32-bit Embedded Processors: The Push for Higher Performance

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Abstract

In the evolving world of avionics and defense system design, many engineers face the problem of designing a higher performance product with lower power requirements and a small form-factor. Microcontrollers meet the integration and power restrictions of embedded designs, but do not provide enough throughput and performance. Today, avionics designs need the integration of a microcontroller with the performance of a microprocessor. Many companies are providing embedded microprocessors to meet this need.

New integrated 32-bit microprocessors offer fast data manipulation with the features needed to reduce a design's chip-count and power consumption. With today's applications, system designers must move to integrated, surface-mount microprocessors that satisfy their design issues.

This paper will explore the advantages of integrating peripherals with a powerful 32-bit microprocessor. It will detail the power management and peripheral features that make integrated microprocessors the answer to small form-factor avionics designs.

Today's embedded designs call out for a new processing engine. Avionics and defense systems need a processing engine with the integration and low power consumption of a microcontroller and the horsepower of a microprocessor. The microelectronics industry is meeting this need with integrated 32-bit embedded processors. Embedded processors provide microcontroller peripheral support, low power consumption and features for high performance processing.

Microcontroller Peripheral Support

Embedded processors integrate many popular peripherals needed in avionics and defense applications. One application supported by microcontroller peripherals is event driven processing. Peripherals such as programmable input/output ports, timers, counters, and interrupt controllers provide the events that control the CPU's processing. Serial ports provide a communication path for other subsystems and test equipment. Another important microcontroller peripheral is the watch dog timer. Unlike a personal computer, an embedded system is a "black-box" to its user. If the system is not functioning properly, a watch dog timer may cause a system to reset or provide a warning to the user.

Embedded processors include many microcontroller features, but they do not integrate all microcontroller peripherals. Every semiconductor vendor analyzes the target market(s) and provides the necessary features to make the product a success. For example, it is cheaper to implement a highly accurate analog-to-digital converter with support chips than it is to integrate one on-chip. Embedded processors usually do not integrate pulse

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	Programmable I/O	Timer/ Counters	Interrupt	Watch Dog Timer	Serial Ports	A/D Converter	PWM	Capture/ Compare
Microcontrollers								
87C51FC	✓	✓	✓	✓	✓		✓	✓
87C196KC	✓	✓	✓	✓	✓	✓	✓	✓
Embedded Processors								
80C186EB	✓	✓	✓		✓			
80386EX	✓	✓	✓	✓	✓			

Table 1. Microcontroller and Embedded Controller Peripheral Support

width modulators and comparators. Most high performance applications do not need these peripherals. Table 1 summarizes the typical microcontroller peripherals integrated on embedded processors.

Low Power Consumption

When faced with the challange of a high-performance/low-power system, a design engineer can turn to a 32-bit embedded processor solution. Embedded processors bring the best power management techniques from both the microcontroller and the microprocessor to avionics and defense designs. The Intel386™ EX embedded processor, for example, has four features to ensure low power operation: a static CPU core, an idle mode, a powerdown mode, and a system management mode.

Static Cores. Static CPU cores retain their state even when the incoming clock is removed or reduced. The Intel386 EX embedded processor's CPU core is a fully static version of the Intel386 SX microprocessor. Even with the addition of peripheral units, the new core helps to reduce the power rating by 10 percent while retaining the performance of an Intel386 SX CPU.

Idle and Powerdown Modes. Microcontroller features include idle and powerdown modes. Idle mode freezes the CPU clocks, but leaves the peripheral clocks toggling. The CPU stops executing instructions, and the peripherals continue to function. Idle mode operation decreases the Intel386 EX embedded processor's power rating by approximately 66 percent. Powerdown mode freezes both the

