PowerPC Technical Issues: Competitive Analysis (3/95)

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TOPIC ---

The article "PowerPC Business Issues: Competitive Analysis" covered some of the business reasons why Pentium and its follow-on processors will be at an increasingly great disadvantage relative to PowerPC. This article looks at some of the many technical reasons why an aging CISC architecture such as the x86 architecture of Pentium is at a significant technical disadvantage to a modern RISC architecture like PowerPC.

DISCUSSION ---

But without looking at a single technical advantage the reader can note that the largest computer manufacturers in the world, in all categories of computing, supercomputers, mainframes, minis, workstations and now personal computers have all made a commitment to RISC architecture, despite the fact that they have all risen to their current positions by selling CISC based computers. It should be obvious that if these companies, with their vast technical expertise and huge stake in CISC technology have concluded that CISC is a dead end and that RISC computing is the future, there must be some very sound technical reasons. Surely the leaders of all the various categories of computing, companies like of Cray, IBM, DEC, HP, Apple, Sun, and others would not invest their futures in RISC technology if CISC technologies couldn't be pushed to keep up. But all of these companies and many more have come to the inevitable conclusion that, in the final analysis, the most important criteria for a viable computing architecture is performance and price/performance. And when it comes to performance and price/performance the CISC architectures of the 70s, no matter what techniques are used to push them into the 90s, simply will not be able to keep up with a modern RISC architectures such as PowerPC.

Not only have the top computer companies chosen RISC but the world's largest semiconductor companies, companies that have also have risen to dominance in a CISC world, have seen the advantages of RISC and with a single exception have all made major commitments to RISC. The one major exception is of course Intel, the maker of Pentium, and the company with the most to lose as the CISC era comes to a close.

Because it is now widely accepted within the computer design community and beyond that RISC microprocessor architectures are superior to CISC architectures Intel has started calling its CISC architecture, "RISC-like." But this is simply

a marketing department's attempt to gloss over a major architectural weakness. A CISC architecture can not be a RISC architecture anymore than Byzantine Architecture can become Modern Architecture.

The difference between an architecture and an implementation A microprocessor architecture, like a building's architecture, embodies the underlying design philosophy and potential capabilities of that microprocessor. The architecture includes such design decisions as the number of and size of the instruction registers, the manner in which instructions are moved to and from memory, whether or not floating point numbers are a standard data type, etc. A microprocessor implementation on the other hand is similar to the materials that are used to build a building. The microprocessor's architecture is the ultimate determinant of what the microprocessor is capable of and how it will do it. Once an architecture has been defined there is no going back. Byzantine architecture is Byzantine architecture regardless of whether it is implemented in stone or concrete.

Intel proponents try to convince the market that the 486 and Pentium are, "RISCy" or "RISC-like" by pointing to certain features in the current implementations that are also used in RISC processor implementations. Intel's hope is to confuse the unwary by pointing to implementation techniques such as pipelining and superscalar execution, while ignoring the actual architecture. But it is the architecture that defines whether a processor is CISC or RISC and the architecture is fixed very early in the life of a processor family. The initial foundation of the Intel x86 architecture was set in place by the 8080 in 1972. And the blueprint of the x86 architecture was drawn up for the 8086 in 1978. The architecture has expanded since then but in order to maintain complete backward compatibility with all previous x86 software the basic x86 architecture must remain unchanged. The best that Intel can hope for is to implement some of the techniques in their newer processors that are used in more modern RISC processors. The number of techniques that they are able to borrow and the extent to which the x86 architecture can benefit from these techniques is limited by the design decisions made way back in the early 1970s.

Don't be misled. A microprocessor's architecture can not be changed by its marketing department; just because Pentium uses some of the same implementation techniques used by RISC architecture processors, it is not RISC. Only those processors that have been initially designed as a RISC architecture are RISC. And it is only those processors which can fully derive the price, performance, and other benefits of a modern RISC architecture.

Why should a user care whether a microprocessor is RISC or CISC?

The only reason why a user should care about whether or not a processor is RISC or CISC is if they want to be able to choose the architecture with the best performance, best price/performance and the ability to rapidly advance to even higher levels of performance and price/performance over time. Comparing PowerPC to Pentium is a good example of how a modern RISC architecture compares to an older CISC architecture on these criteria. PowerPC delivers a higher level of performance than Pentium and is able to do so with fewer transistors, in a smaller die, at a lower price. These are not unrelated features. Fewer transistors means smaller die size and less heat. A smaller die size allows for a less expensive chip.

