

# From Somerset to SoC

## A Decade of Innovation

It all began as a bold idea—Motorola, IBM and Apple Computer join together to collaborate on a new kind of microprocessor designed to compete head-to-head with the Intel architecture. The idea grew. The collaboration flourished. And after the first couple of years, the PowerPC® architecture and Intel's x86 architectures were trading speed records and performance benchmarks in what appeared to be a CPU battle for computer board space.

But appearances can be deceiving. From the very beginning, the vision behind the PowerPC architecture was not focused on computers alone. What the collaborators had in mind was a whole new processor roadmap to serve the "three Cs"—computers, communications and consumers, such as consumers of chip-laden cars.

The PowerPC microprocessor is, and has always been, a superlative computing engine. In the first 100 days after Apple introduced

the first PowerMac computer with the PowerPC 601 processor, it outsold Pentium-based systems and ushered in a new era of processor performance and capability. A decade of continuous innovation was underway, with much more to come. In 2004, Motorola's Semiconductor Products Sector became Freescale Semiconductor, Inc. a wholly owned subsidiary of Motorola. The story of our collaboration on PowerPC technology is an important part of our history and illustrates our commitment to innovation, past and present.

In the decade since the first PowerPC products entered the market, our processors using the PowerPC core have steadily evolved in performance and capability to today's powerful MPC74xx processors for the networking, communications and pervasive computing markets and the MPC5500 Family for the automotive market. These high performance PowerPC devices incorporate tens of millions of transistors on a chip and are manufactured in state-of-the-art 130 nm silicon-on-insulator (SOI) process technology, migrating soon to 90 nm and beyond.

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# 10 Years of Innovation: A PowerPC and PowerQUICC Processor Retrospective

## 1994

- > MPC601 shipping in volume—first PowerPC processor
- > Apple began shipping 601-based Power Macintoshes on March 14, 1994
- > Motorola, now Freescale Semiconductor Inc.\*, and IBM unveiled MPC604 processor with performance up to 100 MHz

## 1995

- > MPC860 PowerQUICC™ I announced, taking the leading 68K-based MC68360 QUICC communications processor to the PowerPC architecture

## 1996

- > PowerPC 603e introduced, with performance scaling up to 240 MHz

## 1997

- > Motorola and IBM announced the PowerPC 750 and 740, employing an advanced design that provides high performance using less power
- > PowerPC 604e announced at speeds up to 350 MHz
- > 300 MHz version of PowerPC 603e introduced

## 1998

- > PowerPC 750 announced, performance scaling to 366 MHz
- > MPC8260 PowerQUICC™ II introduced—next-generation integrated communications processor employing a PowerPC 603e core

## 1999

- > MPC860 Plus announced, offering substantial performance increase with performance up to 80 MHz
- > MPC855T announced—first PowerQUICC I device with integrated Fast Ethernet
- > MPC7400 announced—G4 processor delivering quantum performance leap for embedded and desktop systems, employing AltiVec™ vector processing technology and performing up to 500 MHz

## 2000

- > MPC7410 announced—manufactured in 0.18μ technology, enabling low power performance at up to 500 MHz
- > Motorola announced shipment of its 100 millionth communications processor

## 2001

- > MPC7450 announced, with performance up to 733 MHz
- > New MPC850DSL offered an 80 MHz 8xx core targeting the DSL market

## 2002

- > MPC7455 introduced—first PowerPC device to reach 1 GHz and manufactured using SOI technology
- > *Gartner Dataquest* reported Motorola's industry-leading communications processor market share at 74.7 percent
- > PowerQUICC II processors migrated to 0.13μ technology and performance increased to 450 MHz

## 2003

- > MPC7457/47 PowerPC processors launched, delivering performance up to 1.3 GHz and 1 GHz performance at less than 10W
- > MPC8560 PowerQUICC™ III processor demonstrated on stage at the Smart Networks Developer Forum—first e500 core device, and first communications processor to incorporate RapidIO™ interconnect technology
- > MPC885 PowerQUICC I Family, MPC8272 PowerQUICC II Family and MPC8555 PowerQUICC III processor introduced, integrating security throughout the entire PowerQUICC portfolio

