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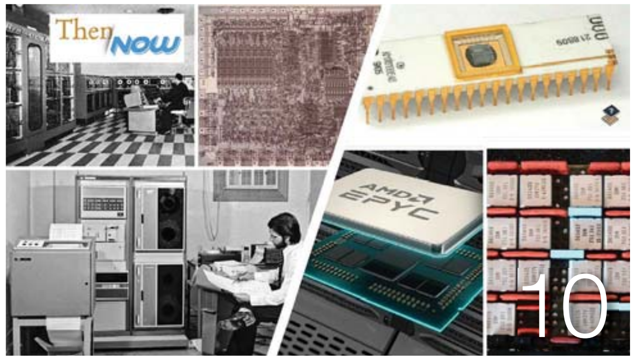


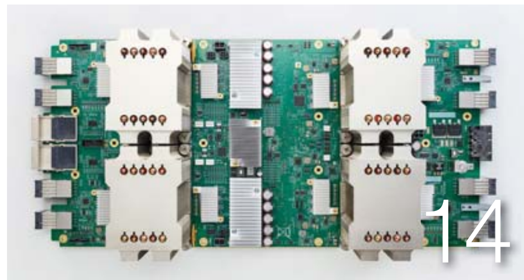


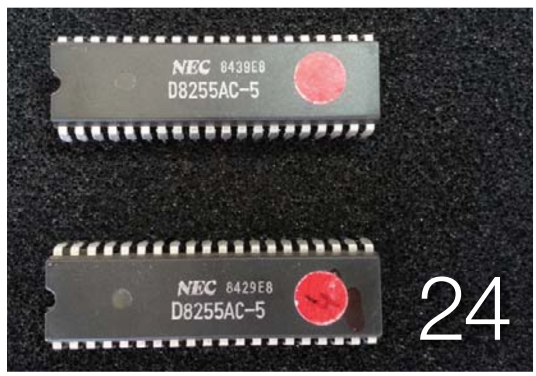



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**ELECTRONIC DESIGN** (ISSN 0013-4872) is published bi-monthly in Jan/Feb, Mar/Apr, May/June, July/Aug, Sept/Oct and Nov/Dec by Endeavor Business Media, 1233 Janesville Ave., Fort Atkinson, WI 53538. Paid rates for a one-year subscription are as follows: $60 U.S., $90 Canada, $120 International. Periodicals postage paid at Fort Atkinson, WI and additional mailing offices. Printed in U.S.A. Title registered in U.S. Patent Office.  For subscriber services or to order single copies, write to Electronic Design, PO Box 3257, Northbrook, IL 60065-3257. POSTMASTER: Send change of address to Electronic Design, PO Box 3257, Northbrook, IL 60065-3257. Canadian GST #R126431964.

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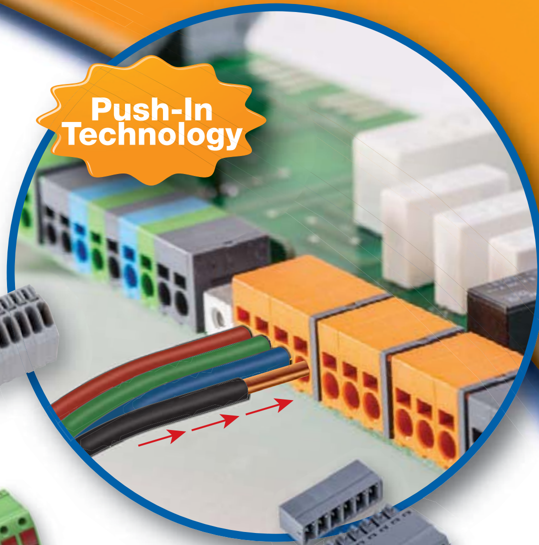


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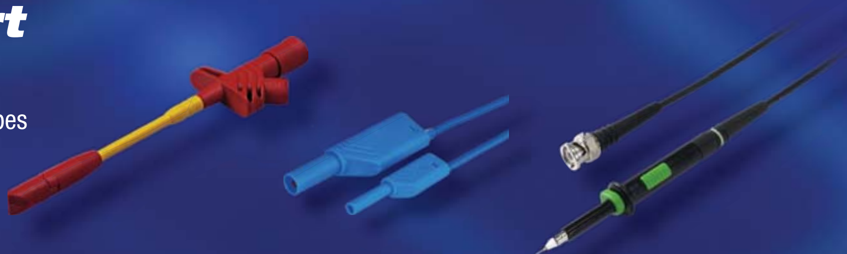

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## Editorial


**WILLIAM WONG** | Senior Content Director
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# Remote Collaboration, Digital Twins, and the Metaverse

**FORECASTING IS ALWAYS FUN** when you get it right, but that only happens occasionally. On the plus side, going with the trends tends to be the way to stay out of trouble. On the downside, COVID-19 has affected everyone and everything, so take anything like this as a very big grain of salt. It may be a while before certain things come to fruition.

That said, some clear trends have emerged in the electronics space when it comes to development. Remote collaboration has always been growing, accelerating in fits and starts over the past two years as a large amount of the workforce was forced to work from home. Articles based on our annual salary survey bear this out. I didn't have much of a problem since I've been doing that for the past three decades, but when you have to switch in a week, it tends to be a bit disconcerting.

Video conferences and general collaboration tools like Microsoft Teams are the mainstay at this point, but the number of development tools with integrated collaboration support is rising significantly. What's interesting is that the collaboration support facilitates working with others. However, it also ties all those people to the platform in a way that's hard to migrate to integrate with other platforms.

Enter the metaverse. The idea of a virtual environment isn't new. Actually, the term is rather old, but it's becoming more commonly used as companies like Facebook rename themselves as Meta. Unfortunately, these metaverses tend to be walled gardens. Such metaverses also may be focused on particular solutions like NVIDIA's Isaac robot simulation environment.

Robotic simulation is only a subset of these virtual environments and linking them to the design world and real world is where digital twins have become involved *(see figure)*. Again, digital twins aren't a new idea, but often these have been created and used in isolation. We're moving toward an environment where they're ubiquitous or at least very common and usable by a wider group of people.

So, the general forecast is that virtual reality (VR), augmented reality (AR), digital twins, and the metaverse will continue to expand in their use and functionality. And practical and economical uses of these technologies will grow as they become cheaper and more functional. High-resolution VR and AR glasses have made things practical, although not necessarily cheap. In addition, technologies like ray tracing are providing more natural visual presentations.

Luckily the forecasts presented by *Electronic Design* are not limited to this one in print or online. Our first print issue of the year has a number of articles looking ahead and our digital Top Stories forecast issue includes these articles and many more that address topics from development tools to semiconductors. ■

*Kunnicha-Luengrungwaree | Dreamstime | 195994280*

**The metaverse and digital twins go together hand-in-virtual-hand.**

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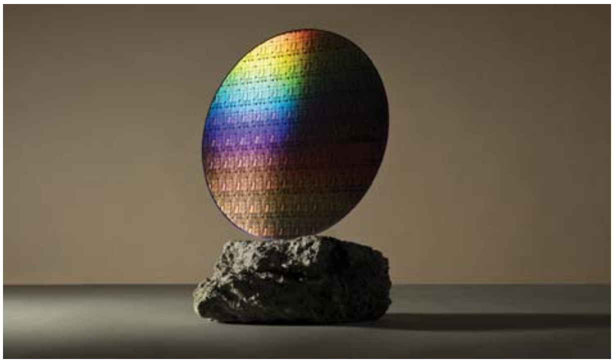

## IBM Unveils Vertical Transistors to Try to Keep Moore's Law Alive

The Vertical-Transport Field-Effect Transistor, or VTFET, could double the speed of the FinFETs that have dominated the chip landscape for a decade, according to IBM.

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## The Impact of GaN on Advanced Automotive Design

In this video, Alex Lidow, Founder and CEO of Efficient Power Conversion (EPC), discusses the growing role of GaN in advanced embedded applications like automotive, among others such as space systems.

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## MEMS Spiderweb Forms Super-Sensitive, Noise-Resisting Vibration Sensor

Inspired by the spiderweb's vibrational sensitivity despite noise, researchers created an analogous high-performance silicon-nitride MEMS version.

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## CES 2022 Virtual and In-Person

This year's Consumer Electronics Show was smaller, but in-person, with lots of virtual components, too.

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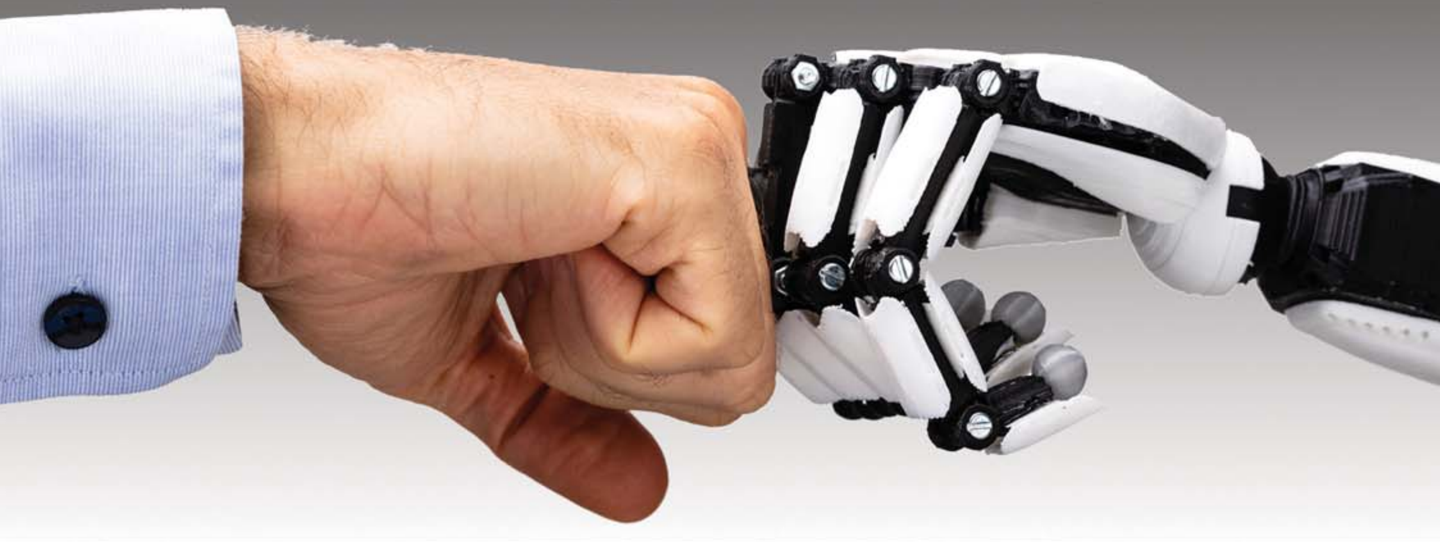
# THERE'S A KEYSTONE IN EVERY GREAT INVENTION.



