Evolution of the x86 Architecture

It's Been a Long Road From 8086 to Katmai—What's Next?

For nearly 20 years, derivatives of the instruction-set architecture Intel created for the 8086 have dominated the world of general-purpose computing. Thanks to the spectacular success of the IBM PC and the standard it spawned, the x86 architecture has achieved a level of success that no one would have dared hope for.

For years, the architecture evolved slowly, and often ineptly. The 80186 was incompatible with existing PC software, because Intel didn't fully anticipate the rigors of DOS compatibility. The 286 inflicted on the industry a memory-management scheme that wasted thousands of man-years of programmer effort and held back OS and application technology for years. With the 386 and its paged memory management and 32-bit extensions, the x86 architecture finally achieved a level good enough for its remaining weaknesses—plentiful as they are—to be relatively insignificant.

Intel executives are well aware of the value of stability and compatibility. Once the 386 level was reached, architectural change all but stopped. The 486, Pentium, and the P6 implemented essentially the same instruction set. For 10 years, the instruction set stagnated, yet Intel was able to deflect the attacks of the RISC architectures through the power of compatibility with the PC software base.

With the MMX extensions, which debuted in early 1997 in Pentium/MMX, Intel made its biggest instruction-set addition in a decade. Unlike the 8086-to-286 evolution, however, which introduced incompatibilities in existing programs if the new memory-management features were enabled, no compatibility with the past was sacrificed. This approach was necessary to overcome Intel's natural anxiety about doing anything that would compromise the value of the software base—like requiring changes in existing code.

Spurred by the emergence of multimedia applications with huge performance needs and lots of readily available data parallelism, MMX triggered an avalanche of instruction-set extensions. AMD, Cyrix, and IDT each announced its own extension for SIMD floating point at Microprocessor Forum 1997. The three companies quickly recognized that unity would increase value to each of them, and they all settled on a derivative of AMD's scheme and labeled it 3DNow.

Intel will counter with Katmai New Instructions (KNI) in 1999. Unlike 3DNow, which uses the FP/MMX registers, KNI adds eight new 128-bit registers (see MPR 10/5/98, p. 1). This makes KNI more powerful than 3DNow, enabling four-wide SIMD FP and mitigating the paucity of registers.

With IA-64 set for a mid-2000 debut in Merced, KNI presumably is the end of Intel's efforts to add major extensions to the x86 architecture. Intel, which doesn't use the term x86 but calls it Intel Architecture (IA), talks about IA-64 as the 64-bit version of the architecture. In reality, it is an entirely new 64-bit instruction set that has nothing to do with the x86 architecture except that it is implemented in the same chip and includes instructions to support mixing of x86 and 64-bit programs. The 64-bit architecture no doubt includes a superset of the functions in KNI, operating on the larger register file.

Intel's competitors, on the other hand, don't have IA-64 on the horizon. Through 1999, 3DNow will continue to be of some interest, since there are games and other programs that support it, and it will be available in low-cost processors. Software support for KNI will mushroom in 1999, but Katmai won't serve the entry-level market. So for much of 1999, KNI and 3DNow can coexist, serving different segments.

In 2000, however, Intel will surely make KNI available throughout its product line. AMD would like the K7 to compete in the upper echelons of the market, and this is likely to require KNI—or something even better. AMD could presumably implement KNI in a hypothetical "K7-2." If, however, AMD is sufficiently encouraged by its ability to get software support for 3DNow, it might decide to try to leapfrog KNI, just as 3DNow did to MMX. PowerPC's AltiVec extensions provide one example of how multimedia instruction sets can go well beyond what KNI offers.

In the long run, Intel will move IA-64 into the mainstream PC space. The 64-bit instruction set does something no extension can do: it replaces the core integer instructions. Should the PC market someday demand a 64-bit instruction set, AMD might counter with Alpha; it is negotiating an Alpha license and has hired key Alpha architects. Just as IA-64 processors will support both x86 instructions and 64-bit instructions, AMD could do the same with x86 and an extended version of the Alpha instruction set.

With Compaq as its partner, AMD might be able to pull this off—but the easier path for AMD, in terms of market acceptance, would be to build IA-64 processors. Software developers focus on the highest-volume architectures, and this will continue to make it difficult to compete with the x86—and, in time, with IA-64. Others may be able to innovate around the fringes, but competing with Intel for the core architecture is another matter entirely. M

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