Chapter 8. Inside and around the CPU

In this and the following chapters, I will focus on a detailed look at the CPU. One of the goals is help to you understand why manufacturers keep releasing new and more powerful processors. In order to explain that, we will have to go through what will at times be a quite detailed analysis of the CPU's inner workings.

Some of the chapters will probably be fairly hard to understand; I have spent a lot of time myself on my "research", but I hope that what I present in these chapters will shed some light on these topics.

Naturally, I will spend most of my time on the latest processors (the Athlon XP and Pentium 4). But we need to examine their internal architectures in light of the older CPU architectures, if we want to understand them properly. For this reason I will continually make comparisons across the various generations of CPU's.

I will now take you on a trip inside the CPU. We will start by looking at how companies like Intel and AMD can continue to develop faster processors.

Two ways to greater speed

Of course faster CPU's are developed as a result of hard work and lots of research. But there are two quite different directions in this work:

- More power and speed in the CPU, for example, from higher clock frequencies.
- Better exploitation of existing processor power.

Both approaches are used. It is a well-known fact that *bottlenecks* of various types drain the CPU of up to 75 % of its power. So if these can be removed or reduced, the PC can become significantly faster without having to raise the clock frequency dramatically.

It's just that it is very complicated to remove, for example, the bottleneck surrounding the front side bus, which I will show you later. So the manufacturers are forced to continue to raise the *working rate* (clock frequency), and hence to develop new *process technology*, so that CPU's with more power can come onto the market.

Clock frequencies

If we look at a CPU, the first thing we notice is the *clock frequency*. All CPU's have a working speed, which is regulated by a tiny *crystal*.

The crystal is constantly vibrating at a very large number of "beats" per second. For each clock tick, an impulse is sent to the CPU, and each pulse can, in principle, cause the CPU to perform one (or more) actions.
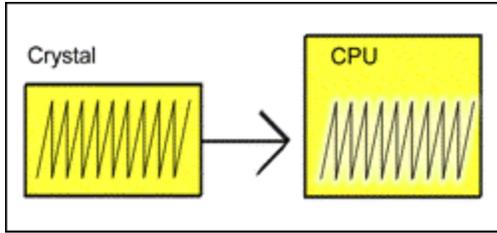
Chapter 8. Inside and around the CPU

Fig. 54. The CPU's working speed is regulated by a crystal which "oscillates" millions of times each second.

The number of clock ticks per second is measured in *Hertz*. Since the CPU's crystal vibrates millions of times each second, the clock speed is measured in *millions* of oscillations (*megahertz* or *MHz*). Modern CPU's actually have clock speeds running into *billions* of ticks per second, so we have started having to use *gigahertz (GHz)*.

These are unbelievable speeds. See for yourself how short the period of time is between individual clock ticks at these frequencies. We are talking about billionths of a second:

Clock frequency	Time period per clock tick
133 MHz	0.000 000 008 000 seconds
1200 MHz	0.000 000 000 830 seconds
2 GHz	0.000 000 000 500 seconds

Fig. 55. The CPU works at an incredible speed.

The trend is towards ever increasing clock frequencies. Let's take a closer look at how this is possible.

More transistors

New types of processors are constantly being developed, for which the clock frequency keeps getting pushed up a notch. The original PC from 1981 worked at a modest 4.77 MHz, whereas the clock frequency 20 years later was up to 2 GHz.

In Fig. 56 you can see an overview of the last 20 years of development in this area. The table shows the seven *generations* of Intel processors which have brought about the PC revolution. The latest version of Pentium 4 is known under the code name Prescott.

Gen.	CPU	Yr (intr.)	Clock Frequency	No. of transistors

Chapter 8. Inside and around the CPU

1	8088	1979	4.77- 8 MHz	29,000
2	80286	1982	6-12.5 MHz	134,000
3	80386	1985	16-33 MHz	275,000
4	80486	1989	25-100 MHz	1,200,000
5	Pentium Pentium MMX	1993 1997	60-200 MHz 166-300 MHz	3,100,000 4,500,000
6	Pentium Pro Pentium II Pentium III	1995 1997 1999	150-200 MHz 233-450 MHz 450-1200 MHz	5,500,000 7,500,000 28,000,000
7	Pentium 4 "Prescott"	2000 2002 2003 2004	1400-2200 2200-2800 2600-3200 2800-3600	42,000,000 55,000,000 55,000,000 125,000,000

Fig. 56. Seven generations of CPU's from Intel. The number of transistors in the Pentium III and 4 includes the L2 cache.

Each processor has been on the market for several years, during which time the clock frequency has increased. Some of the processors were later released in improved versions with higher clock frequencies, I haven't included the Celeron in the overview processor. Celerons are specially discount versions of the Pentium II, III, and 4 processors.

Anyone can see that there has been an unbelievable development. Modern CPU's are one thousand times more powerful than the very first ones.

In order for the industry to be able to develop faster CPU's each year, new manufacturing methods are required. *More and more transistors* have to be squeezed into smaller and smaller chips.

Chapter 8. Inside and around the CPU

Fig. 57. A photograph from one of Intel's factories, in which a technician displays the Pentium 4 processor core. It is a tiny piece of silicon which contains 42 million transistors.