## ROBOTS, AUTOMATION & THEIR ELECTRONICS

### Featuring Battery Clips, Contacts & Retainers

Though robots and automation are in use today in a wide variety of industries, robotics is still considered a futuristic idea. Many may be surprised to learn that the first electronic robots were built in 1948. What's even more surprising is evidence of the first automaton taking us back 800 years and writings from Turkey indicating automatic devices used to entertain.

Entertainment was the main drive behind the development of automatons for many centuries. Eventually, the benefits of automating simple, repetitive functions reached the manufacturing sector and grew into the complex, computer-driven automation we know today.

Advances in computers and electronics have facilitated fast progress for industrial automation. Factories and other industrial operations use robots for a wide range of automated processes.

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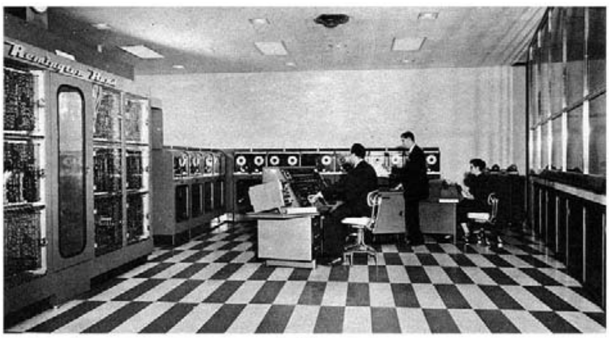
WILLIAM G. WONG | Senior Content Director

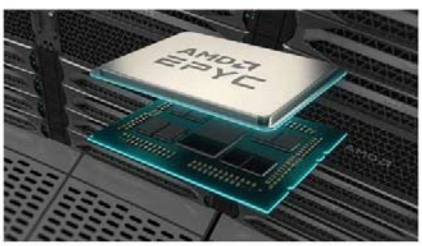
# Processors Have Come a Long Way

**From mainframes to MPUs, processor technology has progressed significantly since *Electronic Design* was first published.**

Computer processors were well underway when *Electronic Design* magazine first hit the shelves 70 years ago. However, this new electronic fare that included the UNIVAC (Universal Automatic Computer) is a stark contrast to some of the latest technology like AMD's 128-core Zen 4 EPYC server chip *(Fig. 1)*.



(a)



(b)

**1. The UNIVAC family (a) started out with vacuum tubes. The single-chip, 128-core AMD EPYC server (b) processor is built on 5-nm transistor technology.** *(Courtesy of AMD)*

The UNIVAC I was actually the second commercial computer; it had a liquid mercury, delay-line memory containing 1,000 words of 12 alphanumeric characters. It ran at low megahertz speeds and could read 7,200 decimal digits/s. The thought of a computer of any sort that fit in the palm of your hand, which could communicate wirelessly with the rest of the world, was in the realm of science fiction along with ray guns and flying cars. Those other items haven't progressed as fast as processor technology, but we have them all now.

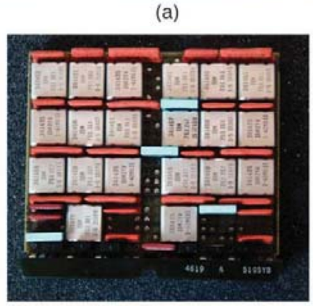
The AMD processor is built on 5-nm transistor technology running at gigahertz speeds. Its power consumption is on the order of a couple hundred watts compared to early mainframes that required many kilowatts along with forced-air or even water cooling. The UNIVAC used 125 kW of power and weighed in at 13 tons. Multichip servers typically have gigabytes to terabytes of external storage, not to mention on-chip registers and multilevel cache systems.

Processor and computer architectures were just evolving. The UNIVAC 1103A was the first computer to have interrupts. Inputs were often punch cards, paper tape, or magnetic tape, while output typically included reams of 132-column paper (14-in.-wide paper at 10 characters/in. plus borders). The blinking status lights were not LEDs and rows of toggle switches were standard fare.

## Mainframes

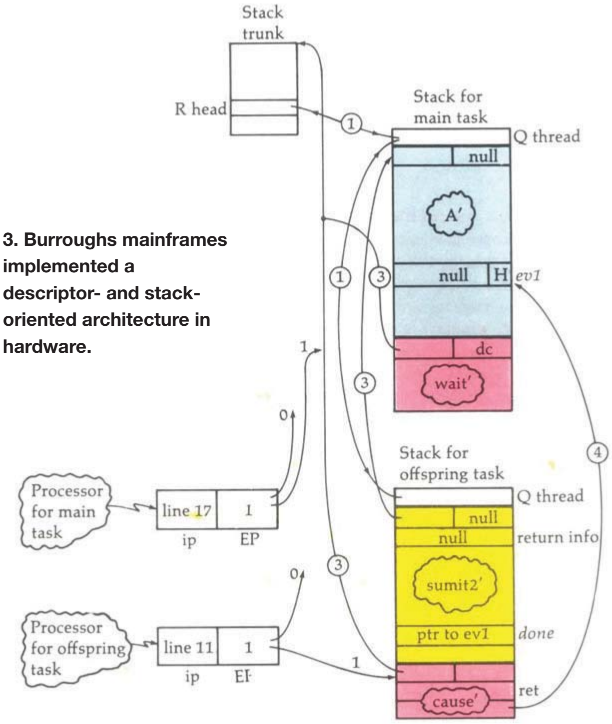
Mainframes were usually housed in special rooms, with raised floors for cabling and cooling being the norm for decades. The famous International Business Machines (IBM) System/360 (S/360) started out in 1964 *(Fig. 2)*. The S/360 replaced five other IBM computer families.

(a)



(b)

**2. The IBM System/360 (a) revolutionized mainframes. Shown are the 360's chips (b).** *(Courtesy of IBM and Creative Commons)*




3. **Burroughs mainframes implemented a descriptor- and stack-oriented architecture in hardware.**

The S/360 introduced IBM's Solid Logic Technology (SLT). This packaging technology mixed custom hybrid circuits that included discrete, flip-chip-mounted, glass-encapsulated transistors and diodes plus silk-screened resistors on a ceramic substrate. The basic architecture starts with sixteen 32-bit registers, 8-bit bytes, and 24-bit addressing. The EBCDIC character set was the preferred encoding with ASCII becoming the accepted standard now. Nine-track magnetic tape was ubiquitous and eventually the IBM 3340 "Winchester" disk drive was added to the mix.

IBM was joined by the "BUNCH" (Burroughs, UNIVAC, NCR, Control Data, and Honeywell). Each had its own architecture. Programming languages like FORTRAN and COBOL joined assembler, making processors easier to program.

Operating systems were typically written in assembler, but the Burroughs B5000 mainframe was programmed in Algol. The Burroughs ESPOL (Executive Systems Problem Oriented Language) Algol-variant provided system access and was used to write the Master Control Program (MCP). There was no assembler for these mainframes. The C programming language didn't become available or popular until much later. The term MCP was later used as the name of the antagonist in the *Tron* movie franchise.

I like to mention the B5500 since it was one of the first mainframes I used. It had a descriptor- and stack-oriented architecture that was implemented in hardware *(Fig. 3)*. It also employed tagged words that differentiated data and code. The B6500 moved to an 8-bit variable-length instruction set.

Multiprocessor systems were common, but each processor was typically a box or board. Though mainframes still exist, they have migrated to the latest multicore chip technologies.

## Minicomputers

The desire to shrink computers and make them more accessible morphed the mainframes into minicomputers, which were available from mainframe companies plus a host of others including Digital Equipment Corporation (DEC), Data General, Hewlett-Packard (HP), Prime Computers, and Wang Laboratories.

The typical minicomputer was 16-bit and weighed in at about 50 pounds; it didn't require a custom-built room although air conditioning helped. One could be acquired for as little as $10,000. They were constructed using readily available LSI technology. The 7400 series of transistor-transistor logic (TTL) logic chips was a popular implementation tool. These chips are still available but rarely used to implement processors anymore.

I used a dual-processor version of the HP 2000 minicomputer in high school *(Fig. 4)*. It was a timesharing system that could host dozens of teletype terminals with optional punch-paper tape units and eventually cathode-ray-tube (CRT) displays. Long-distance connections courtesy of 300- and 1200-baud modems were the norm.

4. **The 16-bit HP 2100 minicomputer had 16 kB of magnetic core memory and used magnetic tape for removable storage.** *(Courtesy of Creative Commons)*

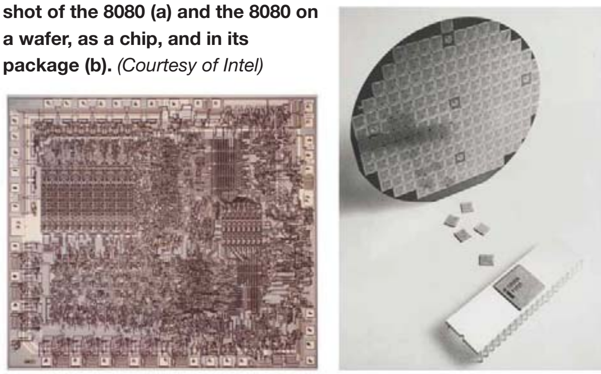
The 12-bit DEC PDP-8 was a popular platform and the 16-bit PDP-11 was eventually turned into the LSI-11 chipset.

## Microprocessors

Microprocessors compatible with minicomputers were available. However, 8-bit microprocessors that eventually drove the personal-computer (PC) revolution can track their evolution to the Intel 8008, which was replaced by the Intel 8080 in a 40-pin dual-inline package (DIP) *(Fig. 5)*. The initial clock rate was 2 MHz and instructions required a minimum of four cycles to complete. There was no caching, pipelining, or multithreading yet.

The 8080 was implemented using N-type metal-oxide-semiconductor logic (NMOS) and non-saturated enhancement-mode transistors as loads. It was compatible with 5-V TTL. The MPU had 8-bit registers that could be combined into 16-bit registers. A 16-bit stack pointer provided a recursive environment.

**5. The 8-bit Intel 8080 sparked the PC revolution. Shown are a die shot of the 8080 (a) and the 8080 on a wafer, as a chip, and in its package (b).** *(Courtesy of Intel)*



(a) (b)


**6. The IMSAI 8-bit Intel 8080 is built around the 8080 processor.** *(Courtesy of Intel)*

The Intel 8080 was the heart of the IMSAI 8080 microcomputer *(Fig. 6)* that showed up in the movie *WarGames* and was mentioned in *Ready Player One*. The Intel 8085 was a single-voltage, 5-V part that was eclipsed by the Zilog Z80. The Z80 was inside the Epson QX10 with 256 kB of RAM that ran an all-in-one office suite called VALDOCS, which I worked on while at Rising Star Industries.

