Four top-tier vendors at PC Expo announced their intention to make notebook computers based on Transmeta’s Crusoe processors. Some of these systems will use a new version of Crusoe that has twice as much on-chip L2 cache. Transmeta has also revealed a two-year roadmap of processors with higher clock speeds, greater integration, lower power consumption, and new VLIW cores, as Figure 1 shows.

The four PC vendors throwing their weight behind Transmeta’s unusual x86-compatible processors (see MPR 2/14/00, “Transmeta Breaks x86 Low-Power Barrier”) are Fujitsu, Hitachi, IBM, and NEC. All the vendors plan to introduce notebooks in the ultralight class, ranging in weight from 2.8 to 3.5 pounds, with TFT screens ranging in size from 10.4 to 12.1 inches. The notebooks are scheduled to ship this fall.

Crusoe processors are well suited for lightweight notebooks, because their low power consumption eliminates the need for cooling fans and large heat sinks. Furthermore, ultralight notebooks don’t compete in the same performance class as larger, heavier laptops, where Intel’s mobile processors have a speed advantage.

Some of the new notebooks will use the Crusoe TM5600, which has 512K of on-chip L2 cache—twice as much as the TM5400 announced in February. In other respects, the TM5600 is identical to the TM5400. It will be manufactured by Transmeta’s foundry partner, IBM Microelectronics, in a 0.18-micron copper process and packaged in a 474-pin ceramic BGA. Doubling the L2 cache increased the die size to 88mm², which is 20% larger than the TM5400’s die (73mm²).

According to Transmeta, the TM5600 is 5–15% faster than the TM5400 and consumes 2–17% less power. Although doubling the size of the L2 cache and enlarging the die would normally increase power consumption, Transmeta says the TM5600 actually uses less power when running typical Windows software, because it makes fewer accesses to main memory over the 3.3V I/O bus.

However, Transmeta still has not released any results of common industry benchmark tests, such as Ziff-Davis...
Media’s Winstone. Transmeta claims—with some credibility—that existing benchmark programs are misled by the unusual caching and dynamic-recompilation behavior of Crusoe’s code-morphing (x86 emulation) software. According to Transmeta’s estimates, a TM5400 Crusoe running at 700MHz delivers about the same raw performance as an Intel Pentium III at 500MHz.

**Surprising Power Measurements**

To back up its claims that Crusoe processors typically consume only 500mW to 1.5W—including the integrated north-bridge controller—Transmeta showed MDR a test system that graphically displays a constant measurement of minimum, maximum, and average power consumption. We experimented with several Windows applications, including Microsoft Word, Internet Explorer, an MP3 audio player, and a DVD movie player. As Figure 2 shows, average power consumption is indeed in the range promised by Transmeta and rarely spikes above 6W. And the test system revealed startling differences in power consumption among applications. For example, merely selecting a paragraph of text in Word briefly gobbled more power than decoding the MPEG-2 stream of a DVD movie.

Faster Crusoe processors are coming next year, according to Transmeta’s roadmap. In 2H01, Transmeta will migrate its cores to IBM’s 0.13-micron copper process, which offers the option of silicon-on-insulator (SOI) technology (see MPR 5/1/00-01, “IBM Paving the Way to 0.10 Micron”). The process shrink will reduce core voltage to 1.2V and boost clock speeds about 25%, even if Transmeta doesn’t use SOI. The TM5600 would move into the 700–900MHz frequency range at this geometry.

To take further advantage of the 0.13-micron process, Transmeta plans to introduce another new processor, the Crusoe TM5800, which will have 1M of on-chip L2 cache. It will use the same core as the TM5600 and TM5400 and retain the 474-pin CBGA package.

In 2002, Transmeta plans to revamp its Crusoe line with an entirely new CPU core based on an enhanced VLIW architecture. This core will have a faster FPU and will target a 0.13- or 0.10-micron process. Transmeta expects this unnamed chip (probably TM6xxx) to have twice the performance of existing Crusoe processors while reducing typical power consumption below 500mW.

The code-morphing software will also get an overhaul. Because that software translates x86 instructions into native VLIW instructions on the fly, Transmeta has virtually unlimited freedom to change the inner workings of the CPU core without breaking compatibility with operating systems and applications.

**Equally Aggressive Embedded Roadmap**

Transmeta’s roadmap calls for similar improvements to the company’s line of Crusoe processors for Mobile Linux information appliances. The current product is the TM3200, formerly known as the TM3120 (renamed because of a trademark conflict).

Next year, Transmeta plans to introduce two new chips, the TM3300 and TM3400. Both will come in smaller packages (360-pin CBGAs instead of 474-pin CBGAs), achieved by eliminating the unused pads reserved for the DDR-SDRAM interface on TM5xxx-series chips, but they will retain their SDR-SDRAM interfaces. The downsized package will allow Transmeta to sell the TM3300 for less than $50. The TM3400 will be the higher-end model, adding a 256K on-chip L2 cache and LongRun power manager.

