I’m back.

In my column in the September 2017 issue of IEEE Power Electronics Magazine, I talked about a class I was going to be teaching at the University of Colorado, Boulder. This class was a project lab for students in a master’s degree program who are preparing for jobs in the industry. On the first day of my class, the students were given a specification and a schedule for a 25-W output LED driver with universal ac input voltage and a 0–10-V dimming signal input. They were also given real-life requirements for product safety (e.g., creepage and clearance distances) and component derating. The students had to pick their topology and operating mode, choose a control IC, design the circuit, verify the circuit by simulation or using the IC vendor’s tools, design a circuit board using Altium, design and wind their transformer, procure their parts, build the pcb-board, debug it, and demonstrate a working board to me by the first week of December 2017. This was not the usual “paint by numbers” engineering lab.

It turned out that the deadline for the March 2018 issue of this magazine was right around the time I was completely busy helping students finish their projects. I tried to work with the editor-in-chief but found it difficult to give the students the help they needed and write the column as well to meet the March deadline. So I went back to the lab with the students, and the editor-in-chief sent the March issue off to the printer without my column.

So how did the students do? Seventeen of the 19 students had working boards at demonstration time. Two, who learned some valuable lessons about how data sheets are not always correct, would have made it with a couple of more days. The feedback my assistant instructor, Roger Bell, and I received from the students was overwhelmingly positive. They were all challenged. For many, this was their first original design, and they had a great sense of accomplishment when they successfully demonstrated their converters. They looked forward to interviewing and being able to literally or figuratively throw hardware on the table and say, “I made that!” Roger and I are looking forward to teaching this project lab again in the fall.

I am writing this column after returning from the IEEE Applied Power Electronics Conference and Exposition (APEC) 2018. The conference has left me wondering, “What’s next in power electronics?”

I remember that back around the year 2000, I was thinking that there was not much left to do in power electronics. Of course, there can and always will be incremental improvements. But, at that time, commercial power supplies were of very high density, high efficiency (90% or more), and low cost (US$0.10–0.20 per watt). MOSFETs and IGBTs were quite good and low cost. There was noise about silicon carbide (SiC), but the problems were huge, so who knew if it would ever become practical? Digital control was interesting but expensive and was always “three years away” from being practical in volume commercial production. I just was not seeing that there was going to be any new and exciting areas to explore in power electronics.

Geesh, I was really wrong about that.

In the nearly 20 years since then, we have seen an explosion of new devices, technologies, and applications in power electronics. After the telecom crash of 2001, the cost of .025mm digital CMOS silicon plummeted to pennies per square millimeter. This finally made digital cheap enough to use in commercial power supplies. Today, we are drowning in advanced control ICs finely tuned to countless power conversion applications. While the data sheets look like they did when power supply control ICs were all analog, today these controllers are mixed-signal marvels with powerful digital cores.

Superjunction silicon MOSFETs have pushed beyond the theoretical limits of silicon in terms of resistance. Switching losses have also been greatly reduced. Yesterday’s leading-edge efficiency of 90% is now considered useless, as server and telecom power supplies now routinely offer 96–98%

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efficiency with power conversion densities well above 40 W/in\(^2\).

SiC has made great strides and is now a viable choice for higher-power or higher-voltage applications where cost is not the main driver. In the meantime, gallium nitride has quickly been adopted for high-performance switching applications in the middle-voltage range (200–900 V). The efficiencies being reported by leading-edge researchers—and products—in the higher-power applications are so high (99.3–99.7%) that measuring them accurately is a real problem.

Both enabled and driven by the advances in switching devices and digitally enable advanced control, power electronics applications have sprouted and grown so rapidly we can hardly keep up.

Electric propulsion has long been used in rail transportation, such as street cars and light rail systems. What we often call a diesel locomotive uses electric motors for driving the wheels. But now we are seeing electric propulsion become practical in vehicles ranging from the family car to delivery vehicles to full-size tractor trailers. This move toward electric vehicles is enabled by advances not only in battery technology but also in power electronics. The high-power electronics used to drive electric motors and move energy into and out of the batteries today can operate at efficiencies well above 90% with high reliability and small size and weight.

We are also seeing power transmission within aircraft changing from hydraulic to electric as the More Electric Aircraft initiative advances. Indeed, the Boeing 787 Dreamliner electric power system can deliver more than a megawatt.

Combine electric propulsion with electrically powered actuators, and we have robots. Robotics is an area that requires advanced power electronics. Yes, robots require advanced processing of sensor information and advanced control algorithms as well as optimized mechanical design, but they also need advanced power conversion. From providing battery and power management that optimizes operation time to motor drives that offer high power and speed at low weight, power electronics is a crucial part of all robotics. Today, when talking to students about careers in power electronics, I often encourage them to consider the opportunities in robotics.

Another application enabled by power electronics developments, a technology that was only a dream in the year 2000, is wireless charging. While not quite ubiquitous, in the coming years we can expect to see wireless charging of our mobile electronics everywhere, from our desktop to the coffee shop to our hotel rooms. Wireless charging of vehicles is also advancing. I personally have worked on wireless charging of cars and transit buses. While admittedly not as efficient as directly wired chargers, the convenience of wireless charging is making this an attractive option.

In the last 20 years, we have seen a huge growth of wind and solar power. Both rely heavily on power electronics to efficiently convert energy and interface with the grid. The growth of renewable energy and so much distributed generation is upsetting the existing power distribution infrastructure. For more than a century, keeping the power grid regulated and stable was done by managing the power output of a few central generating plants controlled exclusively by the utility company. Now, power is coming into the grid from many sources, many of which have an output that varies with the wind or weather. How to manage the grid and keep it stable under these conditions? More advanced power electronics with even more advanced control.

But after 20 years of power electronics advancement at such a dizzying pace, I again find myself thinking like I did 20 years ago—that there is not much new left for power electronics. I keep wondering what new power electronic device technologies, packaging technologies, topologies, and applications are next. Talking with people at APEC, seeing the papers, and roaming the exhibition hall only reinforced that feeling. Certainly there was a great “buzz” and “energy” at APEC. But all of the discussions focused on improvements to existing devices, architectures, and applications. It leads me to think that we are in for a period of time where we “digest” the rapid advancements of the past few years and settle into a period where these technologies fully mature.

But as soon as I catch myself thinking those thoughts, I hear alarm bells in my head. I now know how I was wrong 20 years ago when I was thinking that not much new was coming. So, even though I keep looking around and don’t yet see the “next big new thing,” I also suspect that it is on its way and will soon burst into view like a train rocketing out of a tunnel. And I am sure whatever is coming that I don’t see now will keep power electronics an exciting and rewarding profession for many more years to come.

About the Author

Robert V. White (bob.white@ieee.org) has over 30 years of industry experience as a power electronics engineer. He has worked in product design, systems and applications engineering, and technology development. He has been an active volunteer with the IEEE Power Electronics Society, serving several years on the Administrative Committee, two terms as technical vice president, and as a Chapter chair. He earned a B.S.E.E. degree from the Massachusetts Institute of Technology and an M.S.E.E. degree from Worcester Polytechnic Institute. He is currently pursuing a Ph.D. degree in power electronics at the University of Colorado, Boulder. Presently, he is the chief engineer of Embedded Power Labs, a power electronics consulting company. He is a Fellow of the IEEE.