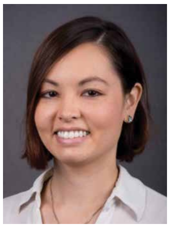
Industry Pulse

by Stephanie Watts Butler and Kristen N. Parrish

Digital Twins: The Real Opportunities

Sometimes, knowing when a new buzzword has transitioned from hype to something real can be easy to identify. However, comprehending the opportunities beyond the hype can be more challenging, especially if several buzzwords are involved. NVIDIA's GTC Conference keynote given by CEO Jensen Huang (viewed over 27 million times) [1], frequently mentioned "digital transformation" and its requisite enabler "Digital Twin," in conjunction with artificial intelligence (AI). Hot topic conference talks, coupled with related investments and acquisitions, indicate that perhaps "Digital Twin" could be something real. In this edition of the Industry Pulse column, we will introduce you to the concept of the Digital Twin, how it differs from both AI and a traditional model, and examine the opportunities in power semiconductors and power electronic systems.

A unified definition for Digital Twin does not currently exist. Here are some definitions:

- At its simplest level, a Digital Twin is a virtual, dynamically synchronized representation of an asset in the physical world [2].
- A Digital Twin is a virtual representation of real-world entities and processes, synchronized at a specified frequency and fidelity [3].

The National Academies of Sciences, Engineering, and Medicine (NASEM) utilizes a more verbose definition, but it stresses bidirectional interaction between the virtual and the physical, and an emphasis on predictive capability to "issue predictions beyond the available data to drive decisions that realize value [4]." A recent article proposing a Digital Twin framework for smart manufacturing reviewed several different definitions for Digital Twins, including the trait of being able "to understand, predict, and optimize performance of the physical twin" [5]. The intended purpose or use being an important part of the definition of the Digital Twin was emphasized by several speakers and attendees at a recent NIST CHIPS workshop on Digital Twins, and was cited as also being discussed at a preceding SEMI Digital Twins workshop [6]. In addition, the purpose must be known to determine the required accuracy and fidelity of the model (digital representation), synchronization methodology, and associated decision-making algorithms because as the great statistician Dr. George Box noted "All models are wrong, some are useful."

Consequently, we are proposing a working definition for a Digital Twin which includes its intended use. A Digital Twin must possess four critical attributes shown in Figure 1.

Having a digital representation, at the simplest construct, is a traditional model, regardless of how the model is generated or its intended use. AI is also succinctly different than a Digital Twin. Simplistically, think of AI as

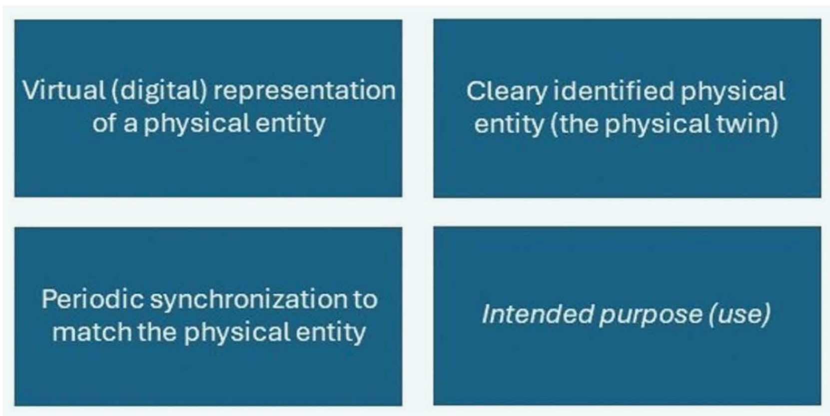


FIG 1 Four attributes of a Digital Twin.

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the math (for generating the digital representation or part of the synchronization or part of the decision-making algorithm). Consequently, AI and model are relevant terms with respect to defining a Digital Twin, but are not the same thing as a Digital Twin.

A digital transformation has already begun for the design, verification, validation, manufacturing and operation of all electronic systems and their components, including power electronics and semiconductors. However, the term "Digital Twin" may not be used due to the relative infancy in the broad use of the term. The first use of the phrase "Digital Twin(s)" in the IEEE Power Electronics Magazine was an article from 2017 noting that IEEE Energy Conversion Congress and Exposition conference (ECCE) 2017 had a special session on "Internet of Things and Digital Twin for aviation" [7]. A more extensive use of the term was in an article from 2019 reviewing the first "Design Automation for Power Electronics (DAPE)" which was co-located with the 2018 ECCE conference in Portland. The authors noted the DAPE workshop identified "Digital Twins" as one of three emerging trends for design automation, and discussed the evolving work around the term [8]. Since then, five more magazine articles have incorporated "Digital Twins," including an article which includes discussion of using Digital Twins for health monitoring [9]. That article included a useful graphic, shown in Figure 2. This current edition contains the article "Building the Electric Power Grid One Unit at a Time" which refers to "circuit twins for parameter estimation" implying the use of digital twins of circuit for use in parameter estimation for diagnosis in the Intelligent Power Stage. These articles demonstrate the broad applicability of Digital Twins across the power electronics ecosystem. Furthermore, the recent NIST workshop and SEMI whitepaper were examining Digital Twins with respect to semiconductor design, manufacturing, and release to market.