## 2004

- > Freescale introduces MPC7447A PowerPC processor, offering 1.42 GHz performance and on-chip power management features
- > MPC8560 PowerQUICC III processor wins High-Performance Embedded Processors category in annual Analysts' Choice Awards from *Microprocessor Report*
- > Freescale introduces MPC8349E PowerQUICC II Pro Family based on e300 SoC platform and unveils next-generation PowerPC cores and SoC platforms at the Smart Networks Developer Forum

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# PowerPC Platforms

## **The Beginning**

In 1991 Apple, IBM and Motorola, in a group effort called AIM, put their heads together and decided to collaborate on a new microprocessor design, initially to satisfy Apple's desire to move beyond the 68K architecture for their desktop computers. Motorola and IBM took on the challenge to construct the new architecture, which had its roots in IBM's POWER architecture, at a jointly owned research facility in Austin, Texas, called Somerset (named after the legendary site of King Arthur's round table).

Carlos Gutierrez, currently the director of Freescale's\* Networking and Computing Systems Group, began at Somerset as a team leader in the MPC620 project.

Gutierrez remembers the Somerset management went out of its way to create a fun and creative environment to foster ingenuity and attract some of the finest talent in the world.

"At the time, having flexible work hours and wearing shorts to the office was unheard of at Motorola, but at Somerset, it was part of the new culture. Even the building was rebuilt to our specifications. It had a large atrium with many large, open meeting spaces. The idea was to provide a sort of 'cross pollination' of ideas between floors. Interestingly enough, one problem we didn't anticipate was with the differences in corporate technical jargon," recalls Gutierrez. "We literally had to learn how to speak the same language. But before long, it was

impossible to tell the difference between a Motorola and an IBM employee. Even our badges had both logos. All this fostered a powerful incentive to create," Gutierrez says, "And we all worked very hard to make Somerset a success."

By 1994 the first PowerPC processor, the MPC601, was shipping in volume, and Apple quickly introduced its first PowerMac that same year. Somerset also announced the MPC604 PowerPC processor in 1994 and the PowerPC 603e, originally for Apple portable devices, in 1995. Slipped in between these two announcements, however, were the introductions of the MPC821 for portable electronics and the MPC860—the first embedded PowerPC microprocessors.

In 1989, two years before AIM was established, Motorola introduced its MC68302 multiprotocol communications processor. This highly integrated device was something wholly new to the semiconductor world, and by 1993 Motorola rolled out a second-generation MC68360 QUICC (Quad Integrated Communications Controller) product. The QUICC name reflected a design that included four serial communications controllers. However, with the ascendancy of the PowerPC architecture, the third-generation communications processor was built around a PowerPC core. The MPC860 PowerQUICC™ integrated communications processor stepped onto the embedded stage in 1995.

The PowerPC platform, by design, provides an optimal processing foundation for embedded designs. Its minimal silicon requirements readily enable higher integration, making it possible to pack a RISC processor core and loads of peripheral functions on a single chip, while simultaneously reducing power consumption and heat generation—an ideal scenario for creating an industry-leading communications processor architecture.



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# PowerQUICC Processors

## The PowerQUICC Family

Since the mid-1990s, the PowerQUICC processor family has grown to become the industry's most widely used communications processor architecture. According to a May 2003 *Gartner Dataquest* report, PowerQUICC architecture had captured nearly 83 percent of the communications processor market. To date, Freescale\* has shipped over 140 million communications processor units to more than 350 customers worldwide. The PowerQUICC platform has garnered more than 5,000 design wins, such as digital subscriber line (DSL) modems, DSL access multiplexers (DSLAMs), wireless local area network (WLAN) equipment, intelligent access devices (IADs), telecom switches, wireless infrastructure, packet telephony equipment, and small office/home office (SOHO), enterprise virtual private network (VPN) routers, as well as printer, imaging and storage applications.

Each new generation of PowerQUICC processors has taken advantage of newer and more powerful PowerPC processor cores designed to serve emerging market demands for higher levels of performance and functionality. The architectural strategy is simple enough—start with the appropriate PowerPC processor core, integrate a communications processor module (CPM), then “plug in” reusable system blocks from Freescale's extensive intellectual property library to fit a particular market niche or customer application requirement.

