The Linley Group

A Guide to High-Speed Embedded Processors

Fourth Edition

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Looking for a Fast Processor?

The number of markets for high-speed processors continues to grow. In networking alone, these speedy chips are needed for complex functions such as intrusion detection and other security functions, storage management, router control plane, and networking services. Consumer devices such as set-top boxes, HDTV receivers, and automobile navigation systems also need high-performance CPUs, as do high-speed printers, thin clients, kiosks, industrial control, medical imaging, and a host of other devices.

These applications share a need for speed but also the flexibility that a general-purpose processor provides. These chips use standard instruction sets such as MIPS, PowerPC, ARM, and x86, allowing programmers to use a wide variety of operating systems and development tools. System designers prefer a chip that integrates easily into their designs.

These applications have diverse requirements for performance, power dissipation, peripheral integration, and price. As a result, several vendors are selling dozens of different processors into the embedded market. In fact, we had to exclude processors below 400MHz or so, a speed range that is easily achievable by synthesizable cores today. This report focuses on companies developing their own CPUs to deliver extra performance to the customers that need it most.

Get the Facts Quickly

"A Guide to High-Speed Embedded Processors" provides an in-depth look at these products and vendors. This completely revised report from The Linley Group provides extensive coverage of high-end embedded processors with over 170 pages of information on AMCC, AMD, Broadcom, Cavium, Freescale, IBM, Intel, Marvell, PMC-Sierra, RMI, and Via Technologies.

The report focuses on general-purpose RISC and x86 processors at speeds of 400MHz and above, excluding specialized architectures (e.g. DSP, NPU). This report covers most PowerQuicc chips; the PowerPC 440/460; Intel's embedded Atom, Tolapai, and Merom; the entire Octeon family; RMI's XLR and XLS; Marvell's new Discovery processors; and many other RISC and x86 processors.

This handy guide, packed with valuable information, brings you up-to-date on the newest developments in this important market and gives you the analysis you need to help choose a supplier or partner in this field. In addition to networking, the report discusses processors that can be used in high-end consumer applications and printers. It also provides market share and market size data for the embedded segments covered.

The Linley Group

"A Guide to High-Speed Embedded Processors" begins with tutorials on the key technologies implemented by these products, background on the embedded market, and a discussion of the newest technology and market trends. Following these introductory chapters, the report delivers thorough coverage of all announced products in this area. For each of these vendors, the report examines the performance, feature set, and architecture of each product, highlighting its strengths and weaknesses in a consistent, easy-to-compare fashion. The report concludes with our own comparisons of these products and conclusions about which will fare best.

Make Informed Decisions

The Linley Group's founder and principal analyst, Linley Gwennap, draws on more than a decade of experience in analyzing microprocessor technology to explain the microarchitecture and system interfaces of each device and how it will affect application performance. Coauthor Joseph Byrne adds his extensive expertise as a semiconductor analyst to the mix. As the leading vendor of technology analysis for networking silicon, The Linley Group has the expertise to deliver the technical and strategic information you need to make informed business decisions.

Whether you are looking for the most effective solution for your application, a vendor to partner with, or a rising company to invest in, this report will cut your research time and save you money. Get the inside scoop on this market segment. Order "A Guide to High-Speed Embedded Processors" today.

This report is written for:

- Engineers who are designing embedded systems that require high-performance processors.
- Marketing and engineering staff at companies that sell chips that connect to or interact with high-speed embedded processors.
- Technology professionals who wish an introduction to high-speed embedded processors.
- Financial analysts who desire a detailed analysis and comparison of embedded processor vendors and their chances of success.
- Press and public-relations professionals who need to get up to speed on this technology.

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The following excerpt is from "***A Guide to High-Speed Embedded Processors, Fourth Edition***." This PDF contains the complete table of contents, list of figures, list of tables, preface, and executive summary. The full report may be purchased from The Linley Group.

A Guide to High-Speed Embedded Processors

Fourth Edition

Published May 2008

By Linley Gwennap and Joseph Byrne

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About the Authors

Linley Gwennap

Founder and principal analyst of The Linley Group, Linley Gwennap is one of the most respected analysts in the microprocessor industry. He has followed the industry for more than 15 years. A prolific writer, Linley has published hundreds of articles in a variety of publications including *EE Times, Upside Magazine, Electronic Business, Nikkei Electronics,* and the *San Jose Mercury News.* His work has also been translated into Japanese and German for international publications. He has written several book-length reports, including *A Guide to Wireless Handset Processors* and *A Guide to Communications Processors.*

Linley also provides high-level consulting to the microprocessor industry on subjects such as product positioning, strategic analysis, and competitive assessment. He has assisted companies such as Agere, Applied Materials, Hewlett-Packard, IBM, Intel, and Motorola, as well as several smaller companies and investment firms.

