

# Microprocessor at 50: A Time to Celebrate and Energize for the Future

Lizy Kurian John , *The University of Texas at Austin, Austin, TX, 78712, USA*

Vijaykrishnan Narayanan , *Pennsylvania State University, State College, PA, 16802, USA*

Microprocessors have become more pervasive than any other landmark invention of the entire human civilization including the wheel, in spite of arriving a few millennia later. Many pioneers who have helped shape this amazing journey of microprocessors from its birth in 1971 to its omnipresence today share their perspectives in this special issue. Industry leaders in commemorating the special anniversary are keen to continue these innovations to an even greater extent and broader societal impact.

It has been a remarkable journey from a few hundred transistors to new machine learning engines that occupy an entire wafer with more than a trillion transistors. The journey has had its share of drama and intense competition, both technical and legal. However, in this issue, the entire industry has come together to celebrate this landmark event for microprocessors. We express our gratitude to industry leaders such as Pat Gelsinger (Intel CEO), Jensen Huang (NVIDIA CEO), Lisa Su (AMD CEO), Simon Segar (ARM CEO), Mark Papermaster (AMD CTO), and Mark Liu (TSMC President) for sending their thoughts and memories at this significant milestone.

There are approximately 30 articles, big and small, in this issue. The first article, from Federico Faggin, the designer of the first commercial microprocessor (Intel 4004), relives the moments of the microprocessor's birth. The next article, from John Hennessey, walks us through the five decades of innovation, highlighting the major contribution of each decade.

The articles from AMD, Intel, ARM, IBM, NVIDIA, Cerebras, etc., provide unique insights on the twists and turns in the microprocessor journey and serendipitous moments that led to breakthroughs. Steck, previously of Intel, presents artifacts and descriptions of Intel processors from 80387 to Pentium 4. Christie *et al.* of AMD write about their challenges from the

early days of AMD to the leadership position today. Colwell rekindles one of the quintessential debates on the RISC versus CISC arguments, providing insights to the Intel's micro-ops design in his article on the origins of Intel's micro-ops. This is followed by Keckler *et al.* describing the evolution of the graphics processing unit (GPU) from NVIDIA. Lauterbach's story on the case for wafer-scale integration and the development of the largest chip ever built, the Cerebras WSE-2, is captivating. Grisenthwaite presents the twists and turns in the evolution of the ARM microprocessor, which has become pervasive in the modern device-connected world. Webb highlights how the IBM mainframes embodied many of the microarchitectural innovations present in modern-day processors. Bose of IBM presents a historical perspective of the IBM POWER processor family from the viewpoint of presilicon performance modeling. Iyer *et al.* of Intel describe how cache architectures have co-evolved with technology and application needs over the past few decades. Glenn Henry's article portrays computer history from the 1960s to now, spanning from IBM to Centaur Technologies, describing his personal journey alongside.

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Microcontrollers are often considered the cheaper and slower cousins of microprocessors that are used abundantly and pervasively. History of Motorola microcontrollers from Raghunathan, McDermott's article on the Motorola bus and integration and stories from Vansingel of Renesas and Martin of Microchip portray the history and evolution of microcontrollers and demonstrate how indeed they were the early pioneers of Systems-on-a-Chip (SoCs). The

embedded systems market has seen the transformation of the microcontrollers with large and sophisticated SoCs. Swaminathan and Vega describe the advances in heterogeneous SoCs over the last 15 years, emphasizing their impact on application domains including gaming engines and autonomous drones.

VLIW architectures, which have a success story in the embedded and signal processing world, are covered in the article on the Texas Instruments C6X family of processors from Simar and Tatge. Wanda Gass describes early DSP processors from Texas Instruments and the amazing story of the 1987 doll with speech recognition, the Julie doll. Wanda still owns a working Julie doll and you can find her picture in the issue posing with her Julie doll. It is difficult to believe that there was a doll with speech recognition in 1987!

Good designs are only possible with good performance evaluations. The founding of performance evaluation organizations such as the Standard Performance Evaluation Corporation (SPEC) in 1988 is an important event in the history of microprocessors and computer systems. John Mashey, one of the original founding persons behind SPEC, discusses not only SPEC's founding but also a variety of events in the history of the development of the microprocessor in his article. John Henning of Oracle Corporation and current Secretary of SPEC conducted original experiments to present the dramatic improvement in performance of microprocessors in his article.