Pentium vs. PowerPC Comparison Chart

Feature	Pentium	PowerPC 601
Architecture	32-bit CISC	64-bit RISC(7)
Age of architecture	15-20 years(1)	3 years
Maximum instructions per cycle	2	3
On-chip cache size	16 KBytes	32 KBytes
Core logic transistor count(2)	~2.2million	~1.3million
Die size	262.4mm2	118.8mm2
Estimated manufacturing cost(3)	$483	$76
Heat dissipation @66 MHz	13 watts	7 watts
General Purpose Registers	8 32-bit	32 32-bit
Floating Point Registers	8 80-bit	32 64-bit
Primary operating system	16-bit (4)	32-bit(5)
Follow on processors	NA(6)	603, 604, 620

Notes for Table:
1) Depending on whether the 8080 or the 8086 is used as starting point.
2) Total transistor count less transistors devoted to on-chip cache
3) Based on Micro Design Research estimates published 8/2/93
4) DOS and Windows 3.1
5) System 7
6) Intel has not announced additional x86 processors.
7) PowerPC 601 is a 32-bit implementation of the 64-bit PowerPC architecture

CISC architecture requires more transistors

RISC processors can generally achieve higher performance with fewer transistors. Pentium, the latest generation of x86 processor, uses over 3.1 million transistors to achieve integer performance similar to that of PowerPC 601 using only 2.8 million transistors. But nearly a half of the 601's transistors are used by the 32 KB on-chip cache while Pentium uses only a quarter of its transistors for the cache. Comparing the core logic of the two processors shows that Pentium uses nearly a million more transistors (2.2 million) devoted to actual core logic than the PowerPC 601 (1.3 million) to achieve roughly the same level of integer performance and substantially lower floating point performance.

Pentium requires far more transistors devoted to core logic in order to implement its CISC architecture. The considerably higher core logic transistor count increases the cost of Pentium, imposes barriers to easily achieving higher clock speeds, and contributes to increased heat.

All future versions of the x86 architecture will be similarly afflicted with large transistor counts in order to maintain their architectural heritage. Intel will undoubtedly be able decrease the size and improve the heat dissipation of Pentium somewhat, but future versions of the x86 will likely continue to be at size, cost, heat and probably clock speed disadvantages to PowerPC chips.

The cost of manufacturing Pentium vs. PowerPC

No semiconductor company publishes its actual cost of manufacturing various chips. But by looking at the various factors that affect the cost of making a chip, a fairly good estimate of the cost of producing a microprocessor can be made. MicroDesign Resources recently took a look at these factors for both PowerPC and Pentium. Examining a number of variables, including die size, wafer size, estimated yield, packaging and test costs they estimated that it currently costs Intel approximately $480 to produce a single Pentium chip while the cost of manufacturing a PowerPC 601 chip was estimated at $75. This is a tremendous differential, and there is little to suggest that Intel can close this cost gap. Because as an Intel VP recently stated in the Wall Street Journal both Pentium and PowerPC are subject to the same cost dynamics the cost of manufacturing both processors can be expected to decline at approximately the same rate. And equally important it can be expected that future generations of both processors will have a large cost delta as well.

Future Performance

The fact that PowerPC is only in the first generation of its life cycle while Pentium is already over 15 years and many generations into its life cycle has some important implications for expected performance difference over time. InfoCorp looked at the various factors likely to influence the performance of Pentium and PowerPC over the next few years. This information together with previously published information available from both Intel and Motorola was used to create the following chart. This chart shows the absolute performance levels of both Pentium and announced versions of PowerPC. Both Pentium and PowerPC start out with approximately equal integer performance in their current generations and both improve considerably over time. But as is obvious from the chart InfoCorp expects future generations of PowerPC will outperform Pentium by many times. Had InfoCorp chosen to chart the floating point performance of the two the performance advantage of PowerPC would be even more dramatic.

Intel's emulation performance FUD (Fear, Uncertainty, Doubt)

Those in the Intel camp like to make statements like, "PowerPC can only run DOS applications in emulation mode which is unacceptably slow." They often go on to state that "emulation is many times slower than running native."

What the Pentium camp conveniently forgets is that because PowerPC is many times faster than a typical 486 the PowerPC can still deliver high performance even when running DOS emulation. Considering that the only reason many users would even want to run older DOS applications is to run things like a terminal emulator or a text editor that they have become used to performance should not be a significant issue.