Intel wasn't alone with the 8080. A host of other 8- and 16-bit microprocessors like the Motorola 6800 and MOS Technology 6502 was in everything from the Atari 2600 to the Apple II.

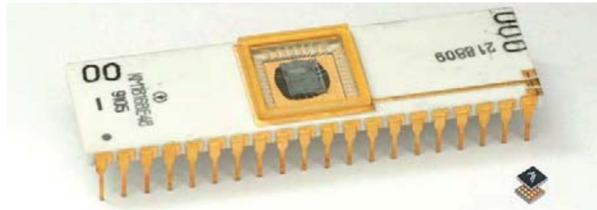
But it was the 16-bit Intel 8088 and the 8086, along with IBM, that created the Personal Computer family. The 8088-based IBM PC and its BIOS started the consumer side of things. It had a floppy disk and eventually a 5-MB hard disk.

The 8088/86 architecture was designed to make migration from the 8080 easy, but they were neither source- nor code-compatible. It's a world of difference from the x86 compatibility we know today.

### Current Architectures

Processors have scaled up in performance and down in size. It's possible to get 8-, 16- and even 32-bit microcontrollers in BGA packages only a couple millimeters on a side. They typically have on-chip clocks, flash memory, serial and parallel interfaces, as well as analog-to-digital and digital-to-analog converters. Some even have on-chip sensors for testing things like temperature.

That's a far cry from the first single-chip microcontroller I used, the Intel 8748, an 8-bit processor with a UV EPROM



**7. The 8-bit, 0.7-MHz 8748 UV 2-kB EPROM microcontroller in a 40-pin package is massive compared to the 2-mm$^2$ chip-scale package (CSP) for the 32-bit, 48-MHz, 32-kB, flash-based NXP Kinetis KL03.**

*(Fig. 7)*. The current NXP Kinetis KL03 is available in a 2-mm2 chip-scale package (CSP). The 32-bit, Cortex-M0+ runs at 48 MHz with 32-kB flash compared to the Intel 8748 featuring an 11-MHz clock delivering 0.73 MIPS with a 2-kB UV EPROM.

Packaging also is changing how processors are put together. 2.5D and 3D stacking has been used extensively for memory and for higher end processors. There's also wafer-based solutions like the one from Cerebras Systems that puts a trillion transistors to work with a focus on machine-learning algorithms.

The choices now at hand for developers are radically different from years ago. Multicore processor chips are readily available from small microcontrollers to chips designed for cloud-based servers. Processor architectures have included x86, Arm, MIPS, RISC-V, SPARC, and POWER. Of these, x86 and Arm now dominate with RISC-V on the rise.

Having access to a massive amount of transistors has made system-on-chip (SoC) solutions with many different processors possible—the variety is mind-boggling. Likewise, the use of dedicated processors for functions from security to network management are now common.

The ramp up of the Internet of Things (IoT) and IoT devices has pushed the need for security processors and secure storage on chip. Dedicated communication processors are sometimes added to the mix as well as utilizing low-power processors to augment a higher-performance processor when reduced computational requirements are in effect. Low-power options have led to always-on operation, so there's no real off button these days.

While I have concentrated on the basic central-processing-unit (CPU) architectures, we should not overlook the plethora of new architectures like graphics processing units (GPUs), FPGAs, and programmable accelerators for tasks such as machine learning. General-purpose GPUs (GPGPUs) and CPUs share multichip communication links. GPU programming takes single-instruction, multiple-data (SIMD) and vector computations to another level, and software developers are now mixing target platforms to achieve optimal performance.

There's also a move to disaggregation in server architectures. This is again changing how we look at chip and system design. Whereas the SoC looks to put different things on one chip, disaggregation enables storage and communication to be moved to a remote location. ■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JAMES MORRA | Senior Staff Writer

# Technology Giants to Step Up Chip Design Ambitions in 2022

**If 2021 is any indication, 2022 will see tech giants take even greater strides in custom chip design.**

Some of the world's largest technology firms are shunning standard chips in favor of designing them in-house, a move that's roiling the semiconductor industry and shifting the balance of power in the sector.

Now Amazon, Apple, Google, Microsoft, Tesla, and other Silicon Valley titans are taking things to the next level in a bid to build chips with improved performance, power efficiency, and cost. The push into custom chips is a mounting threat to industry giants such as AMD, Intel, Qualcomm, and others, and it has forced chip firms to respond by rolling out silicon specifically designed for customers' needs in areas such as AI.

While tech giants revealed a wide range of custom chips for data centers and consumer devices in 2021, they are set to step up their ambitions again in 2021, taking control of even more aspects of chip design.

Apple is in the final year of swapping out the Intel chips in its Mac laptops and desktops in favor of its own in-house processors, modeled on the high-end A-series chips at the heart of its flagship iPhones and iPads.

The plan fits into the technology giant's broader strategy of replacing many third-party parts with bespoke chips, a strategy that springs from Apple's philosophy that owning key technologies is a major advantage over rivals. Brady Wang, a semiconductor analyst at Counterpoint Research, said the use of custom chips eases its dependence on a single supplier and helps it roll out unique, differentiated features in its devices.

Wang said that Apple's investment in custom chips gives it more control over future releases of its iPhone, Macs, and other hardware and a higher grip on the ecosystem building software and apps for its products.

The likes of Amazon, Facebook, Google, Microsoft, and others are increasingly taking pages from Apple's playbook, replacing off-the-shelf server chips from Intel in favor of in-house chips tailored for their needs.

On top of that, the custom chip-making race comes during an ongoing global chip shortage that's raising costs across the supply chain. The supply chain challenges are pushing companies to reconsider where they buy chips.

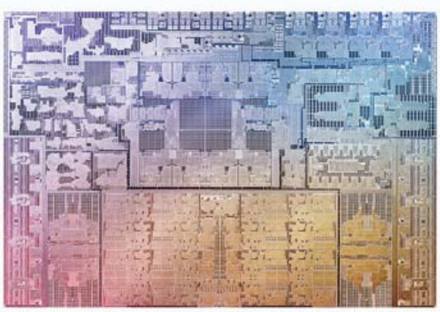
### "Apple Inside"

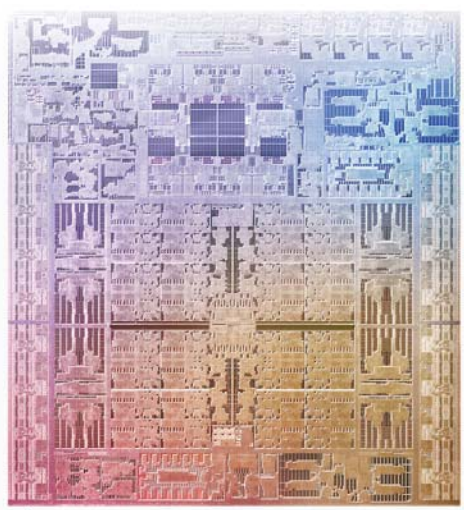
Apple was an early mover in the world of in-house chip development, releasing the first generation of its Arm A-series systems-on-chip (SoCs) for the iPhone more than a decade ago. Apple has improved the mobile chips and the central processing units (CPUs) inside to the point where they can rival Intel's chips for PCs.

In recent years, Apple has targeted its chip-making prowess at the iPad and other gadgets in its lineup, such as the Apple Watch and AirPods wireless headphones, to roll out features that stand out from rivals.

For Apple, the strategy gives it control over a more complete package of technology in its iPhones, iPads, Macs, and other consumer gear, ranging from software and


M1


M1 Pro


M1 Max

Die shots of Apple's M1 processors for Macs.

the operating system to the system hardware and silicon inside. Building more of the silicon and sensors that it previously outsourced has helped Apple stand out because it can plan how the chips work together to cut power and ramp up processing speeds.

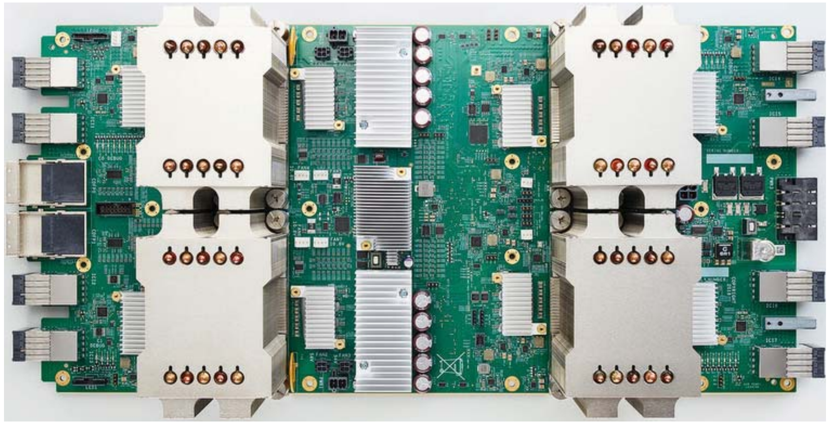
Apple's chip-making ambitions have reshaped the hierarchy of the semiconductor industry, analysts said.

Its success with the A-series processors in the iPhone has pushed the company to the front of the line for the world's most advanced process technology from TSMC, even placing it ahead of the likes of Qualcomm and AMD.

But it's taking things to another level with the M1 processors for Macs. In 2020, Apple announced it was moving away from Intel's products in favor of in-house "Apple Silicon" chips, including the M1 chip that now sits in the latest iMacs and iPads. Apple announced plans to phase these chips into its desktop and laptops in a two-year period, ousting the Intel chips used in Apple's PCs for the last decade and a half.

The M1 stunned the semiconductor industry with its combination of performance and high levels of energy efficiency. These attributes stem from the tighter integration between Apple's silicon, hardware, and software. Apple is upping the ante with the 5-nm M1 Pro and M1 Max used in its MacBook Pros, which have what it calls "unparalleled" performance for video editors, photographers, and other "pros."

Unless its chip division faces delays, 2022 is the year Apple completely pushes Intel out of its Mac lineup, even ousting it from the top-of-the-line Mac Pro desktop, which currently runs on Intel's Xeon server CPUs.



**The second generation of Google's Tensor Processor Unit (TPU) for the data center.**

### Silicon Powerhouse

Part of the calculus for Apple is economics. The consumer electronics giant can handle the engineering costs of in-house chips because of the savings that result from simplifying its supply chain. Instead of paying Intel, Qualcomm, or another semiconductor firm to design a chip and then get it manufactured, Apple can develop the chips itself and work directly with its foundry partners to contract out production.