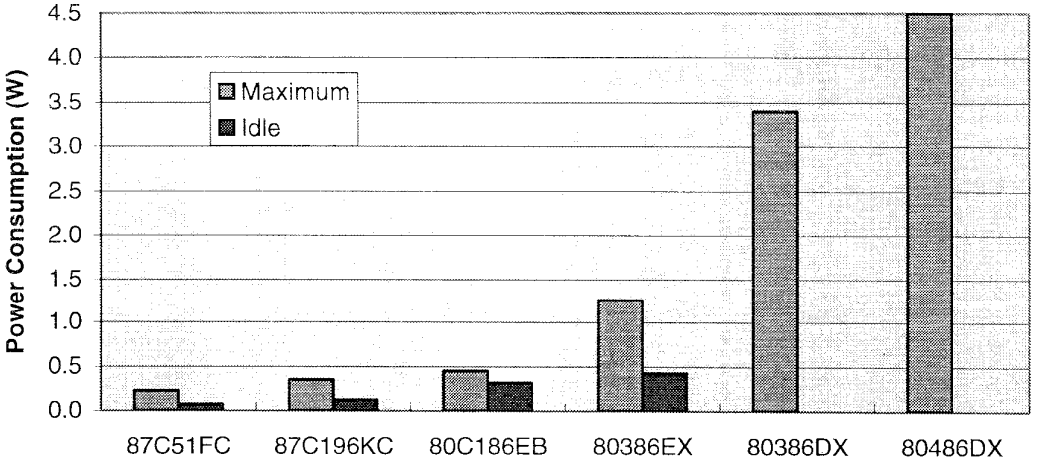

Figure 1. Intel Microcontroller, Embedded Processor, and Microprocessor Power Consumption

core clocks and the peripheral clocks. The CPU and the peripherals stop functioning until the processor is removed from powerdown mode. While an embedded processor is operating in powerdown mode, the power rating drops into the μWatt range.

Figure 1 gives example power ratings for microcontrollers: the 87C51FC and 87C196KC; embedded processors: the 80C186EB and 80386EX; and microprocessors: the 80386DX and 80486DX. Notice that the microprocessors do not support the idle mode feature.

System Management Mode (SMM). The Intel386™ EX embedded processor borrows SMM from microprocessors designed for notebook computers. An external interrupt activates SMM. Once the CPU recognizes the interrupt, the processor saves its current state and begins to execute the SMM handler. The handler is transparent to the application and can shut down external subsystems to reduce power consumption. Another interrupt can deactivate SMM mode returning the CPU to its previous state.

Avionics and defense applications can easily implement SMM. For example, a display system can temporarily shut-off power to a flat-panal display screen when the information is not needed. When the user needs the information, a push of a button can reactivate the screen. With the screen consuming a significant portion of the system's power, SMM can provide extreme power dissipation savings.

Although originally introduced for power management, SMM can be used for other purposes such as debugging or implementing an alternate operating system. The discussion of SMM implementation is beyond the scope of this paper.

Features for High Performance

In addition to offering a subset of microcontroller peripherals and a variety of power management features, 32-bit embedded processors offer powerful computing cores with features to support intensive data manipulation and high speed data throughput.

Powerful Computing Cores. With a Intel386 SX CPU core, the Intel386 EX embedded processor provides the computing performance of an industry standard 32-bit CPU. Add, subtract, multiply, and divide instructions all execute in nanoseconds compared to microcontrollers' microsecond integer performance. For even higher performance data manipulation, the Intel386 EX embedded processor supports floating point operations with the Intel387™ SX math coprocessor.

Figure 2 summarizes the computation advantages of a microprocessor core. Note that the 87C51FC is manipulating 8-bit operands, the 87C196KC 16-bit operands, and the 80386EX

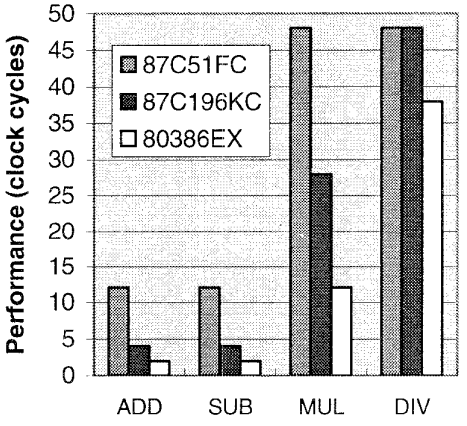

Figure 2. Integer Instructions (clock cycles)

32-bit operands.

Embedded processors also offer higher frequency products. Figure 3 gives examples of the available microcontroller and embedded processor frequency offerings with their associated MIPS ratings.