Intel is also trying to confuse customers about the performance of Macintosh applications running on PowerPC. Because Apple has control over both its hardware system design as well as its operating system it is in a position to ensure that current Macintosh applications will run with good performance on PowerPC based Macs. By rewriting performance critical parts of System 7 Apple has relieved software developers from the need to rewrite their existing software to run well on PowerPC based Macs. And customers will be able to run

their current software on the new PowerPC based Macintosh computers without having to purchase new applications or an emulator.

Upgrades

Many users are excited by the possibilities of next generation processors like PowerPC and Pentium, but until computers based on these chips are more widely available they can't buy one. The obvious answer for these customers is some sort of an upgrade to their existing systems. Both Intel and Apple plan on offering upgrades to next generation processors to their customers.

Pentium Upgrade Hoax

Intel's inability to produce Pentium processors in large volume has caused it to pursue another strategy in order to take advantage of the hype it has created for Pentium. Intel has convinced most of the companies which manufacture 486 based PCs to include a socket on their motherboards to accommodate some sort of Pentium upgrade processor. This processor which was originally code named P24T is now called Pentium OverDrive. The PC trade press though has reported a number of reasons why an end user who purchases a 486 based computer in anticipation of upgrading his machine to a "Pentium" based processor may be in for a disappointment.

Most of the reasons are related to the high thermal output of Pentium and the reduced performance a user can expect when putting a 66 MHz "64-bit" processor into a 33 MHz board designed for a 32-bit processor.

The problems which Intel faces with the Pentium OverDrive are not just speculation on the part of industry analysts. Intel admits that there is an upgrade problem. One of the ways it has attempted to address this problem is by redefining the socket specifications for the Pentium OverDrive processor. The current version of the socket being used is already on its third iteration, (it's called Pentium OverDrive 3) and the Pentium OverDrive part has not even been announced yet, much less shipped. And Intel itself has acknowledged that there are some supposedly Pentium upgradeable systems being shipped by various PC manufactures which will not be Pentium upgradeable as advertised.

PowerPC Upgrades

Apple has announced that low cost PowerPC upgrades will be available for most of the current Macintosh computers, and third party manufacturers are developing PowerPC upgrade boards for other Macintosh models. There are some critical differences though between the PowerPC upgrades for Macintosh computers and the Pentium OverDrive upgrades being advertised by Intel. Because the PowerPC 601 chip has a thermal output not significantly higher than current high end 68040 processors heat dissipation should not be as critical an issue. From a compatibility standpoint, compared to the hundreds of different 486 based systems that Pentium OverDrive must be compatible with, there are relatively few models of Macintosh which need to be tested for compatibility. And because unlike the Pentium OverDrive, which is not yet shipping, the PowerPC chip is already shipping it can be tested in actual Macintosh computers. The lower cost of the PowerPC processor compared to announced Pentium pricing will allow Apple to make PowerPC upgrades available to current Macintosh owners at a very

reasonable price.

Conclusion

PowerPC is an advanced, modern microprocessor architecture designed and manufactured by the world's leading semiconductor and personal computer companies. And as such, PowerPC has a number of key technical and business advantages over the older CISC based architecture, Pentium, being offered by a single supplier, Intel. And while Intel would like the market to believe that Pentium's ability to run all existing DOS applications will be the only important feature when choosing a microprocessor architecture IBM, Apple, Motorola, and an increasing number of industry observers believe that PowerPC's superiority in the areas of price, performance, time to market, multiple sourcing, and salability to higher performance levels, will be even more important especially in light of PowerPC's ability to run the vast majority of the installed base of existing software, and to run that software at a performance level higher than many customers are able to run them on their current Intel based hardware. Businesses can not afford to handicap themselves with an aging architecture when newer higher performance more cost effective solutions will be adopted by their competitors.

While those customers not currently held captive to the Intel's aging x86 architecture will be the first to reap the benefits of a migration to PowerPC, those with substantial investments in commercial and custom applications currently running on an x86 processor will also be attracted by the price, performance, availability and future of the PowerPC architecture. Those who believe that customers will not migrate to a clearly superior technology are probably the same group who thought that technically superior CDs could never replace the vast installed base of vinyl LPs.

For further competitive analysis on PowerPC versus Pentium, please refer to the following Tech Info Library articles:
1) PowerPC Business Issues: Competitive Analysis
2) RISC and CISC, Why the Difference: Competitive Analysis

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