Thus, the technology giant can pass the savings on to customers or shareholders, industry analysts said.

Apple's chip department has blossomed in recent years to what is reportedly thousands of engineers, bolstered by its deal to buy PA Semi over a decade ago. Leading the effort is Johny Srouji, the head of hardware technologies, who has become one of the core members of Apple's executive team during its campaign for custom silicon. He helps chart out the features in future Apple chips years ahead of time.

Over the years, it also worked closely with many of its chip vendors to get semi-custom parts made for its products. Many of the firms responded by building out whole divisions specifically devoted to Apple chips.

To back up its "in-sourcing" strategy, Apple is opening offices and hiring chip designers in areas such as cellular modems from suppliers such as Qualcomm in San Diego, California, and Intel in Portland, Oregon.

Over the last decade, the company has expanded its exploits in custom chip development, building a wide range of components for its consumer gear such as power-management ICs and Bluetooth ICs as well as more of the modules inside its SoCs, such as the graphics processing unit (GPU) and memory controllers. It has also created many of the advanced sensors and the haptic engine in its phones and other gadgets.

Apple will likely take its semiconductor ambitions to new levels in the future. The company is reportedly readying its first 5G baseband modem, a vital iPhone component that it currently buys from Qualcomm.

### Take to the Clouds

Apple's accomplishments in chip-making have been a revelation for other technology firms fighting over the cloud-computing market and pursuing dominance in other fields, such as artificial intelligence (AI).

Amazon, Google, and Microsoft are moving deeper into chip design to wring more performance out of the millions of servers spread out in globe-spanning networks of data centers, which they use not only internally but also rent out to outside firms over the cloud. Even small improvements in performance or cuts in the cost of powering and cooling chips in servers add up in the context of their vast operations.

Google and other technology giants continued to rely on third-party components for years while amassing the engineering depth and gaining the expertise they needed to design chips and other parts themselves.

But as they did so, they also pushed suppliers to incorporate custom features into the parts they needed.

Intel has said in the past that around 60% of its server processors sold to companies that run vast data centers are customized to a customer's needs, usually by disabling features of the chip they don't need.

Google was an early mover in the cloud sector, releasing its first custom chip called the Tensor Processing Unit (TPU) as a way of slashing costs and improving the efficiency of AI chores in its data centers starting in 2016. In 2018, the company said it would allow other companies to buy access to those chips through its cloud service in a shot against NVIDIA. It's currently on its fourth-generation TPU.

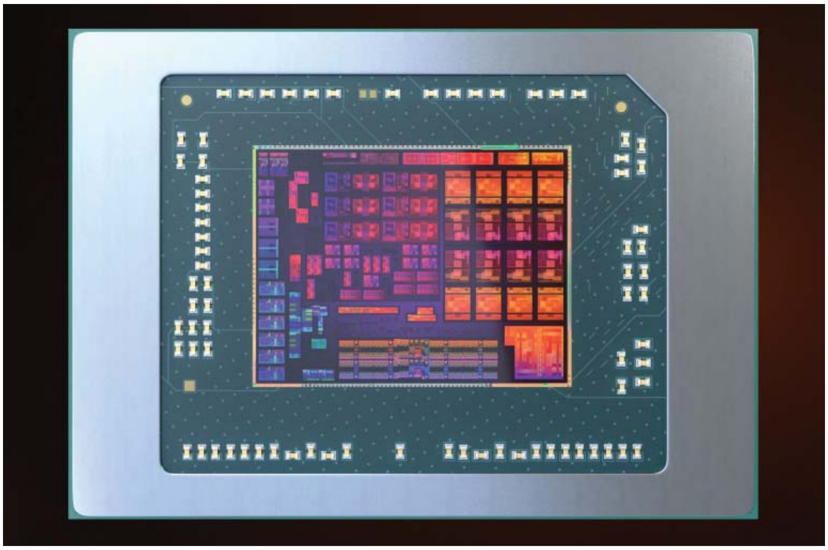
Microsoft, the No. 2 player in the cloud industry behind Amazon, has also invested in chip designs for data centers, including a class of programmable chips based on Intel FPGAs to run artificial-intelligence tasks.

Amazon has designed a wide range of networking chips and other processors for its cloud-computing arm, called AWS, including a family of server CPUs called Graviton based on blueprints from Arm. It has upgraded the Graviton CPUs every year since it rolled out the first generation in 2018. Last year, it released Graviton3 with over 50 billion transistors crammed in 64 cores and support for DDR5 and PCIe Gen 5.

AWS said that it has moved into making its own processors given the performance gains it would see by stripping out the unnecessary features in Intel's Xeon server processors that dominate the data center.

According to AWS, cloud-computing services based on its in-house Arm server CPUs cost significantly less than others that depend on Intel's Xeon chips because of the gains in energy efficiency and speed.

Amazon rolled out another server chip that it calls Trainium, which is designed to train machine-learning models and is set to battle against NVIDIA GPUs. The chip should be available to its customers by early 2022. The cloud vendor said it would run training up to 40% more cheaply than NVIDIA's flagship GPUs. It also announced its second-generation chip for carrying out AI software after it's trained, called Inferentia.



**AMD said Ryzen 6000 mobile processors would be the first x86 CPUs to include Microsoft's Pluton IP.**

Amazon's chip-making endeavors started taking shape after buying chip startup Annapurna Labs in 2015.

Tesla is also throwing its weight behind server chip development: The electric-vehicle firm announced last year that it is building out a processor called the "D1" and a computer system called "Dojo" based on it for use in data centers to help train the AI models behind the self-driving mode in its cars.

## Custom Silicon Surge

As Amazon, Google, Microsoft, and other technology firms take on Apple's dominance in the consumer electronics markets, they are also expanding their chip-making ambitions to close the gap with Apple.

Google rolled out its latest Pixel 6 smartphone with a custom processor called Tensor that integrates the core processing modules in the phone, including the CPU, GPU, and other intellectual-property (IP) blocks.

Rick Osterloh, Google's senior vice president of hardware, said Tensor gives it the computing resources it needs to roll out advanced features in areas such as image processing it hopes will set its products apart. The chip, which is specifically designed to assist with AI tasks, takes over the slot held by Qualcomm's Snapdragon chips in every generation of the Pixel, which the company rolled out in 2016.

Google is reportedly getting closer to rolling out in-house CPUs for its Chromebook laptops. The company allegedly plans to use its chips in laptops and tablets that run its Chrome operating system by 2023 or so.

But at this stage, not every technology firm is looking to handle all aspects of chip design by themselves.

Microsoft currently uses Intel-based processors for the majority of its Surface line of laptops. But in recent years, it has partnered with Qualcomm to design the Arm-based processor at the heart of its Surface Pro X laptop. Qualcomm has also partnered with Microsoft to develop a mobile chip from the ground up to run battery-powered, ultra-light augmented-reality (AR) headsets for use by both consumers and businesses.

But the software giant is no stranger to semiconductor development. Microsoft is reportedly developing a central processor for servers it rents out over the cloud and possibly for Surface devices in the future, too.

Last year, the software giant rolled out a new generation of the electronic pen that pairs with its Surface laptops. A custom chip inside called the "G6" is used to restore some of the physical sensations that are lost when writing or drawing on a display. The chip is used to create vibrations to mimic the feel of a pen on paper such as when users scribble through a word to delete it or circle a phrase to select or highlight it.

**Power Shift**

The scale of the technology firms bringing chip design in-house presents a challenge for chip companies. Their customers have the financial firepower to bypass them completely and build the chips themselves.

NVIDIA, the largest U.S. semiconductor firm by market cap, is valued at about $695 billion. Intel is at $226 billion. Amazon, Apple, Microsoft, and Google-parent Alphabet each top $1.5 trillion in market valuation.

Microsoft is also persuading partners in the chip sector to put its intellectual property in their products.

Microsoft has rolled out an ultra-secure co-processor called Pluton that will go into future computer chips for PCs, including its Surface laptops. The Microsoft-designed module can block the theft of secret keys used in cryptography or other information by locking it within a secure zone in the CPU. Pluton promises to add another layer of hardware and software protection against hackers trying to get inside the system.

AMD, Intel, and Qualcomm plan to incorporate the ultra-secure Pluton security module into future CPUs for PCs that run the Windows operating system. Microsoft introduced Pluton in 2018 as part of its Azure Sphere IoT service, working with chip firms to build it into microcontrollers for Internet of Things devices.

AMD plans to ship the first x86 processor for PCs with Pluton inside in early 2022.

**Serious Competition**

In the end, Amazon and other Silicon Valley titans have said they want to boost competition in the chip sector by offering more choices and, in the process, push semiconductor vendors to step up their game.

It's unclear what it would take at this point for Amazon, Apple, or other technology giants to return to off-the-shelf, third-party chips. Even so, chip firms need to take the competition seriously over the long term.

For Intel, Qualcomm, and other chip giants, 2022 will be another year of trying to prove customers wrong. ■

ALIX PAULTRE | Editor-at-Large


# A Hopeful Look Forward in 2022

**In a disruptive time, it's important to remember that every cloud has a silver lining.**

The past few years have presented society with myriad challenges and developments—some good, some bad. Every community has been impacted by current events, and each has had to address the challenges in their own way. The electronics community was not isolated from the events sweeping the planet and has had to address these issues as well. The greatest benefit from overcoming these issues are the solutions created and their impact on the future.

The year 2022 promises nothing to no one, and none of us can predict what will happen in the coming year. However, trends and technologies are creating next-generation products and services that will positively impact this coming year and the ones following. These include the maturation of collaborative tools, the increasing adoption of wide-bandgap semiconductors, and the expansion of intelligent systems into every powered device.

## Continued Expansion of Collaborative Tools

Collaborative software and connectivity in bench tools aren't brand-new developments. These solutions have been around for years, but they were largely used by big widespread organizations and remote contractors. However, the pandemic situation created a "perfect storm" for collaborative tool adoption. The need to work remotely became a critical issue for many organizations, and they turned to connected hardware and collaborative software to address their telepresence problems *(Fig. 1)*.

The ability to work remotely is just one of the benefits of such tools, and the real advantages became apparent once companies started using them. Beyond simple communication and file exchange, these tools also create a more organized and integrated design environment that delivers benefits across the board. For example, modern collaborative design software tracks all parts and components specified for a design, eliminating the need for an additional engineer just to create the bill of materials for the project.

These and other force-multipliers are not only enabling people to work together remotely, but also empowering the design process by completely integrating and digitizing all of the elements in a way that provides a flexible and capable real-time design ecosystem. When leveraged with smart manufacturing and Industry 4.0 capabilities, these collaborative tools can enable reiterative design—constantly tweaking a product during production to integrate and optimize every aspect that can be in a continuous process.