Linley's expertise, a rare combination of deep technical understanding and business savvy, is frequently sought by the technical and business press. He is often quoted in *The Wall Street Journal, Electronic News, Business Week,* the CNet web site, and other leading technology and business publications. He has also appeared on CNNfn, CNBC, Fox News, Tech TV, and National Public Radio. In 1997, Linley was profiled in *Worth* magazine as the analyst who "decodes Intel for the rest of us."

He founded The Linley Group in 1999 to provide technology and market analysis to a broad group of clients. Since then, the firm has established itself as the leading vendor of technology analysis of the networking-silicon industry.

Before founding his company, Linley served as publisher and editorial director of MicroDesign Resources' *Microprocessor Report*, leading the top independent technology-analysis team in the microprocessor industry. Under his leadership, the publication won the Computer Press Award for best industry newsletter four times in six years. He joined MDR in 1992 as its first full-time analyst.

Before joining MDR, Linley spent eight years working on RISC systems at Hewlett-Packard. As a design engineer, he developed test and initialization firmware for HP's PA-RISC servers, gaining a deep understanding of the operation of large multiprocessor servers. He later worked on PA-RISC processor design.

Linley then served as program manager for HP's Model 810 and 815 Unix systems, successfully driving those projects to market. He began seriously analyzing the microprocessor industry while serving as product marketing manager for HP's PA-7x00 family of RISC processors.

He graduated cum laude from Yale University with a bachelor of science degree in electrical engineering. While at Yale, Linley also studied at the graduate School of Organization and Management. As a student, he served as vice president of the Yale Political Union and chairman of the university's Independent Party.

Joseph Byrne

Joseph Byrne is a senior analyst at The Linley Group. With more than 15 years of industry experience, he is one of the industry's leading analysts covering the semiconductor market. He has published numerous reports analyzing various segments of the industry and is the coauthor of *A Guide to Access Processors* and *A Guide to Next-Generation Wireless*. Joe has spoken at several investor forums and industry conferences, including Communication Design Conference, Network System Design Conference, Gartner Semiconductor Conference, Selby Venture Partners' LP Conference, and the BusinessWeek IT Symposium at Comdex. He has frequently been quoted in both technical and business publications, including *EE Times, Unstrung, Electronic Business,* the *San Jose Mercury News,* NewsFactor Network, and the wire services.

Before joining The Linley Group, Joe served as a principal analyst for semiconductors at Gartner Research. In this role, he was responsible for tracking technology trends and market size, preparing market forecasts, and assessing the competitive landscape. His expertise also includes evaluating business and strategic plans, advising startups and major IC suppliers on marketing and positioning strategies, and providing insight to VCs and investment banks to support investment decisions.

Joe led Gartner's coverage of networking semiconductors in the era of the telecom boom and bust. Thereafter, he led Gartner's coverage of computing semiconductors, including microprocessors, system-logic chip sets, and graphics processors. Through both eras, he led coverage of wireless LAN chip sets. Joe also authored Gartner's seminal report on digital-camera technology, and he covered embedded microprocessors in the late 1990s. Before serving as an analyst, Joe held consulting positions with Gartner, Deloitte Consulting, and smaller firms in the U.S. and Europe.

He began his career as a microprocessor designer for SMOS Systems, where he honed his technical skills as a principal engineer. He earned a bachelor of science degree in electrical engineering and computer science from Duke University and an MBA from the University of Michigan.

About the Publisher

The Linley Group

The Linley Group is the leading vendor of technology analysis on networking, communications, and consumer-electronics semiconductors, providing a unique combination of technical expertise and market knowledge. We help clients understand the market for these devices, their product requirements, the choices available, and which ones are best for a particular application.

Technology Reports

For clients desiring off-the-shelf assistance, we offer standard reports on specific topics. These in-depth reports provide an overview of a particular market segment, including market size and share, key trends, and expected developments. The reports then analyze all available products, highlighting their strengths and weaknesses. Readers find our reports particularly useful when they are selecting a vendor or partner.

Our reports are written by our own expert analysts. Technical accuracy is very high, as each vendor provides information about its products and reviews our presentation of those products. We add our analysis and insight, comparing and contrasting the various offerings and indicating the applications for which they are best suited. To ensure that our opinions are objective and unbiased, The Linley Group does not accept stock or retainers from the companies we cover. Our reports are used by more than 200 companies, including leading equipment makers, chip makers, software vendors, and investment firms.

Our reports cover Ethernet chips, network processors, communications processors, embedded processors, security processors, storage processors, switch fabrics, and high-speed interconnect as well as processors and connectivity chips for mobile devices. Additional titles are in development. We offer our reports in paper and PDF formats. Multiple paper copies and multiuser PDF licenses are available at significant discounts.