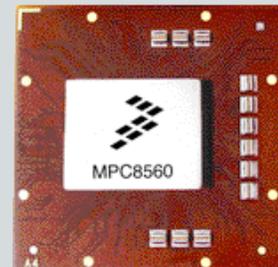
In the PowerQUICC family of integrated communications processors, the central combination—what makes these processors so successful and attractive to customers—is

the CPM, which is essentially an application-specific communications protocol accelerator, married with PowerPC core performance. What feeds so many market requirements is Freescale's ability to add appropriate system blocks needed for a particular application.

The PowerPC core played an important role in extending the capabilities of the CPM as Tom Starnes, an analyst with Gartner, Inc., explains, “They got on the datacom wave early with a unique and very capable data communications processor. The CPM's flexibility allowed it to adjust to the evolving protocols,” he says, “As networks rapidly grew in size and sophistication, however, the company needed to boost system performance. The CPM was the critical element to the market with the host processor being a secondary consideration. PowerPC had established itself as a leading RISC architecture, so it replaced the earlier 68K-based host processors attached to the CPM. PowerPC and advancements in the CPM allowed the QUICC Family to spread into a broad range of high-performance networking applications.”

Therein lies the key to Freescale's embedded core strategy with the PowerQUICC family of processors—integrate the best combination of performance and functionality to keep forging ahead, to ensure that the PowerQUICC family of communications processors remains preeminent in the market today.

The PowerQUICC II Family, launched in 1998, uses the PowerPC 603e core, pushing 450 MHz to drive such applications as Fast Ethernet, asynchronous transfer mode (ATM) and peripheral component interconnect (PCI). The award-winning PowerQUICC III



Family, which began sampling in mid-2003, incorporates the more powerful e500 PowerPC core, which gives this next-generation family of communications processors up to 1 GHz performance. The PowerQUICC III Family also supports new, application-critical capabilities, such as Gigabit Ethernet and double data rate (DDR) SDRAM, and it's the first communications processor family with RapidIO interconnect technology.

The e500 core is unique in that it is the first PowerPC core designed from the beginning as an embedded core. Does this mean that the PowerPC core story has now become the PowerQUICC story? Well, yes and no. Yes, because the PowerQUICC Family roadmap includes continuous PowerPC core enhancements geared toward peripheral-laden embedded communications processor architectures. No, because the PowerPC core strategy is not limited to the PowerQUICC family of integrated communications processors. It is the strategy for the entire line of PowerPC embedded processors.

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# Processing Power for the Automotive World

Since the advent of the MPC500 microcontroller in the mid-1990s, Freescale's\* 32-bit family of PowerPC microcontrollers has answered the processing needs of a wide range of automotive applications, from high-end powertrain systems to driver information systems (DIS).

Over the years, the company has expanded its portfolio of PowerPC microcontrollers to offer smarter, more powerful solutions, such as the highly integrated MPC5500 microcontroller family, introduced in 2003. Building on the

success of the MPC500 devices, this family adds more "street smarts" to next-generation powertrain systems, helping car manufacturers meet stringent performance, emissions and fuel economy standards.

"The semiconductor content in vehicles continues to grow year over year," says Will Strauss, president of the analyst firm Forward Concepts. "Automotive electronic systems manufacturers are requiring extremely high performance for their powertrain systems in order to control more complex engine and transmission functions, such as multipoint fuel injection and direct diesel injection. Semiconductor suppliers, such as Freescale, are responding to these requirements with more powerful, highly integrated micros."

Freescale is also responding to the burgeoning automotive/telematics market through its support of the mobileGT™ alliance. Our solution for this market is the MPC5200 device, a highly integrated, cost-effective PowerPC microcontroller designed for telematics communications, DIS and hands-free phone module applications.