**1. Shown are results from the *Electronic Design* 2021 Salary Survey about how COVID-19 affected respondents' day-to-day jobs.**

The upshot of all this is that collaborative hardware and software tools will not be put aside as people return to their offices, as the advantages of using them go far beyond the ability to work remotely. A digitized, integrated, and optimized design, development, and manufacturing process will continue to provide benefits to the electronic design industry long after the initial need for telepresence passes.

Initiated by isolation, collaborative tools will continue to expand in functionality and capability even as people are working side-by-side again.

### Wide-Bandgap Power Will Change the World

Wide-bandgap (WBG) semiconductors have been coming to a slow boil for the last few years, as they slowly win over the electronic engineering community. The significant performance advantages of gallium-nitride (GaN) and silicon-carbide (SiC) products have been to a greater or lesser degree offset by their newness and additional cost over legacy silicon devices.

Using WBG devices as drop-in replacements can provide some performance advantages, too. However, to realize the full benefits, the power electronics must be redesigned, increasing adoption resistance.

This is another space where adoption has been impacted by the pandemic, giving WBG devices additional opportunity to show their mettle. The resulting disruption to the supply chain caused those with the resources to migrate their designs from legacy silicon to WBG discretes to ensure inventory. This in turn caused them to migrate their power electronic designs to more advanced topologies to take full advantage of WBG benefits.

The benefits of these new devices should not be taken lightly, as the wide energy difference in WBG semiconductors between the top of the valence band and the bottom of the conduction band enables them to operate at higher voltages, temperatures, and frequencies. These aspects not only improve power-management capability, they also can directly impact the performance of the systems involved. For example, the high switching frequency of GaN-based power supplies enable systems like LiDAR that rely on speed to flourish.

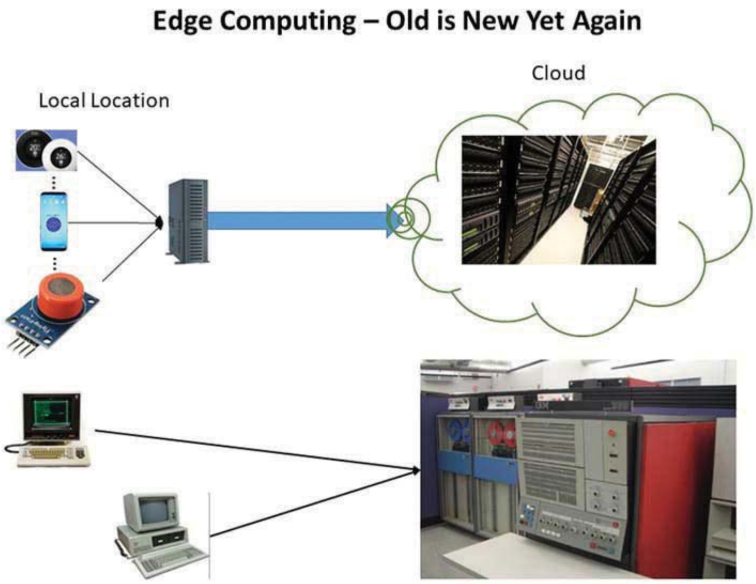
This migration of power electronics to WBG will not ease as the supply chain improves, since the benefits of GaN and SiC go far beyond their ability to simply replace silicon in a design. Their performance advantages are so profound that few who start using them go back to silicon unless their budget demands it. Even that price issue will fade as WBG availability continues to grow. 2022 may very well be the year that silicon is declared obsolete in power applications.

## The Edge of the Cloud and Its Devices Will Get Way Smarter

Luckily the internet existed when the pandemic started, or we would all have gone stir crazy by now. (One wonders what people did when they were quarantined during the great flu epidemic.) The impact of the quarantines on people and the rise of importance of the internet in daily work and personal life migrated the venue from primarily entertainment to a vital part of our societal infrastructure, without which many today wouldn't even know how to function. Social interactions became more dependent on telepresence as well.

Though the rise in the internet's importance in society was impacted by the pandemic, its growth and expansion into our lives was already underway and is continuing apace. The cloud and Internet of Things (IoT) were already in existence and on their way to higher levels of functionality and penetration, so the situation "merely" sped up the process. Now people's work and social lives revolve around the internet and its avatars.

The biggest trend for the future of the internet is the continued evolution of edge computing and more powerful IoT devices *(Fig. 2)*. The migration of as much logic horsepower from the central server to as close to the user or server application as possible will continue until the industry reaches theoretical maximums. This evolutionary migration will continue to impact society in multiple ways for the foreseeable future.




**2. The biggest trend for the future of the internet is the continued evolution of edge computing.**

Edge computing directly addresses multiple issues within the cloud, such as latency, bandwidth usage, and security. For example, in a security surveillance situation using facial recognition, performing first-level discrimination to pass probables to central control instead of a stream of wideband data saves everything from RF bandwidth to response time. Or using a smart robotic hand to reduce the amount of control needed from central logic, or performing sensor conditioning and fusion in a modular solution to reduce demands on the central processor.

## Looking Forward

All of these trends are leveraging one another to create a more functional and capable societal infrastructure, empowering and enabling people and applications in new and interesting ways. Advanced connected design tools leveraging next-generation WBG power electronics, driving smart and versatile edge devices and systems, will continue to transform how we live, work, and recreate. These powerful trends are not only helping us deal with the current reality, but they will speed us on our way to the future. ■

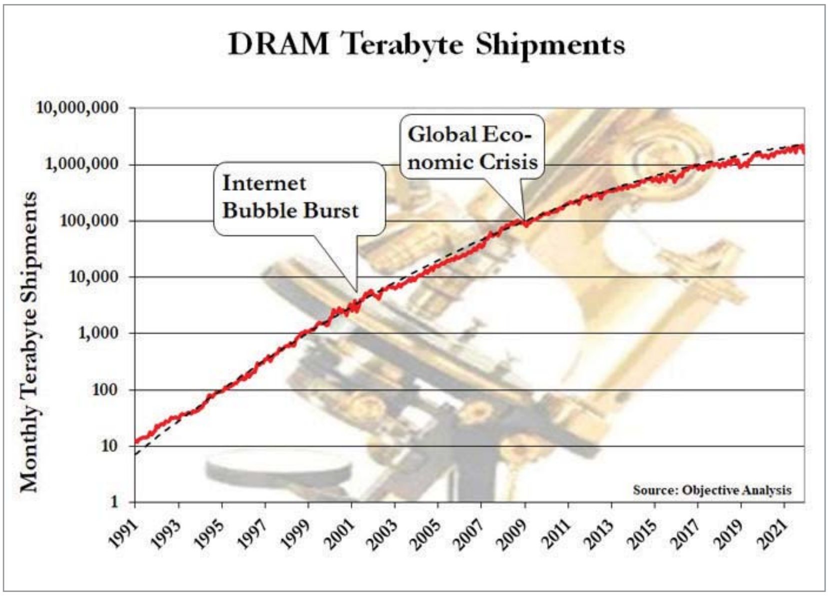
JIM HANDY | General Director, Objective Analysis

# Semiconductors 2022: A Growth Market Comes into Focus

**After last year's semi market boom, will 2022 follow suit? Objective Analysis provides their insight on what may unfold in this turbulent industry atmosphere.**

The past two years have been eye-opening. Who would have guessed that the semiconductor market would shine through a multi-year pandemic of a deadly disease? Yet, that's exactly what happened. With that as a starting statement, what might lie in store for 2022?

Objective Analysis has seen forecasts that run the gamut from the very negative to wildly optimistic. We will add our voice to this clamor with our 6% growth prediction, but the following paragraphs will explain both how we arrived at 6% and the circumstances that could move that number either up or down.




**1. DRAM demand grew predictably as illustrated by the monthly WSTS DRAM gigabyte shipments from 1991-2018.**

### Forecast Drivers

The Objective Analysis Forecast Model has provided the company with consistently accurate forecasts for the past 14 years. In fact, unlike other forecasters, we post our past successes and failures on our website because we're proud of our success rate. But our forecast model doesn't count on being able to predict events like those driven by a pandemic. Let me explain the basic underpinnings of this forecast model:

*Demand grows predictably:* With rare exceptions, demand increases at a relatively steady rate. This is borne out by *Figure 1,* which illustrates monthly WSTS DRAM gigabyte shipments from 1991-2018. There's remarkably little noise in this curve, but a very close look will find drops in 1996, 2000, and 2009, two of which are called out. We've also had shortages that are harder to observe in 1995, 1999, and 2018. While these shortages and oversupplies might appear as mild fluctuations in this chart, they dramatically impact pricing. It's not too difficult to produce a reasonably accurate demand forecast by extrapolating this trend.

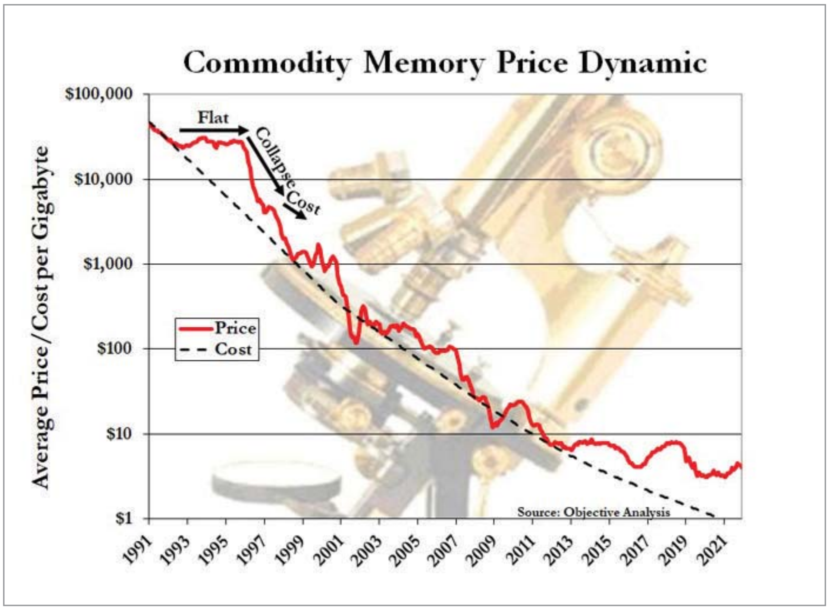
*Supply increases less consistently:* As a general rule, chip manufacturers add capacity during profitable years, and fail to add capacity during unprofitable years. Combined with predictable demand, this leads to oversupplies and shortages. If you know this year's semiconductor capital spending, then you can make a reasonable guess at whether the semiconductor market will be oversupplied or in a shortage two years from now.