Memory Space. A microcontroller incorporates program memory and data memory on-

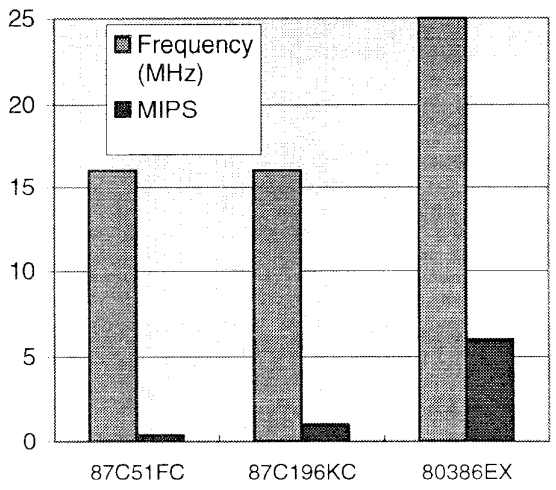

Figure 3. Frequency and MIPS ratings

chip. This is not practical for an embedded processor designed for high-speed data manipulation requiring significant program and data memory space. Implementing large blocks of memory off-chip is more cost-effective. Because embedded processors must access a profuse amount of memory in a short amount of time, they offer optimized bus interfaces and several integrated memory support peripherals.

Bus Optimizations. The Intel386™ EX embedded processor has several bus features to support small form-factor, high performance systems with significant memory needs:

- To reduce the amount of external support logic, the address and data buses are demultiplexed. Separate read and write enable signals provide glue-less SRAM and EPROM interfaces.
- For increased data throughput, the bus controller can transfer 8-bits of data per clock cycle.
- To increase the address space, two additional address lines have been added for up to 64 MBytes of available system memory.

Support Peripherals. The Intel386 EX embedded processor has integrated three additional peripherals to support small form-factor, data intensive designs.

- The Direct Memory Access (DMA) controller improves throughput by managing data transfers for the CPU.
- The chip-select unit reduces the amount of external support logic by providing eight programmable chip-selects.
- The DRAM refresh unit reduces the amount of external support logic by providing the refresh signal to DRAM memory devices.

Addressing Modes and Instruction Set. Microprocessor CPUs provide addressing modes and instructions not offered by microcontrollers. With complex addressing modes, the embedded processor directly supports implementation of the arrays and structures necessary for efficient data manipulation. Other instructions, like string control, provide the programmer with tools for working with data streams. These microprocessor features provide a strong tool set for the embedded software engineer.

Sophisticated Software Support. With a powerful microprocessor core, 32-bit embedded processors bring sophisticated software support to small form-factor embedded designs. Features like memory management support real-time operating systems and true multitasking. With this level of sophistication, system designers can implement Ada runtime systems where once only assembly languages were supported.

Design Comparison

To demonstrate the advantages of an embedded processor, compare a microprocessor design and an embedded processor design. With the same CPU performance as the microprocessor, the embedded processor offers an extreme reduction in board real-estate and power consumption.

Table 2 provides a rough estimate of the board real-estate and power consumption

	Package Area (mm^2)	Power (W)
CPU	1228.5	1.50
Refresh control, chip-selects & control logic	972.1	1.30
Interrupt Control	1132.1	0.05
Timer/counters	486.0	0.10
Parallel I/O Ports	808.1	0.05
Asynchronous Serial Ports	566.1	0.02
DMA Control	808.1	0.43
Intel386 SX Microprocessor Implementation	**6001.0**	**3.45**
Intel386 EX Embedded Processor	**2043.9**	**1.25**
	↑3X	**↑3X**

Table 2. Form-factor and Power Savings of the Intel386™ EX Embedded Processor

savings of an embedded processor. An Intel386™ SX microprocessor system design providing similar Intel386 EX embedded processor functionality requires over three times the board space and power. With an embedded processor, the reduction in printed circuit board area and power consumption add up to big cost savings.

Conclusion

The integration of on-chip peripherals and a 32-bit processor core provides the same performance as a microprocessor with the form-factor and power consumption of a microcontroller. With a more powerful instruction set and memory interface features than a microcontroller, an embedded processor offers fast data manipulation and throughput.