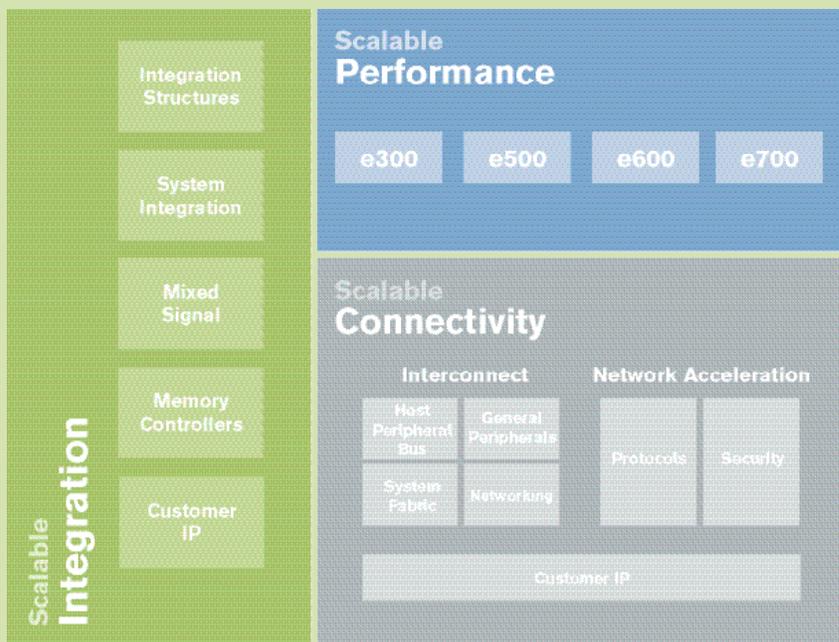
As the semiconductor content in automobiles continues to expand, along with market demand for higher processing power and more on-chip features, Freescale remains committed to driving its PowerPC platforms to higher levels of performance and integration.

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## Performance, Connectivity and Integration

Remember the three Cs—computers, communications and consumers? The original vision for the PowerPC architecture is alive and well in the scalable PowerPC SoC platforms for the networking, communications and pervasive computing markets. The common PowerPC core-based SoC platforms that Freescale is continually developing provide three important benefits to customers—scalable performance, scalable connectivity and scalable integration.

"When developing a new platform, we don't just focus on frequency at any cost, we go out to make it the best performer available for a particular market," says Dan Bouvier, Freescale's PowerPC Architecture Manager. "We work within a design envelope and manage its strengths and its restrictions. We don't go outside the envelope, or it would no longer appeal to the target market."



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# Scalable Performance

Scalable performance comes in the form of a continually advancing line of PowerPC cores and platforms engineered to address specific application needs. Maintaining compatibility while evolving an architecture to meet the needs of an evolving marketplace is key. Freescale continues to develop new scalable PowerPC cores and platforms, using existing cores as a foundation for further innovation, while always maintaining compatibility with the PowerPC instruction set architecture.

A case in point: the e300 core, the power plant inside Freescale's new MPC8349E PowerQUICC II Pro Family, is an enhanced version of the 603e processor used in previous-generation PowerQUICC II processors. Enhancements include a 32 KB data cache and a 32 KB instruction cache (twice as much L1 cache as used in the 603e) along with integrated parity-checking and other performance-enhancing features. The e300 core remains software-compatible with existing 603e core-based products and is capable of scaling to 667 MHz.

To address even higher performance requirements, Freescale has developed the e600 core by enhancing the powerful G4 core for SoC platforms. G4 is synonymous with Freescale's MPC74xx PowerPC processors, which are widely used in both computing and embedded applications. A hallmark of the G4 core is its optimal balance

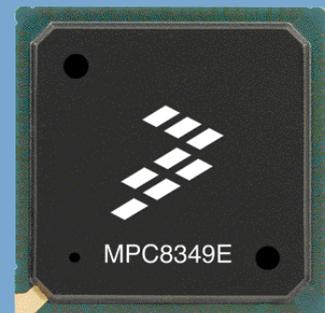
of high performance and low power dissipation, delivering gigahertz-class performance at less than 10W—making it an optimal solution for power-sensitive embedded applications.

Another hallmark of the G4 core, as well as the e600 core, is AltiVec technology, a 128-bit vector processing engine designed to accelerate a wide range of computationally intensive applications. Introduced in 1999, AltiVec technology has powered significant performance improvements across the computing and imaging industries in applications ranging from office automation to cutting-edge medical imaging technology. Freescale is enabling comparable performance gains in the networking and telecommunications markets by providing optimized AltiVec code libraries and application notes for networking-specific tasks, such as TCP/IP protocol stack processing.