*Pricing follows a pattern:* When there's a shortage, commodity prices typically flatten and rarely increase significantly. At the end of the shortage these prices typically fall to cost, and then hug the cost curve until the next shortage occurs. This is graphically illustrated for DRAM prices in *Figure 2.* Although the prices for non-commodity products vary much less than those of commodities, they tend to increase and decrease at the same time as the commodities. The only trick here is determining the timing of oversupplies and shortages.

*Chip production costs decrease predictably:* Gordon Moore was the first to point out the predictability of chip price declines when he wrote the article that created Moore's Law in 1965. While the rate of advancement has slowed over time, costs still decrease at a rate faster than almost any other industry. Since we can predict costs for the next few years with some degree of accuracy, it's not difficult to apply the above pattern to determine prices. These costs show up in *Figure 2* as a black line.

The overall semiconductor market's growth is a function of commodity growth: The memory business, largely DRAM and NAND flash, is the largest commodity in the semiconductor business, accounting for about 30% of revenues, depending on the year. This means that swings in these markets have a profound effect on the total semiconductor market. The chart in *Figure 3* shows the relationship of semiconductor revenue growth to memory revenue growth. The black orb emphasizes the relationship between the two. This means that anyone who can accurately predict the memory market can simply use a ratio to produce an accurate semiconductor forecast.

That's all there is to it.




**2. Commodity prices follow a pattern. When there's a shortage, commodity prices typically flatten and rarely increase significantly. At the end of the shortage, these prices typically fall to cost, and then hug the cost curve until the next shortage.**

**The memory business, largely DRAM and NAND flash, is the largest commodity in the semiconductor business, accounting for about 30% of revenues, depending on the year.**

## Market Anomalies

So, what's making the current market difficult to predict?

- *Demand is behaving abnormally:* At the onset of the pandemic, cell phone and automobile sales simply stopped. In late 2020, cell phone sales rebounded, and in summer 2021, automotive sales recovered. Meanwhile, the work/study/learn/play-from-home phenomenon drove a massive build-out of internet data centers as well as boosted laptop PC sales while dramatically reducing desktop PC sales. In all of this chaos, chip demand has been much greater than the producers expected. This has not only caused a dire shortage of older technologies, but also made both 2020 and 2021 banner years for memory, processor, and other chip makers by driving mild shortages in those markets. It has hampered our ability to predict the timing of shortages and oversupplies.
- *Prices have increased during shortages:* Although commodity prices rarely increase significantly during a shortage, as we saw in *Figure 2*, they have recently undergone important upturns in 2018 and in 2021. Since prices aren't behaving the way they typically do in a shortage, they render it challenging to accurately predict revenues.
- *We are in a pandemic, yet the global economy is faring well:* While Objective Analysis, along with other semiconductor market forecasters, doesn't try to forecast the global economy, a collapse like the one in 2008 can create massive changes to our forecast. We're concerned that the current stimulus packages and lower tax revenues caused by COVID-19 are creating government debt that will be extremely challenging to overcome. Part of that is already causing inflation concerns, and we mustn't be surprised if there's a dramatic economic correction sometime soon. In the near term, though, it appears that stimulus payments, at least in the U.S., are being spent largely on discretionary items, and this is part of the reason for today's demand surge.

With all of this background, how does Objective Analysis see the market developing in 2022?

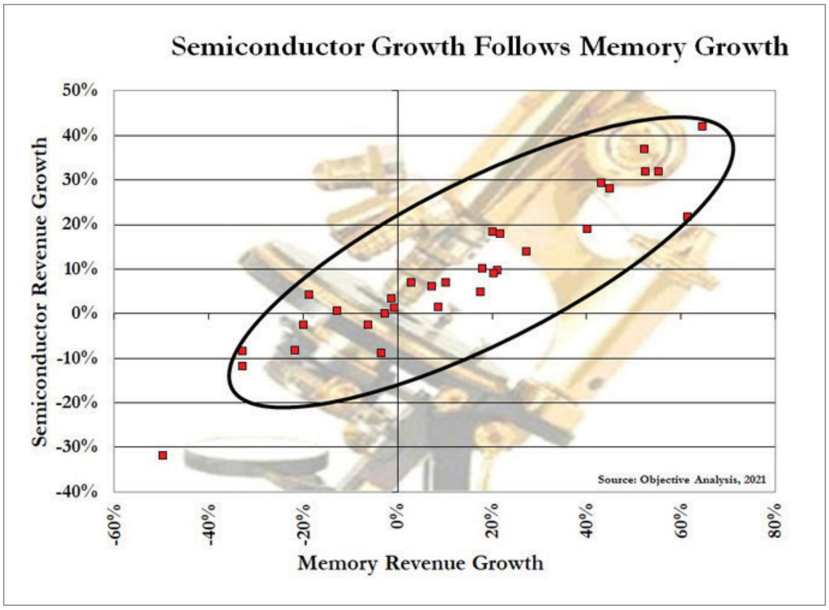
## Predicting 2022

As mentioned at the beginning of this article, we're predicting another 6% growth on top of an amazingly strong

2021, a year in which growth is now poised to reach 26%. This will take 2021 world semiconductor revenues over $550 billion, and 2022 revenues to $590 billion. This is based on our analysis of capital spending vs. the requirements to supply a market in its current state with its current level of demand.

Looking at the worst case, should the global economy fail early in 2022, and should demand dry up as a result, how badly could the market do? Given the current profitability levels of DRAM and NAND flash, memory market revenues could drop by 35%, taking the total semiconductor market down by the high teens.

Could there be further upside from the 6% that our model predicts? It's certainly possible, but it would be driven by phenomena that are incredibly rare in this market, so we don't account for them. This includes significant price increases that, as mentioned earlier, are extremely unusual occurrences.




3. The semiconductor market's growth follows commodity growth.

Our recommendation for corporate management is to plan for our 6% market, but to organize to be able to quickly respond to market changes. That's because there's a higher likelihood than normal such changes will occur in the near future. ■

ALAN LOWNE | CEO, Saelig


# Detecting **Counterfeit ICs**

**"Fake" chips present a huge issue for manufacturing companies trying to source ICs from non-traditional channels. One tool helps simplify the detection process.**

With the current worldwide chip shortage, manufacturers are desperately scrambling to keep their production lines going for electronics goods and automobiles. One solution many companies are turning to is the so-called "gray market"—non-authorized suppliers of obsolete and excess component stocks. While this can be a quick fix, it presents a problem that's challenging to detect and eliminate: counterfeit ICs.

For instance, a Massachusetts man was sentenced a few years ago to 37 months in prison for importing thousands of counterfeit integrated circuits from China and Hong Kong, which were resold to U.S. Navy contractors and installed in nuclear submarines. He also sold components to hundreds of other independent distributors and brokers in the U.S. and Europe, and the fake ICs reached even more government contractors and commercial manufacturers.

The counterfeit ICs were marked as originating from over 30 different IC suppliers. This case, with an unknown number of similar ones, shows that the presence of counterfeit components in the supply chain is a very significant and growing issue.

ICs aren't hard to fake, unlike banknotes. Making "lookalike" parts that resemble real ones takes very little skill. It simply requires finding cheap parts in the same format of package and merely painting new marks on them. This problem has arisen due to the high value of some electronics products, and this issue makes the whole manufacturing chain from assembly house to end-user vulnerable. The number of companies that have been fooled by batches of fake devices is incalculable.

Counterfeiting semiconductors has been a rapidly increasing trend, impacting a wide variety of electronics systems used by a wide gamut of involved parties—consumers, businesses, and military customers. The detection of counterfeit components has become an increasingly important priority for electronics manufacturers and component suppliers worldwide.

The Semiconductor Industry Association has estimated that counterfeit electronic parts have cost manufacturers more than $7.5 billion. Not only are companies suffering losses, delays, and inconvenience, their reputations are being sullied because of the presence of counterfeit ICs in the market.

### What Are Counterfeit Components?

Counterfeiters use several methods to produce their fake goods:

- Empty packages marked to resemble actual ICs.
- Cheap ICs re-marked to resemble more expensive ICs.
- ICs with similar but poorer specs re-marked to resemble better spec, more expensive ICs.
- ICs salvaged from circuit boards.

The most prevalent counterfeiting technique is selling re-badged products. It's a simple matter to remove the existing mark from a chip package and put on a new logo and part number, or a different brand or a different speed—and then sell the semiconductor to an unsuspecting buyer who has no way of making sure that the product is "real." Sometimes the chip is merely an empty package with no die inside *(Fig. 1)*.


**1. Chip package markings can be made to look almost identical to the uncritical observer. Can you tell which is the genuine IC?**

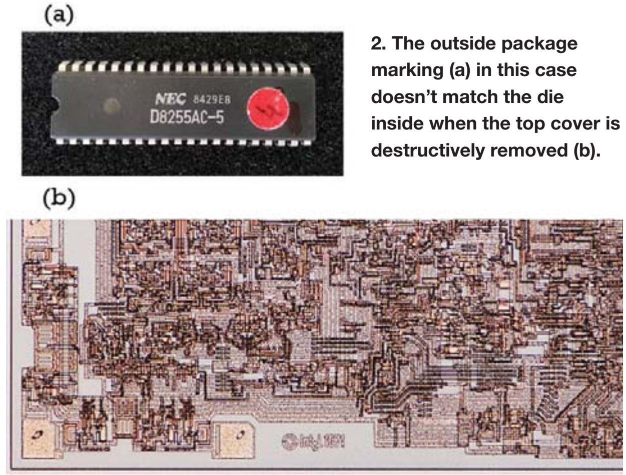
It's true that the finished system would fail before it left the factory. Nonetheless, it still requires expensive investigation and rework, with no replacement part available to replace the bad one, causing the dreaded "Line Down!" But the failure of fake borderline ICs may not occur until the system is in the field, and field repairs can cost 10X as much to fix as those caught before they leave the factory.

Counterfeiting also can occur with chips gleaned from discarded scrap boards. They can be re-marked with a different manufacturer's logo, inserted into the supply chain, and sold to innocent buyers, who naturally assume that the products are genuine.

Usually, it's impossible to identify counterfeit components until they're fitted on a PCB, when the first tests are made on the final product. Failure requires the costly identification of the bad components and then lifting them from all boards in the production line. Complete batches of finished products may need to be recalled to the factory, directly hurting a company's bottom line.

Technical measures to solve this problem have previously included visual inspection of devices for marking errors, which needs a trained eye for all possible variations in marking. Electronically testing or x-raying every incoming batch is another technique.

Another destructive method is to use a complex decapsulation method to visually inspect the IC die with a microscope, immediately losing revenue due to the component's destruction *(Fig. 2)*. Not only is this expensive and time-consuming, but it requires complex training, skilled operators, and expensive equipment.