In 2002, Transmeta plans to introduce the TM3500, which migrates the existing core to a 0.13-micron process. That will reduce the core voltage to 1.2V and boost the clock frequency to 600MHz. There will also be a more integrated version of the TM3500 that has 256K of on-chip L2 cache, LongRun power management, an LCD controller, a USB interface, and a PCI interface. Those additions will bump the pin count back up to 474 but provide system vendors with a more complete system solution. Table 1 summarizes the features of Transmeta’s current and future chips.

Less than six months after its much-hyped public debut, Transmeta has gained the crucial support of some...
Transmeta has aggressive plans to expand its Crusoe line over the next two years while taking advantage of IBM’s latest semiconductor process. (*In this table, “core frequency” refers to the maximum clock-frequency ratings of individual Crusoe processors, not to the range of frequencies supported by LongRun power management. n/a = information not available.)

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Pentium III processors in MMC-2 cartridges with a north bridge, but that feature increases the TDP to 12.8W for the 500/600MHz mobile Pentium III and 19.1W for the 600/750MHz mobile Pentium III.

There are two clock-frequency numbers for each mobile Pentium III processor because they automatically reduce their core voltage and clock rate when unplugged from AC power, a feature Intel calls SpeedStep. For example, the 500/600MHz mobile Pentium III normally operates at 600MHz and 1.35V on AC power, but it steps down to 500MHz and 1.1V on batteries. Likewise, the 600/750MHz mobile Pentium III normally operates at 750MHz and 1.6V on AC power; however, it then steps down to 600MHz and 1.35V on batteries. Table 2 compares the specifications of Intel’s and Transmeta’s mobile processors for PC notebooks.

The differences between Intel’s TDP specifications and average-power estimates are roughly an order of magnitude, which implies the average-power figure is based on a 10% duty cycle. ZD Media’s eTesting Labs (formerly ZD Labs) told MDR that BatteryMark does indeed leave a system in idle states about 80% of the time, because that’s how ZD Media’s engineers think real people use notebook computers. So, as Transmeta alleges, BatteryMark’s light duty cycle could explain the gap between Intel’s average and worst-case power numbers. Figure 3 shows a power-consumption trace of the 500/600MHz mobile Pentium III in battery mode (500MHz).

The Quest for Better Benchmarks
The truth about Intel’s and Transmeta’s power-consumption claims is more elusive, however. For one thing, Intel didn’t base its average-power estimates solely on BatteryMark. The company tested a wide range of desktop PC applications, as did Transmeta.

Not by coincidence, one application Intel tested was a DVD movie player, which is Transmeta’s favorite demo. Playing a DVD movie on a 600/750MHz mobile Pentium III at 600MHz consumes an average of less than 2W, says Intel, and the same task consumes less than 1W on a 500/600MHz mobile Pentium III at 500MHz. But the screen photo in Figure 4 (supplied by Intel) traces the latter processor during DVD playback in battery mode, and it appears to show average power consumption in the 2.3W range. And Intel’s TDP specifications clearly indicate that, to avoid meltdowns, system engineers must design for brief periods of much higher power consumption.

Unfortunately, Transmeta has been less forthcoming with power-consumption benchmarks than Intel. Transmeta criticizes Intel’s BatteryMark score but won’t release one of its own, saying that conventional tests like BatteryMark don’t yield accurate results, because of the TM5400’s unique LongRun technology. LongRun can vary the chip’s core voltage from 1.1V to 1.65V and the clock frequency from 200MHz to 700MHz in 33MHz increments—all while running on battery power and in response to soft-
ware workloads, unlike SpeedStep (see sidebar “Transmeta Explains LongRun”). The TM5400 would probably fare better with tests that simulate a heavier workload than BatteryMark, because LongRun could scale the core to some intermediate voltage and frequency within its broad range. A mobile Pentium III with SpeedStep would, however, be limited to its single battery-mode voltage and frequency.

On the other hand, a mobile Pentium III is likely to deliver more performance than a TM5400, and not just because the TM5400 has to emulate the x86. At its lowest LongRun-controlled power level of 1.1V, the 700MHz
TM5400 cuts back its clock frequency to a pedestrian 200MHz. At that same voltage, the 500/600MHz mobile Pentium III sprints at 500MHz.

We agree with Transmeta that existing power-consumption and performance benchmarks aren’t the best way to evaluate the TM5400’s unique abilities. Still, it would be nice to have more data points. Our experiments with Transmeta’s power-monitoring system lead us to believe that the brief 6W power spikes we observed roughly correspond to Intel’s TDP ratings, and that the TM5400’s average power consumption is indeed in the 1.5W range. If our casual observations are confirmed by more rigorous tests on the Crusoe-based notebook computers soon to hit the market, Transmeta’s promise of “all-day computing” could be realized.

One good sign is that Transmeta has joined EEMBC (EDN Embedded Microprocessor Benchmark Consortium) to help define a new suite of power-consumption tests and is working with other benchmarking organizations to refine their existing suites. Those efforts could benefit all CPU vendors, not just Transmeta. As more CPU architects turn to unusual techniques like LongRun to prolong battery life, power-consumption benchmarks will need to get more sophisticated—and now is not too early to start.