CSC 350 Project #1:

Intel Pentium Pro Processor

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Introduction

Intel's processors throughout the generations have excelled in increasing the performance speed of laptops, desktop computers, and even mobile phones. One specific benchmark was the Intel Pentium pro. Launched in 1995, the Intel Pentium pro microprocessor was the first processor established in the Intel Pentium II family of processors. Being Intel's first 6th generation of processors, the Pentium pro presented some new features that made it outperform its previous generations and lay out a different structure for its architecture. Although it had some weaknesses in performance with certain bit size applications, and with the fact that it was built for the server market, the performance it had established amongst the other Pentium II families was quite impressive. Even more impressive was the fact that the speed of this processor ran with a different Instruction set than the previous models. Even though the processor was discontinued in 1998, these qualities made it a unique processor not only from past generations, but within its own generation of Intel Pentium processors as well.

Architecture Overview

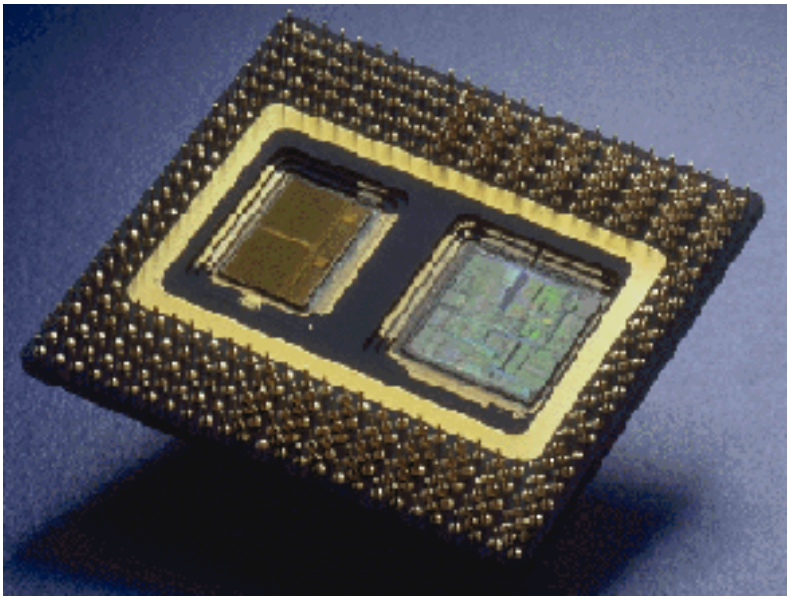

Figure 1: Intel Pentium Pro Processor

For the Intel Pentium pro, there were some notable advancements on its architecture compared to previous generations. The main architectural differences in this processor included the L2 cache for increased data storage. This led to the 64GB of memory it could hold. The main difference of it though was where it was located: “The Pentium Pro L2 cache is internal, located on the CPU itself, and the Pentium Pro uses a 64-bit data path running at full processor speed to link L1 cache to L2 cache” (Thompson and Thompson, 2019). Figure 1

physically displays how the processor was made with two parts; one being the core and the other being the L2 cache. The link established between the two parts is through the L1 cache. Other notable Architectural designs included the memory capacity of 64 GB with the help of the L1 + L2 cache pairing, as well as the increase in die surface area due to the excess amount of transistors for the L2 cache being separate from the core. The processor also ran under a CISC architecture using x86 instructions. This made it the only processor within its generation to use this type of pairing for its ISA. Figures 2 and 3 show the layout of the architectural design and the data regarding each component of the hardware, respectively.

Strengths

The Pentium pro processor at the time had its unique advantages to other developed Pentium processors. One component of this was the processor's out-of-order execution on its instructions. The technique used to sustain this is called super-pipelining, which ultimately avoids wasting clock cycles by queueing up instructions by priority of obtaining the full data on an earlier instruction, even though it may already have obtained the data to execute the next instruction (Thompson and Thompson, 2019). Looking more closely at this method. This shows that the performance of this improves even if the instructions executed are no-op instructions, which would slow down the performance speed otherwise. The Pentium was the first of the Intel processors to implement super-pipelining. Another unique aspect of it was the L2 cache implemented on it. The main goal of this extra cache space was to increase performance when executing instructions, and it did just that. With 4GB of memory, the performance speed increased with processor speed. This also gave it the best of both worlds: the speed and locality of the L1 cache along with vast space of memory for extra storage of data.