Consulting Services

The Linley Group offers customized consulting services for clients that need help with a specific issue. The Linley Group has served a variety of

clients, including Agere, Altera, AMCC, Cavium, Cypress, Hifn, HP, IBM, IDT, Intel, Motorola/Freescale, Wintegra, Xelerated, Xilinx, Crosslink Capital, U.S. Bancorp Piper Jaffray, and Ziff Brothers Investments. Typical consulting projects include the following:

• Working with a startup to help direct its initial product definition to best differentiate it from potential future competitors

• Helping an established semiconductor vendor with messaging and positioning for an upcoming product launch

• Assisting an equipment vendor to select key components that are most appropriate for its application

• Providing valuable insights and technical due diligence to an investment group evaluating whether to invest in a semiconductor company

Our analysts start with a deep understanding of the key technologies in these markets, ignoring the hype and finding the features that make a difference. But we also understand that market success is based on business strategy as much as on technical excellence, and our recommendations are always steeped in the realities of the marketplace. We understand the dynamics of startups and established corporations alike and can shape our message to apply to the client's situation.

Seminars

The Linley Group presents focused seminars that analyze products and design strategies in a particular technology segment, providing information that engineers can immediately use to improve their designs. These one-day events feature in-depth technical presentations from our own analysts as well as leading technologists from the industry. Hundreds of people have already attended.

Please check our web site for a list of upcoming seminar dates, topics, and locations. The web site also offers the proceedings (slides) from past seminars free of charge.

For More Information

Subscribe to *Linley Wire*, our free email newsletter, and get our analysis of recent semiconductor news and events in networking and communications. To subscribe, visit our web site, *www.linleygroup.com*; there you will find more information on The Linley Group, its products, and its services. You can also contact us directly, as shown below.

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Preface

What This Report Covers

This report covers high-performance RISC and x86 processors for embedded systems, either without integrated peripherals (standalone processors) or with integration of only generic system logic, such as memory controllers, PCI interfaces, and Ethernet interfaces. We focus on processors operating at 400MHz and above.

These general-purpose processors are used in many different embedded applications, including networking and communications equipment, networked storage, security appliances, PBXs, kiosks, point-of-sale (POS) terminals, thin clients, high-end printers, set-top boxes, digital video recorders (DVR), car-navigation systems, industrial control, military, and medical imaging.

This report does not cover processors used only in PC or server applications. It does not cover high-performance application-specific processors that integrate special-purpose hardware for data-plane, video, or similar applications. It also does not cover processors with programmable data-plane engines, such as communications processors or network processors.

Who Should Read This Report

This report is designed to meet the needs of a variety of readers:

• Engineers who are designing embedded systems that require high-performance processors

• Marketing and engineering staff at companies that sell chips that connect to or interact with high-speed embedded processors

• Technology professionals who wish an introduction to embedded processors

• Financial analysts who desire a detailed analysis and comparison of embedded-processor vendors and their chances of success

• Press and public-relations professionals who need to get up to speed on this technology

As described below, the report is structured to allow different readers to skip certain sections, as needed. For example, experienced design engineers may wish to focus on the vendor and comparison chapters; financial analysts may instead focus on the tutorial, introduction, comparison, and conclusions chapters.

Organization of the Report

The first four chapters offer tutorial and background material. Chapter 1 provides a tutorial on processor design, including CPU microarchitecture, memory, and I/O interfaces. Chapter 2 provides background on the types of embedded systems that use high-speed processors. Chapter 3 gives general information on the x86, MIPS, PowerPC, and ARM instruction sets. Chapter 4 discusses the common features of high-speed embedded processors and how to measure their performance.

Chapter 5 presents market data such as market size, vendor share, and forecasted revenue as well as our take on current technology trends.

Chapters 6 through 11 cover the top vendors of high-speed embedded processors—AMCC, Cavium, Freescale, Intel, PMC-Sierra, and RMI (formerly Raza Microelectronics)—and their current products. For each vendor, the report provides a company overview, an overview of applicable products, microarchitecture details, system-design information, a roadmap of future products, strategic analysis, and overall conclusions.

Chapter 12 briefly covers several other high-speed processor vendors, including AMD, Broadcom, IBM, Marvell, Montalvo, P.A. Semi, and Via.

Chapter 13 groups the available products into several categories and presents detailed technical comparisons within each group.

Chapter 14 concludes the report with our analysis of market trends and presents our take on which vendors will win in which segments.

Acknowledgments

The authors wish to thank the numerous people at AMCC, AMD, Broadcom, Cavium, Freescale, IBM, Intel, Marvell, P.A. Semi, PMC-Sierra, RMI, and Via who supplied information on their products and reviewed sections of the report. These reviewers helped ensure the highest possible technical accuracy.