This issue includes contributions from a diverse group on their memorable moments with microprocessors. The article "From the Memory Lane! Microprocessor Stories from Deep Within!!" summarizes memories from Linley Gwennap (Editor-in-Chief of *Microprocessor Report*), Kathy Papermaster (IBM veteran of 26 years), Kunle Olukuton (Stanford Professor), Kathryn McKinley (Google Principal Research Scientist), and Timothy Pinkston (University of Southern California Professor). It is followed by several pieces that reminisce about a variety of experiences that range from behind the scene insights of design teams to teaching assembly language programming. We are sure that you will find exciting the articles from Murray Goldman on challenging times at Motorola during the development of Motorola 68000, John Goodacre on the development of the ARM multicore, Pete Harrod on memories with IBM mainframe to ARM processors, Jim Bondi on memorable experience with a Texas Instruments processor that never made it, Preethi Preethichandra of the University of Newcastle (Australia) on Zilog Z80, Robert R. Choderek of the AGH University of Science and Technology, Kraków, Poland, on his

experience with NEC V20, Ann Marie Maynard of IBM on her personal journey with computers, and Cliff Young of Google on his favorite microprocessor, the ATARI ANTIC. Make sure to share these articles with a young reader to kindle their interest to partake in the next 50 years of the microprocessor innovations. But beware, the speaking doll with speech synthesis is too rare to be their vintage Christmas gift.

At 50 years, it appears the microprocessor progress is just heating up, even as the primary driver for the microprocessor evolution, the Moore's law-driven transistor scaling, is losing steam. The middle-aged microprocessor is acting like a teen; things that were fashionable in teen age are returning (e.g., systolic arrays). A new generation of domain-specific processors, especially those that target the burgeoning artificial intelligence market, are emerging. There has been a resurgence of interest in open-source processors with the advent of RISC V, a second wave after the earlier OpenRISC and OpenSPARC initiatives. These efforts have enabled a new generation of startups to bring their innovation without the burden of licensing.

Huge investments are being made around the world in the quest of the next major advance in the microprocessor, from transformative changes, such as quantum processors, to integration advances, such as wafer-scale processors and monolithic 3-D processors. The article from the leadership team at the U.S. National Science Foundation elaborates on the new investments in the next-generation processors and the societal benefits that could result from these advances. Many similar investments are being made around the world, including the European Processor Initiative, efforts to build homegrown processor architectures such as the Longsoon from China, Shakthi from India, and next-generation processors from Elbrus in Russia.

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Finally, this issue highlights the survey results of polling our readers on their favorite microprocessors over each of the past five decades. A diverse group of participants ranging from experienced designers and

professors to novices and young students enthusiastically participated in this poll, and passionately commented on many microprocessor architectures. The poll was publicized at the International Symposium on Computer Architecture (ISCA) 2021, and the *IEEE Micro* website. We present the winners of the individual decades and the overall winners along with some of the comments in the article on the Editor's Poll. We are sure you are eager to find out the results. We also want to emphasize that none of the industry leaders whose quotes appear in this issue participated in the poll.

We thank the various article authors who wrote passionately about the history, challenges, and the thrill of designing microprocessors. The various articles illustrate how intertwined personal lives and

professional careers of those who worked on microprocessors were through these years. We are certain that humanity will win, if we continue to have the same passion for microprocessor and computer system design during the next 50 years.

**LIZY KURIAN JOHN** is a Cullen Trust for Higher Education Endowed Professor with the Electrical and Computer Engineering Department, The University of Texas at Austin, Austin, TX, USA. Contact her at [ljohn@ece.utexas.edu](mailto:ljohn@ece.utexas.edu).

**VIJAYKRISHNAN NARAYANAN** is the Robert Noll Chair Professor of Computer Science and Engineering and Electrical Engineering, Pennsylvania State University, State College, PA, USA. Contact him at [vx9@psu.edu](mailto:vx9@psu.edu).



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