"Using AltiVec technology, the MPC7447 PowerPC processor achieved the highest performance rating of any processor chip tested against EEMBC's telecom and networking benchmark suites," said Markus Levy, president of EEMBC (Embedded Microprocessor Benchmark Consortium), following tests in 2003. "Comparing AltiVec-optimized EEMBC benchmarks with non-optimized results, without raising the

processor frequency or power, the MPC7447 shows a performance increase of up to four times with EEMBC Telemark™ and a three times increase using EEMBC Netmark™."

This kind of performance is being passed on to the e600 core, and it's impressive. But, in a core-based strategy it is only useful if the power is effectively used in concert with the rest of the SoC equation.





## Scalable Connectivity

Scalable connectivity draws on a wealth of Freescale's reusable, communications-oriented system blocks that can be matched with the specific requirements of the targeted applications. Freescale's\* large and growing technology library includes general peripherals, such as Hi-Speed USB; system fabric connectivity, such as RapidIO technology; networking protocols, such as Gigabit Ethernet and ATM; external bus connectivity; security accelerators, such as public key and symmetric encryptions; and, of course, the communications processor module.

The ability to mix-and-match reusable system blocks such as these with the ever-growing family of PowerPC core processors means that Freescale can scale processing solutions to meet the exact requirements of a customer's market. Freescale focuses on a wide variety of embedded markets, including wireless infrastructure, enterprise, access, aggregation and pervasive computing. Each has its own requirements in levels of performance, power consumption and functionality.

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## Scalable Integration

Scalable integration is what gives system developers the capability to push the limits of performance, functionality and economy in PowerPC SoC platforms. It allows developers to take advantage of continually smaller transistor geometries to pack more performance and functionality into a smaller space. The company began integrating cache controllers (L2 cache) in the late 1990s, and now Freescale is integrating switch fabrics, memory controllers and high-speed I/O, among dozens of other reusable functional blocks.

"By improving on-chip integration, we're going after two things," says Bouvier. "First, we're gaining additional performance by putting memory and peripherals closer to the core processor, thus reducing the lengths of the interconnections. Second, we're gaining cost advantages for our customers by reducing the number of discrete components in their system designs."

Delivering stripped-down, discrete PowerPC devices is not the focus of Freescale's product strategy. It's not what customers want. What the market does want is high-performance, cost-effective processing solutions within a reasonable

power envelope in concert with on-chip peripheral features that closely match the customer's application requirements. In response, Freescale plans to integrate a specific PowerPC core with reusable system blocks to meet customers' exact specifications. This goal can often be accomplished through Freescale's exceptionally broad range of standard integrated processor products. When a customer's application requirements call for a unique solution, Freescale can leverage its SemiCustom operation to deliver customized, SoC-based silicon solutions that integrate a wide range of peripheral blocks, including the customer's own technology.

## The PowerPC Advantage

From the very beginning at Somerset, the PowerPC architecture has been a highly managed architecture, meaning it's well defined and very consistent throughout the entire line of products, from the first discrete PowerPC processors operating at just 66 MHz to the latest, more integrated solutions that speed well past 1 GHz.

This continuity of architectural development has been a tremendous advantage for

third-party developers. They know their investments in PowerPC processor-based products are both backward- and forward-compatible, and they can take advantage of future generations of PowerPC platforms without worrying about having to reinvent the wheel. And with planned introductions of more powerful and capable PowerPC cores and platforms on the horizon, including multiprocessing and 32- and 64-bit SoC platforms, the future is that much closer.

In parallel with PowerPC core development, Freescale is also continually expanding its reusable functional block portfolio to include

the latest networking interfaces, external buses, system fabrics, memory controllers, general communications peripherals and security engines, to make sure optimal PowerPC SoC platforms are there when new applications and emerging technologies enter the marketplace to address customer needs.

### ***About Freescale Semiconductor***

Freescale Semiconductor Inc. ([www.freescale.com](http://www.freescale.com)) produces semiconductors for the automotive, consumer, industrial, networking and wireless markets for more than 10,000 customers worldwide.

Freescale Semiconductor, a subsidiary of Motorola Inc., has a 50-year history of innovation and excellence in microelectronics. Based in Austin, Texas, Freescale Semiconductor has design, manufacturing or sales operations in more than 25 countries. Freescale Semiconductor's 2003 sales were \$4.9 billion (USD).

### ***Learn More***

For more information about Freescale products, please visit [www.motorola.com/semiconductors](http://www.motorola.com/semiconductors).