The Journal on Emerging and Selected Topics in Power Electronics has had only six articles, with the first appearing in 2022. Transactions on Power Electronics has had only 12 since 2020. These statistics, considering the number of articles published per publication, show that the use of the term Digital Twin is relatively new to the Power Electronics community, especially in the academic community. Professor Johann W. Kolar, ETH Zurich, Switzerland, has been calling Digital Twin one of the X technologies that will lead to "Future Power Electronics 4.0" revolution which he introduced at IEEE FEP-PCON X in 2019 and continues to refine the concept [10], although he does not deploy the term "digital transformation."

Similarly, industrial members already may be utilizing different digital tools to increase their productivity and quality as part of a digital transformation of their design and build process, and yet not use the term Digital Twin. This situation is demonstrated with the 2023 IEEE APEC keynote by Grant Pitel, Magna-Power Electronics titled "Designing for Manufacturability with Software-Based Constraints: Shortening the Iterative Design Cycle" [11]. Even though Pitel never used the terms "Digital Twin" or "digital transformation," the concepts of digital representation of a physical system with an intended purpose (design and build) combined with synchronization between digital-physical to make accurate decisions are throughout the keynote.

The concept of digital transformation and Digital Twins can also be seen in some of the recent power electronics focused European Union projects, such as Power-izeD—an innovative EU funded project with the tag line Digitalization of Power Electronic Application within Key Technology Value Chains [12], and HORIZON-CL5-2024-D3-01-14: Condition & Health Monitoring in Power Electronics (PE), which had seven proposals submitted in January 2024 [13].

If this sounds interesting to you, there's opportunities to learn—and influence—within the Power

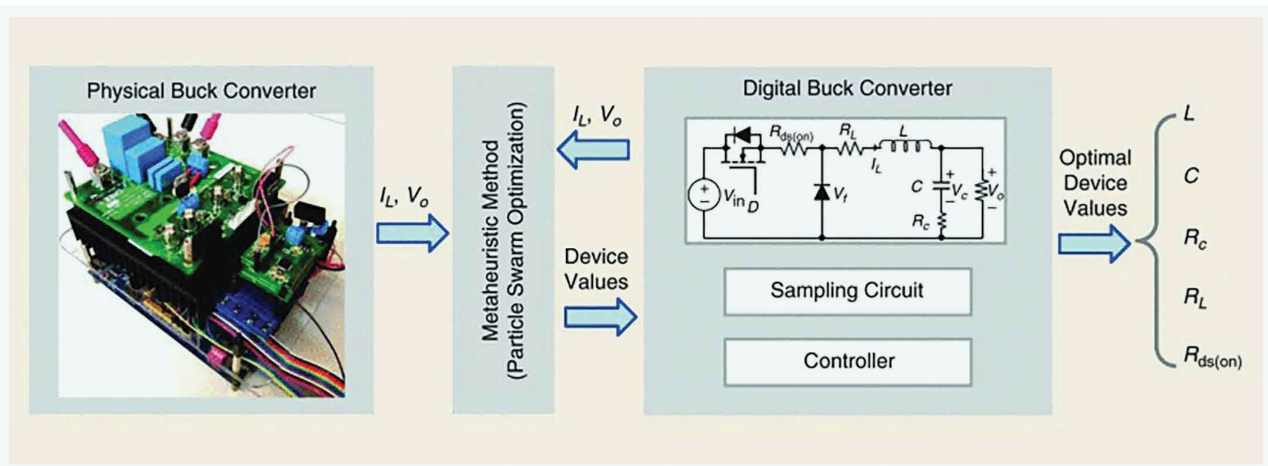

FIG 2 Digital Twin-based health-indicator estimation for a Buck converter [9].

Electronics Society (PELS) too. One of the PELS' 12 technical committees (TC 10: Design Methodologies) is focused on the digital technologies to foster the design of power converters and their components [14]. TC 10 also organizes the annual IEEE Design Methodologies Conference (DMC https://attend.ieee.org/dmc-2024/), and hosted the recent very successful MagNet Challenge [15]. Come join TC 10 and become involved in supporting the digital transformation of the power electronics ecosystem.

