference between a CPU and a human brain is the amount of memory available at disposal. A CPU can store its memory within its caches and even stores relevant instruction there.

The CPU moves so fast that it's user won't realize that it is recalling information, storing it, or transferring it, thanks to the memory caches. A term that may be familiar to readers of this document is RAM or Random Access Memory. RAM is not considered part of the CPU and is a volatile storage area; however, the caches can receive data from the RAM from the Memory Management Unit (MMU) for even faster processing!

Binary – This is known as the language of computers. Represented by 1s and 0s, this information is translated into bits, then bytes, which represent data that is translated by a machine to do whatever way it is programmed to do.

Machine Language – This refers to the binary code that computers translate into instructions via a specified programming language.

Control Unit - Also known as the CU, this operates as the coordinator of the CPU and all its components.

Arithmetic Logic Unit – Also known as the ALU, is located within the circuit of a CPU. It carries out arithmetic and logical operations.

Register – A register (also located in the CPU) accepts, stores, and transfers data and instructions for quick operation.

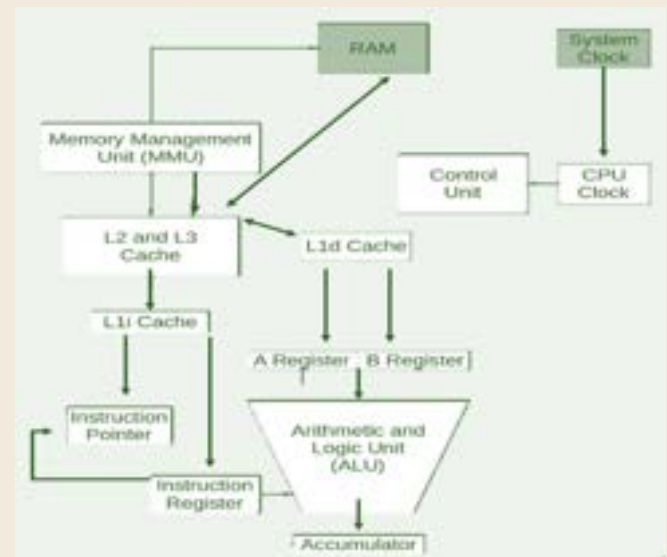


Figure 2. Simplified logical architecture diagram of a CPU. The reality is far more complex. [2]

The CPU Clock

The CPU clock generates signals that the CU utilizes to perform functions. This essentially means that the CPU clock determines the rate at which the CPU can process the instruction cycle. Each signal is referred to as a clock cycle. The CPU can process multiple items during a singular cycle; however, this is dependent on the type and model of CPU.

Clock speed is measured by cycles per second using the units of hertz (Hz). CPU clocks can reach 1 million cycles per second (1 MHz or Megahertz) and 1 billion cycles per second (1 GHz or Gigahertz). *Impressive, right!?* The higher the clock speed, the more instructions per second.

The clock speed can be manually increased to reach a higher performance capability. This is referred to as overclocking and it increases the cycles per second past the system specifications and is generally frowned upon by manufacturers. This act places more stress upon hardware components of the computer and can lead to overheating, inadequate power, and system instability or failure.

Types of CPUs

While the general functionality remains the same, a CPU can be customized for a specific purpose. These CPUs are categorized below according to the types of chips they use to process data:

- Single-core processor: A **microprocessor** with one CPU. This can only process one instruction cycle at a time.
- Multi-core processor: These processors have two or more processors and can complete instruction cycles as they were separate computers although the processors are located together. These are considered high performance processors. Processors that fall under this category include a dual-core processor as shown in Figure 3, a quad-core processor, an octo-core processor, and a deca-core processor.
- Embedded processor: This type of processor is a microprocessor that is specifically use in embedded systems. An example can be found in Figure 4. These can include microprocessors and microcontrollers found in appliances, IoT devices, and even vehicles.

Microprocessor – This device functions as the CPU on a circuit that can be considered compact and integrated.



Figure 3. a multi-core processor [3]



Figure 4. Congatec embedded processor [4]

CPUs in Action – Distributed Computing

Through **distributed computing**, various projects have been launched that harness the power of central processing units worldwide. Computers communicate with other computers that are located on networks completely different from their own.

One distributed computing project that is on hiatus, but interesting nonetheless, is the *SETI@home* [5] project. This project utilizes internet connected volunteers and their idle CPUs to process data from radio telescopes in the hopes of successfully completing SETI (The Search for Extraterrestrial Intelligence)!

Another distributed computing project that is up and running is the *Folding@home* [6] project. This project truly encompasses the great things humans can do with the power of CPUs. Through this program users can download software that will idle CPUs to work “folding”. This refers to the simulation of protein folding and contributes data towards understanding and providing data on diseases like Alzheimer’s, Parkinson’s, Huntington’s, various infectious diseases, and cancer.

Distributed Computing – A multitude of computers working together to solve a problem as if they were one supercomputer.

Conclusion

The central processing unit is the powerhouse of a computer. You likely interact with them multiple times a day. With the knowledge shared above, the way smart machines operate may seem less fantastical; however, the magic of CPUs will never be lost. The complexity of their various components, whether physical or logical, excel towards the pinnacle of innovation.

The clock speed at which these machines can operate, the data that is shared between the memory repositories and the control unit, down to the conversion of electrical signals into binary and machine language have been focal points of this document. Through this information shared above, it’s an indication that such an incredible piece of technology serves as the zenith for how far humans have come. It also serves as a reminder of the potential to how far we can truly go. With the power CPUs hold, the possibilities are *endless*.



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