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1 The CPU

The Processor (Central Processing Unit) is often refered to as the brain of a computer. On the lowest level, it is made of circuits with thousands or up to billions of transistors. In essence, a CPU reads and writes data to memory and performs operations on it based on the instructions it receives. There are many different architectures and processor families but this chapter will explain the most basic inner workings of a processor with a hypothetical model. We will upgrade our CPU on the run to introduce new features and instructions, but start off with a simple CPU that has 4 components:
- A Programm Counter (PC) - Accumulator Register - An Arithmetic Logic Unit (ALU) - Random Access Memory (RAM)
The PC is a register that holds the address of the next instruction located in RAM. First, it is important to understand what a register is. A register is a circuit that can hold a binary value. The size of register is given in bits or in bytes. Our registers are 8 bits wide, meaning they can hold any value between 0 and 255. Registers can be read and written to and will retain their value until they are overwritten again. They are located on the CPU and most CPU operations are done *on* data in regsiters. ¡br/¿ Secondly, it is important to understand that RAM can be addressed by means of *numeric values*, these values are also called a *memory address* and when the address is stored in a register, it is called a *pointer*. So the PC is a pointer to the next instruction in memory. ¡br/¿ Now, the next question arises, what exactly is random access memory? RAM is made of many fields that can store one byte of data. They are similar to registers, in the sense that they hold data, a numeric value between 0 and 255, until they are overwritten again. In RAM, there is a large number of those fields while there may only be a few registers present. RAM takes the form of its own separate hardware, namely RAM sticks. RAM is used by the CPU while it is running, but once the computer is turned off, all the data present in RAM and in registers is deleted. One key feature of RAM is that it truly is random access, meaning there is no particular order in which data has to be stored or retrieved. Each one of those fields has an address and these fields can contain normal data or also instructions for the CPU itself.¡br/¿ The accumulator register is just a register that the CPU uses for temporary storage, before it is either stored in memory or overwritten. Many operations also just work on registers, if we for example add two numbers, one number has to be stored in a register but the other value can be stored in memory. In our hypothetical CPU there is only one register, namely the accumulator.¡br/¿ The next component is the ALU which is a complex circuit that performs binary operations. These operations range from arithmetic operations to bitwise operations of. All these operations are circuits etched in the ALU and a instruction that uses the ALU will execute as follow:
- Operands are loaded into the ALUs own registers. - Instruction triggers the correct arithmetic circuits to perform the operation on the registers in the ALU. - Result is then stored into the destination, our CPU defaults to storing it in the accumulator.