**2. The outside package marking (a) in this case doesn't match the die inside when the top cover is destructively removed (b).**

## Screening

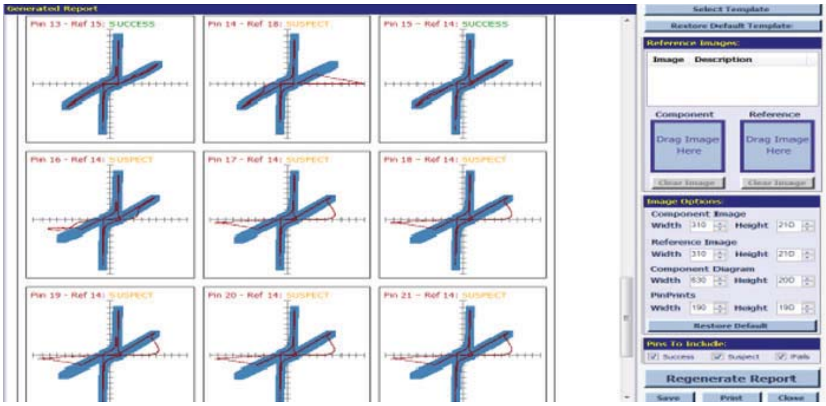
Some distributors have advertised their screening services for verifying components, with a turnaround time of "as little as two days." That's unacceptable in many cases. These companies offer techniques such as x-ray, x-ray fluorescence analysis (XRF), decapsulation, heated solvent testing, visual inspection, and solderability testing, resulting in detailed reports—when all that was required was a determination of "is it a good part?" In reality, this approach is only viable for military or large-volume production runs.

One method is to perform a functional test on a sample of the ICs; an example is logic I/O conforming to a truth table. This will detect gross problems, such as an incorrect logical function, or no function at all. However, they will miss the subtle "out of tolerance" issues—tell-tale signs that a component is counterfeit. With older-technology IC families, different speed variants are often available. Conventional testing equipment with this level of speed test capability is extremely expensive.

## Addressing the Issue

A tool that can verify the identity of received ICs quickly and economically, using a statistically significant procedure, needs to be suitable for all devices and packages, should be easy to operate, and must give fast "good/suspect/fail" results. An example of such a solution is the ABI Sentry Counterfeit IC Detector, a PC-driven product that can check the validity of parts in seconds.

Simple to use, the tool enables any receiving department to operate the equipment. The analysis takes place in the background, and the operator only sees a simple "Good Device," "Blank Device," or "Fail Device" message, with the option to produce a detailed report to send to the supplier.




**3. V-I testing applies a voltage waveform between two IC pins and measures how the current drawn changes as the applied voltage varies.**

The ABI Sentry is a benchtop device that uses an advanced form of V-I testing on any IC chip to determine its electrical characteristics or "signature" *(Fig. 3)*. V-I testing applies a voltage waveform between two IC pins and measures how the current drawn changes as the applied voltage varies. This response is directly related to the device characteristic, its internal structure, and manufacturing processes.

Running every possible pin-to-pin combination on the IC under investigation, the device provides a great deal of insight into the IC, more than simple systems that are restricted to testing between pins and ground. The Sentry's Matrix V-I Test can reveal differences between devices with different functionality but similar technology. A re-labeled fake chip with a similar I/O pinout would be detected by this test.

## Establishing the Signature

The V-I characteristics captured by Sentry are called PinPrints, which represent the unique signature for a device. Sentry is employed first to test a known-good device and obtain its "gold standard" signature. The subsequent signatures of incoming, unknown chips are compared with the known-good version to check for discrepancies.

Small variations are likely to indicate that the chips are from different manufacturers, or possibly different batches from the same manufacturer. Larger differences, however, suggest that the chips are faulty or counterfeit. Sentry can be customized for each IC type by setting tolerances that define the point at which a tested device is deemed "bad."

If no reference devices are available, two alternatives could be used. Reference data can be exported from other users' machines or libraries and imported into the Sentry's database. Alternatively (and not quite as good), testing can be done across the batch. If there's any variance, then the whole batch becomes suspect and should be rejected. A package with no internal die is easily detected—all pins will show the straight line "null response" of an open circuit.

Sentry contains a set of ZIF sockets accepting adapters for DIP, SOIC, BGA, SSOP, as well as discrete components. The system uses a comparative technique to rapidly analyze and learn new components, and then test the unknown parts. A known-good component is locked into the ZIF socket while a test pattern is applied across all of its pins. The component's response to this test pattern is automatically measured and stored as a benchmark.

A combination of Sentry's electronic parameter settings (voltage, frequency, source resistance and waveform) generate the "signature" for each pin of the IC being checked. It then compares the unique electrical characteristics of known components and with suspect components. Testing between every possible pin combination is included, maximizing the chances of capturing internal fault conditions. Sentry can quickly detect missing or incorrect dies, lack of bond wires, inaccurate pinouts, and pin impedance variations. Simple pass or fail results are returned after testing, offering a high level of confidence in the authenticity of components.

As parts become increasingly complex, 100% testing becomes burdensome, but testing one or two pieces out of, say, 200 pieces is manageable. Experience has shown that variations arising from a suspect shipment will reveal themselves well before such a test is complete. Nevertheless, if 100% non-destructive testing is required, using a Sentry Counterfeit IC Detector is a workable solution.

Sentry is able to identify parts that have a different internal structure, or no structure at all, and even components originating from a different manufacturer. Controlled via USB using the PC software provided, Sentry's stored device library can


**4. Sentry contains all of the hardware required to analyze the electrical characteristics of ICs with up to 256 pins.**

be built up by adding specific known-good devices.

Each device can have documents associated with it in the software, such as photos of device markings, datasheets, and other documents to further help in confirming the integrity of a device. Detailed reports are able to be saved to provide quality-control traceability. Sentry can protect production facilities from the infiltration of counterfeit devices, identifying bad parts before they cause problems.

**Sentry Hardware**

Sentry contains all of the hardware required to analyze the electrical characteristics of ICs with up to 256 pins *(Fig. 4)*. In addition, 256-pin+ devices can be tested by rotating the device (BGA, QFP) to allow all pins to be learned and compared.

Sentry comes with four 48-pin dual-inline (DIL) zero-insertion-force (ZIF) sockets. These can be used directly for older DIP components, but also can be utilized to accommodate a variety of additional socket adapters available for different package types. The socket adapter may contain multiple IC sockets if required, to allow for testing several ICs at the same time or comparing one IC with another. An expansion connector enables custom socket adapters with up to 256 pins to be attached.

ABI Sentry is housed in a sturdy metal box (10.6 × 10 × 3.6 in.) and weighs 8 lbs. It can receive separate interchangeable adapters for accepting various IC packages under test. With its large range of optional adapters, Sentry can accommodate most types of IC packages, including DIP, SOIC, PLCC, QFP, and even BGA. For simplicity of operation, Sentry has no display or keypad, but is entirely controlled by a PC via USB using ABI's custom-designed free software.

**Conclusion**

The ABI Sentry is an example of a practical solution for solving the counterfeit IC issue, using its rapidly learned dedicated library of component data to cross-check each part tested. With lead-time issues making ICs harder to acquire for meeting aggressive manufacturing schedules, identifying any parts that aren't "real" before they enter production can potentially save every manufacturer a great deal of time and money. It also helps build the intangible but hard-to-retrieve trait of brand reputation. ■

**The ABI Sentry is an example of a practical solution for solving the counterfeit IC issue.**

WILLIAM G. WONG | Senior Content Director

# Embedded Forecast: Better Hardware, Suspect Software

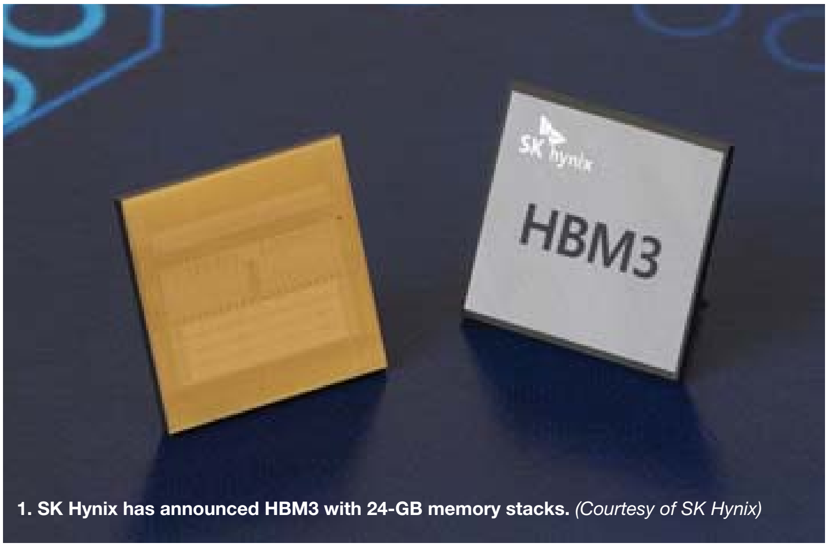
**Bill Wong lays out his predictions on embedded technology for 2022, covering hot trends ranging from PCIe to RISC-V to open-source software.**

For me, some articles seem to write themselves. Forecast articles don't fall into this category probably because I see the consolidation and dependencies occurring within our industry that have made system design more complex. I can remember when size, weight, and power (SWaP) plus price were the main concerns for developers. These days, it also includes details like security, artificial intelligence, availability, communications, compatibility, and so on.

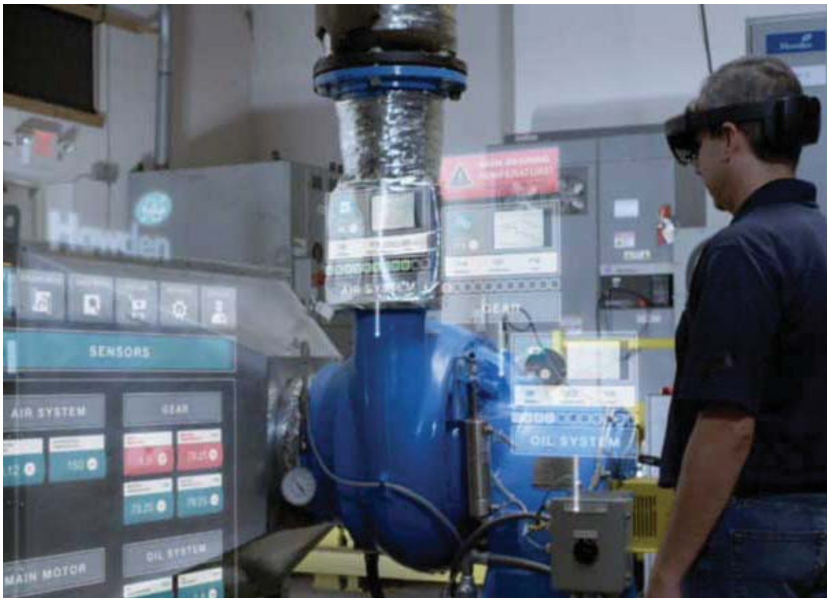
The challenge we have is the span of technology we cover from microcontrollers to cloud servers. The differences along the way have never been more stark. Integration of many different components into a single chip are more common at the low end while disaggregation is becoming the norm in the cloud. In the latter, storage and communication are being broken out from the server box into their own farms connected via high-speed networks.