Thanks go to our ever-vigilant copy editor, Ellen Clements, for keeping our grammar straight, and to Eileen Schmidt, who assisted with production.

Executive Summary

Embedded designers who require maximum CPU performance turn to high-speed embedded processors. For ease of programming, these processors use general-purpose instruction sets such as MIPS, PowerPC, ARM, or x86. Although these instruction sets are interchangeable in theory, in practice there is a strong correlation between the instruction set and the application. Consumer electronics—including broadband gateways, HDTVs, and set-top boxes—mainly uses MIPS or ARM. PowerPC is the top choice for networking equipment such as routers, security, storage, communications infrastructure, and cellular base stations.

Many other applications leverage the PC platform to quickly design complex systems that may involve networking, storage, graphics, and I/O. These systems include interactive kiosks, point-of-sale (POS) terminals, PBXs, industrial control, storage servers, and media servers.

Processor vendors use two approaches to deliver high performance. Companies such as Intel, AMD, and Freescale continue to build powerful CPUs that excel at executing a single monolithic software program. Vendors such as Cavium and RMI (formerly Raza Microelectronics) instead combine several less powerful CPUs on a single chip. This multicore approach delivers better performance per watt, but only for applications that can be divided into many small pieces. Many networking and consumer applications work well with multiple CPUs. Even Intel, AMD, and Freescale have endorsed this trend by deploying dual-CPU processors.

We estimate the total revenue from general-purpose embedded processors was $1.74 billion in 2007, excluding specialized devices such as PowerQuicc and custom devices such as PlayStation 3's "Cell" processor. This revenue rose 10–11% in each of the past two years, and we expect continued growth at nearly this rate through 2011.

Intel generates the most revenue from general-purpose embedded processors, almost all from its x86 line. Simply by offering its standard PC and server processors with extended product lifetimes, Intel can generate hundreds of millions of dollars from a variety of PC-like embedded applications as well as from security and storage designs. Intel's new Atom processor brings x86 performance to embedded applications that require less than 5W for the processor and system logic, but it lacks key features needed in many embedded applications. Intel's forthcoming single-chip x86 processor, code-named Tolapai, has the right feature set for these

applications, but it consumes more power and is more expensive than leading RISC-based processors.

As in the PC market, AMD and Via Technologies compete against Intel in PC-like embedded applications. AMD has been gaining share with its embedded Sempron and Athlon processors, but Via has struggled while waiting for its next-generation Nano processor to debut. Intel's Atom will provide stiff competition for Via in low-cost designs.

With support from Freescale, IBM, and AMCC, PowerPC comprises more than half the embedded RISC market. Freescale offers a broad range of functions and features, particularly for networking and communications, where the company is the leader. Freescale has recently refreshed its product line with the MPC831x and MPC837x at the low end and the dual-CPU MPC8572 at the high end.

Over the past year, AMCC has totally revamped its product line with the 405EX at the low end and the 460 family at the high end. These products provide better price/performance than Freescale's, but AMCC still lacks dual-CPU products or even a single CPU at a speed of 1.2GHz or faster. IBM continues to draw revenue from its standalone PowerPC processors but has stopped developing new standard products, instead focusing on custom products and licensing.

MIPS processor vendors include Broadcom, Cavium, PMC-Sierra, and RMI. Cavium has quickly built a broad processor lineup ranging from one to sixteen CPUs on a chip. With integrated peripherals and security accelerators, these Octeon processors are well suited to security and other networking applications, particularly at the high end. RMI offers a similar lineup under its XLR and XLS brands. These two young companies are focused on building their customer bases. Like IBM, Broadcom and PMC-Sierra have strong legacy revenue streams, but both are changing their strategies to focus on high-volume applications using application-specific processors.

Marvell has designed its own high-performance ARM CPU and launched a line of single- and dual-CPU products at speeds up to 1.2GHz. Using the ARM architecture and 65nm technology, these processors are very power efficient and offer excellent price/performance along with many useful interfaces. These advantages should be enough for OEMs to consider porting their software to ARM.

Although the high-speed embedded market will soon exceed $2 billion, a number of vendors have decided to exit the market after failing to reach 10% share. These withdrawals, coupled with ongoing transitions to multi-CPU devices and greater levels of integration, have created opportunities for new vendors—including Cavium, Marvell, RMI, and AMD—to gain share. In addition, the sudden removal of P.A. Semi from the market, along with delays in next-generation products at AMCC and Freescale, have forced customers to reevaluate their suppliers. This report analyzes the products, capabilities, and strategies of each vendor to determine which products are best suited to each embedded application and which vendors are most likely to succeed in this dynamic environment.