We end this article with the history of a similar digital transformation to provide context to the role of the Digital Twin and the possible impact of the impending digital transformation of the power electronics industry. At the dawn of the integrated circuit (IC) industry, ICs were laid out by hand. Software tool replacements came about in the 1970s as this process moved to computers—the GDSII layout file format arose during this time and is still used today. In the 1980s, the electronic design automation (EDA) industry was born as electronics and semiconductor companies that developed proprietary software for designing and verifying their designs started to spin out these companies. This was arguably the first "digital transformation" related to semiconductors and enabled much of the modeling capability the electronics industry has today. The resulting tools enabled designers not just to layout their transistors, but also understand the impact of layout on their designs by integrating SPICE simulation into the tool.

We will address digital transformation again in a future article as we analyze the various investments and acquisitions happening in the relevant hardware and software tool space, including traditional EDA companies. As we approach the next edition of the *IEEE Power Electronics Magazine*, celebrating the 10th Anniversary of the magazine and almost two years of this column (Industry Pulse), we hope you, the reader, have come to appreciate the insight this column provides to allow you to identify opportunities in the power electronics industry and understand the impact that power electronics is having on the world.

Please share your comments by email or start a discussion on LinkedIn with the tag **#PELS_MPEL

About the Authors

Stephanie Watts Butler, Ph.D., P.E., (Senior Member, IEEE) (s.w.butler@ieee.org) is currently the President of WattsButler LLC, an innovation services company focused on the power semiconductor industry. During her previous career at Texas Instruments, she produced innovations in the areas of power and CMOS process and package technology, processing equipment, materials, reliability, research and development management, manufacturing science, control, fault detection, metrology, and new product development generating 17 U.S. patents. She is the Co-Founder and the Past-Chair of JEDEC's JC70 Wide Bandgap Standards Committee, and the Co-Convenor of IEC's TC47/WG8. She is the Industry Deputy Editor-in-Chief of *IEEE Power Electronics Magazine*, a PELS Member-at-Large (AdCom), and a WIE Committee Member. She also serves on the APEC and WiPDA Planning Committees and PSMA Board of Directors. She is a fellow of the AVS.

Kristen N. Parrish (Senior Member, IEEE) (kristen@ieee.org) received the bachelor's degree from the Rose-Hulman Institute of Technology, Terre Haute, IN, USA, and the master's and Ph.D. degrees from The University of Texas at Austin, TX, USA. Before embarking on a career spanning multiple fields, ultimately working in power electronics at both Texas Instruments, Dallas, TX, USA, and Wolfspeed, Durham, NC, USA. Her work experience includes Research and Development Engineer, a Systems Engineer, and most recently as an Applications Engineer with projects in packaging, magnetics, and silicon carbide. During her career, she has been involved with IEEE at the local section level, serving as the Eastern North Carolina Vice-Chair, the Women in Engineering (WIE) Chair, and the Webmaster, and also at the society level on the PELS WIE Steering Committee. She has also created a mentoring program that connected mentors and YP mentees in IEEE Region 3 during the early days of the COVID-19 pandemic, which was nominated for the MGA Young Professionals Achievement Award. She is passionate about mentoring and career development of women in engineering.

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ciated by younger faculty members just starting their research and teaching careers. The resources he made available in collaboration with leaders from the power electronics and power systems societies to facilitate his mission of expanding power-engineering education are invaluable and will stand the test of time. Along these lines, Prof. Mohan set up CUSP: Consortium of Universities for Sustainable Power, which curated various educational materials at graduate and undergraduate levels.

In addition to his innumerable service activities for the Department of Electrical and Computer Engineering, the University of Minnesota, his profession, and technical societies, he was an integral part of the Minneapolis-St. Paul community. He was very involved with the Hindu Temple of Minnesota, providing guided tours and seminars.

All who had the opportunity to meet and get to know Prof. Mohan will recall his sharp wit, disarming humility, and remarkable intellect. He will be sorely missed and fondly remembered.

Prof. Mohan is survived by his wife, Mary, son Michael, and daughter Tara. His loss is deeply felt by his family, colleagues, and the power engineering community worldwide.

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Book Review

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He was the founding Executive Dean of the Zhejiang University/University of Illinois at Urbana–Champaign Institute, started in 2016. His research interests include address all aspects of power electronics, machines, drives, transportation electrification, and renewable energy, with emphasis on nonlinear control approaches. He published an undergraduate textbook, *Elements of Power Electronics* (Oxford University Press, second edition 2015). In 2001, he helped initiate the International Future Energy Challenge, a major student competition involving fuel cell power conversion and energy efficiency. He holds 42 U.S. patents. He was a recipient of the IEEE William E. Newell Power Electronics Award in 2003 and the IEEE Transportation Technologies Award in 2021. He is the Past President of the IEEE Power Electronics Society, a Past Member of the IEEE Board of Directors, and the Past Chair of the IEEE Transportation Electrification Community. He is a Fellow of the U.S. National Academy of Inventors and a member of the U.S. National Academy of Engineering.

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