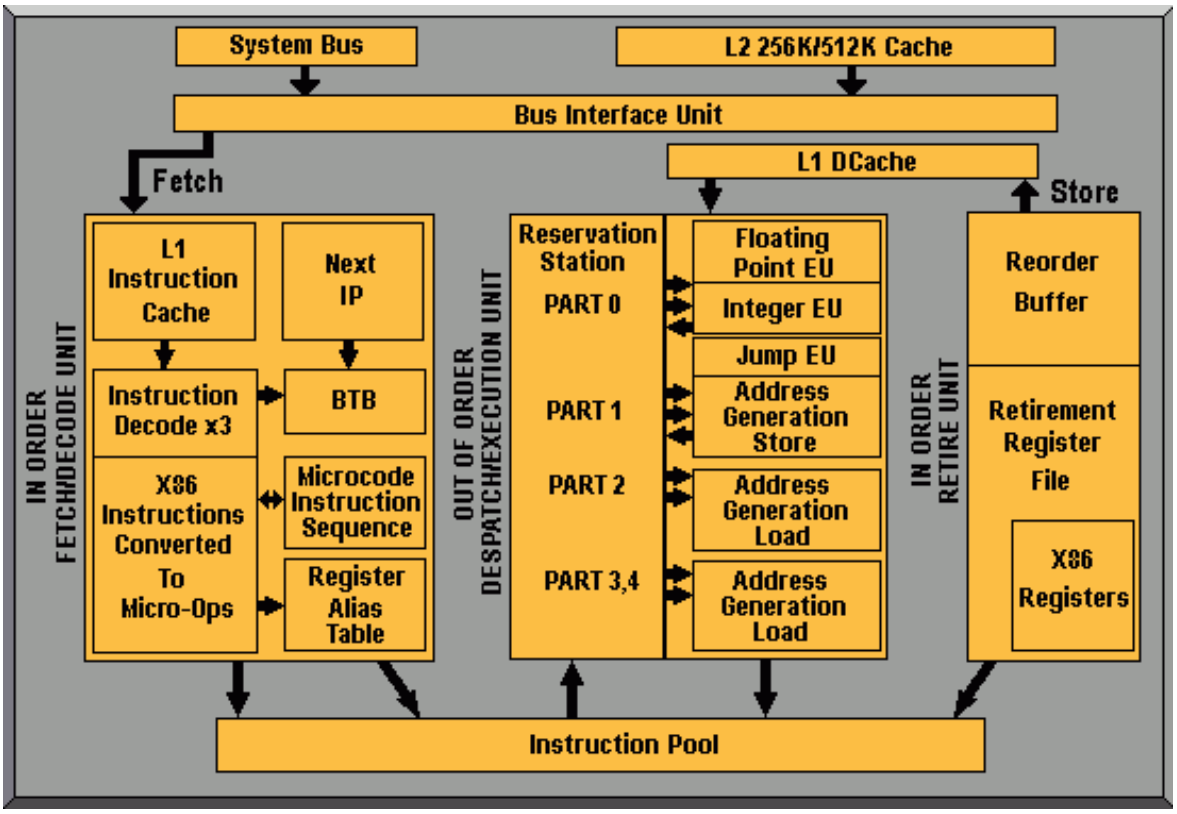

Figure 2: Architectural Layout of the Pentium Pro Processor (Tom's Hardware, 2019)

Code Name	P6
Date Released	1995
Architecture	32 bits
Data bus	64 bits
Maximum memory	64GB
L1 cache	8KB + 8KB
L2 cache	external, 256-1024 KB (CPU frequency)
Clock frequency	150-200 MHz
Front Side Bus (FSB)	60-66 MHz
Floating-Point Unit (FPU)	built-in
Fabrication Process	600-350 nm
Number of Transistors	5,500,000 + cache
Power Consumption	29-47 W
Voltage	3.3 V
Die Surface Area	306-196 mm^2 + cache
Connector	Socket 8

Figure 3: Table of Architectural Data for the Pentium Pro (4).

Weaknesses

Although the Pentium pro had many advantages compared to the other processors at the time, two weaknesses were exposed which gave it a lack of superiority amongst the rest. The Pentium pro was optimized for 32-bit operations, but never with 16-bit operations. This immensely slowed down 16-bit applications such as Windows 95 clients. With 16-bit registers, the Pentium pro could not utilize its out of order implementation used efficiently with 32-bit operations (Smith, 2019). Another problem was the cost of its production: "The Pentium Pro was a very expensive processor to build. Its core logic comprised 5.5 million transistors (versus 4.1 million in the P55C), but the real problem was that the Pentium Pro also included a large L2 cache on the same substrate as the CPU. This L2 cache required millions of additional transistors, which in turn required a much larger die size" (Thompson and Thompson, 2019). The reason for this was the way the processor had been built. With the L2 cache being separate from the core, the additional die space needed for all the transistors accumulated the price of it.

Overall Analysis

With the extra amount of die space used on the processor's architecture for the L2 cache, the Pentium Pro's price skyrocketed; you would think the overpriced processor would have consumers overlooking it. However, even with this increase in cost, "it was a highly successful processor among those users it was intended for. The Pentium Pro found its way into servers, high-end workstations, as well as the homes of graphics artists, and those users that happened to have an annoyingly large budget for computer equipment" (Shimpi, 2019). The Pentium Pro was superior to its predecessors and current generation when used with 32-bit client applications. However, if improvements were made to the architectural design relating to the location of the L2 cache, it could have improved its performance with 16-bit client applications as well. One way Intel could have changed the architecture would be if they had implemented a design where the L2 cache was built into the core. This would reduce the die space needed for the CPU and thus resulting in a less costly processor. Being compared to its replacement, the Pentium II Xeon, it can be shown that the improvement was made in cooling the L2 cache chips while running at higher speeds than the limiting version of the Pentium Pro (Thompson and Thompson, 2019).

Conclusion

With improvements in the 16-bit application compatibility and reducing the cost of production, the Pentium pro could have sustained a much longer lifespan. Regardless of these factors, the Pentium pro established some unique architectural designs. The x86 instruction set it had used made it the only processor within its 6th generation of Intel processors to contain it. Even with the 16-bit flaw, the 32-bit applications that it ran showed superior performance speed. The die space could have been reduced by changing the architectural design and placement of the L2 cache by placing it into the core, which could have resulted in a more affordable (and maybe an even more popular) processor. With these fixes in the architectural design, the Pentium pro would have had a longer duration than the 3-year manufacturing period.

References

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