The growth of PCI Express (PCIe) 5 and the emerging PCIe 6 standard support the CXL and CCIX standards that allow direct access to peripherals and storage. CXL appears to have the momentum after absorbing Gen-Z.

PCIe Gen 4 will remain the mainstay this year, but PCIe Gen 5 platforms are the cutting edge. The challenge will be availability rather than technology. This is more of a concern for high-end applications as many embedded applications fare well even with PCIe Gen 3's 4 Gtransfers/s/pin versus the 64-GT/s/pin rate for PCIe Gen 6.




**1. SK Hynix has announced HBM3 with 24-GB memory stacks.** *(Courtesy of SK Hynix)*




**2. PTC's Vuforia can support viewing digital twins using augmented-reality glasses.** *(Courtesy of PTC)*

We see similar support on the external memory space with the flavors of DDR4 remaining the technology of choice even as DDR5 raises its head this year. Price and availability will limit DDR5's adoption, especially in the embedded space. DDR6 remains on the drawing board.

High bandwidth memory (HBM) also is becoming the norm, taking advantage of stacked memory dies that provide a higher capacity of on-chip memory and higher throughput. That's due to the wide memory bus, which can't be replicated with off-chip memory like DDR or GDDR DIMMs. HBM3 is the latest generation. HBM storage started on GPUs, but it's used on CPUs and accelerators *(Fig. 1)*.

Graphics processing can take advantage of HBM, and more support for ray tracing is leading to a higher demand for on-chip memory as well as offering a significantly improved graphical presentation. NVIDIA has been pushing ray tracing—the company has moved this support down from its top-end solution to the midrange, while Imagination Technologies has delivered support for mobile applications.

Ray tracing is useful but not limited to just gaming applications and multimedia creation. For instance, it will prove effective in virtual-reality (VR) applications. VR and augmented reality (AR) also are moving into the mainstream due to improved hardware.

The metaverse is more than hype, but it will be a while before the general public uses it en masse. This has as much to do with software as hardware. In the meantime, industrial applications of AR/VR will be where the money is, especially when tied into digital-twin support, which is growing significantly in the industry *(Fig. 2)*. The reason for this success has less to do with lower costs but rather improvements of the software and the fact that training and support costs can be dramatically reduced using this technology.

### But Back to Computers and CPUs

Though incremental improvements in single cores marches on, the payback in x86 and Arm platforms remains multicore solutions. Mixing different performance cores in an SoC has already been common but will become more ubiquitous. Likewise, security processors will be more prevalent and easier to use especially when moving to deployment. Security finally moved from a possibility to a requirement when connecting to the cloud.

The growing elephant in the room is RISC-V. Yes, it's just an instruction set definition, but it essentially provides an architecture to build hardware and there are lots of sources these days. Standard, standalone chips are available as well as RISC-V integrated FPGAs and so on. Outfits like Imagination Technologies have added RISC-V to their portfolio. This isn't to say the x86 or Arm architectures are going away, but they now have a significant and distributed competitor.

Another item to look out for is small FPGAs. Though they have been around for a long time, the focus often seems to be on higher-end, higher-performance solutions. What small-count logic devices can do is provide hardware customization that offers a power and price performance edge versus software alternatives. Development tools are easier to use, so all you need is a logic diagram. Given the limited availability of chips in general due to implications of the COVID-19 epidemic *(Fig. 3)*, it makes sense to use a collection of more readily available FPGAs that can be customized.

### Open-Source Software Challenges

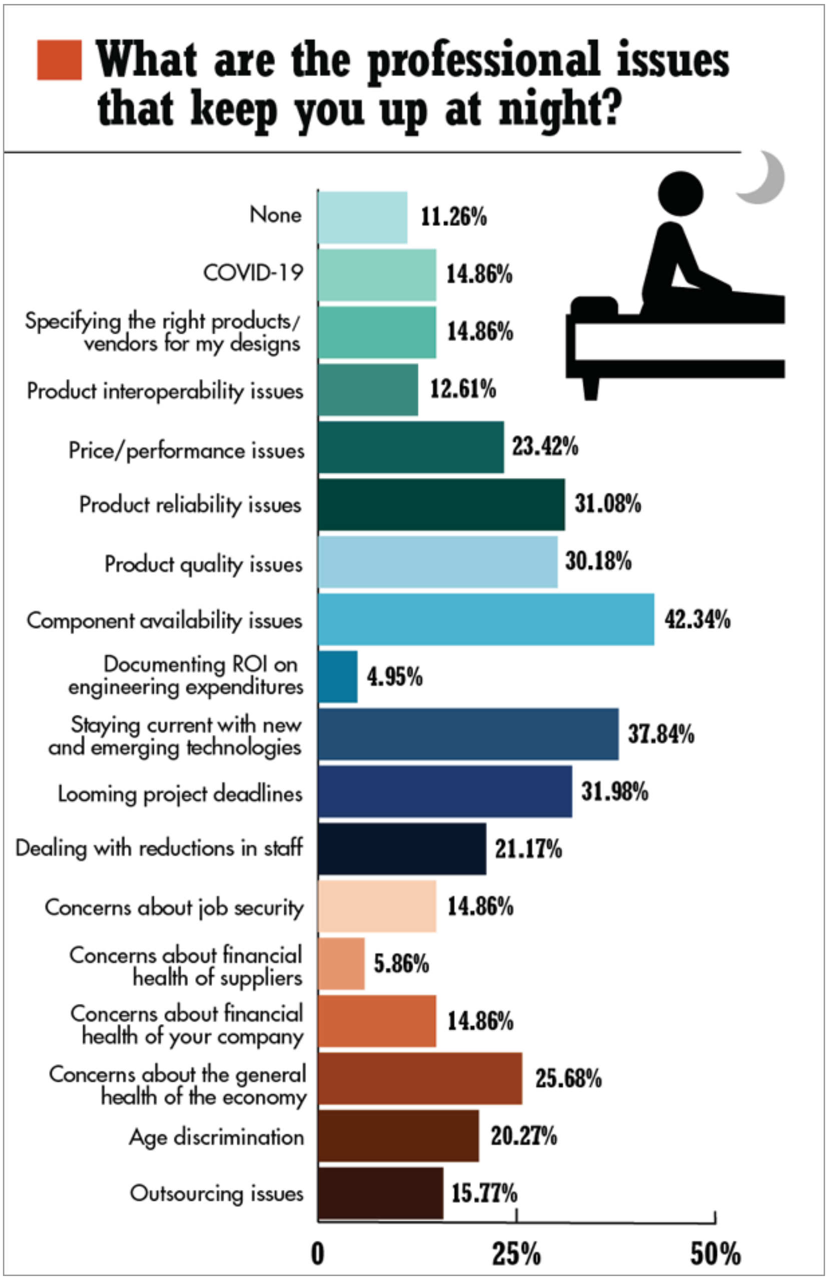
Plenty of proprietary software and libraries are available, but the trend has been toward using open-source software for everything from operating systems to applications. Flavors of Microsoft Windows run on most PCs. However, versions of Linux, such as Android, run on most embedded systems.

Linux is one of many open-source success stories, but it also has significant industry support. That's not the case for the majority of open-source projects. Of course, most open-source projects aren't used by a large audience.

On the flip side, a wide audience of developers not supported by industry still utilize many of these projects. It's led to some challenges for developers that use the fruits of these projects when problems occur. These can range from poor design or usage that open up security holes like Apache Log4j or bugs such as OpenSSL's Heartbleed.

Software inventory and composition software is already a critical tool for some developers that need to track and verify their open-source use. The use of these software composition analysis (SCA) tools will be important for any developers utilizing open-source libraries and tools. It will also increase the interest in companies providing open-source software that they support, thereby alleviating the customer of this chore. Things become a bit more challenging when the end product must be certified. ■

**The growing elephant in the room is RISC-V. Yes, it's just an instruction set definition, but it essentially provides an architecture to build hardware and there are lots of sources these days.**




**3. According to the *Electronic Design* 2021 Salary Survey, the biggest headache for developers is component availability.**

# ElectronicDesign 70 YEARS

## Ad Index



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WILLIAM G. WONG | Senior Content Director

# Check Out Kit Close-up *on Electronic Design*

**Our Kit Close-up video series highlights some of the latest development platforms available to engineers.**

Many years ago, when I started working on electronic projects, there was Radio Shack and Heathkit. Most semiconductor vendors, though, didn't have kits to simplify evaluation and development. Building up a computer from scratch involved dealing with a rack and a bunch of boards. These days, a new chip or sensor isn't released unless a development kit is at least on the drawing board and in the marketing timeline.

It's also interesting to note how kits have progressed from large boxes with documentation, diskettes, boards, cables, and power supplies to a box that often holds a slip of paper and a circuit board. Power is provided by USB cables that you often need to provide on your own; documentation and software are downloaded from the cloud. Sometimes the software runs in the cloud.

Alix Paultre, our Editor-at-Large, came up with the Kit Close-up video review idea and has created most of these videos so far *(see figure)*. They're short and sweet with links where you can get more details about the kits we present. I've highlighted kits in the Lab Bench column for years, but video adds a whole new dimension. Of course, you will have to watch them online using your PC, tablet, or smartphone. *(https://www.electronicdesign.com/magazine/50464)*

Way back, when I was Director of PC Labs for *PC Magazine*, we would have a yearly issue that involved testing every printer we could get our hands on. Moving hundreds of printers through the labs so that editors could test them was a logistics nightmare, but one that always made for good reading.

It was almost practical to hit most of the products on the market. However, these days, the number of kits from one vendor often exceed the number of printers we had in the printer issue. Likewise, our bandwidth for looking at kits is much more limited. Therefore, we tend to cherry-pick the kits we review with the intent of providing you with exposure to new technologies and solutions that will pique your interest.

On the plus side, the latest kits have much more documentation, often with multiple training and review videos on the internet. Typically, the paper that comes in a kit just has a few URLs.

We are posting Kit Close-up videos on a regular basis, so stop by and give them a view. ■

This is an example of Alix Paultre presenting Dialog Semi's SLG47105V HV PAK Four-Output Mixed-signal Matrix Demo Kit.