Software Defined Manufacturing: Enabling Industrial Automation

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Abstract

This white paper aims to explain the basics of software defined manufacturing (SDM), how it relates to the concept of the "digital twin," and how it can be enabled by the efforts of the Open Process Automation Forum™ (OPAF) and other industry-standards bodies. This paper also reviews an application example of the smart factory, as well as some of the interconnect products and technologies that enable industrial automation and chart a path to the future of software-defined manufacturing.

Introduction

Manufacturing productivity has long benefited from automation, with many factories regularly incorporating robotics and software-controlled automated equipment into their production lines. Currently, much industrial automation is challenged by "vendor lock-in," due to proprietary designs as compared to an open ecosystem. Many argue that factories could realize even greater efficiency gains with an open architecture for industrial automation which would include common platforms, interfaces, and technologies. Taking this one step further, manufacturers can optimize their use of software in the factory. Software-defined manufacturing (SDM) is a growing area of interest, and it may be a method to enable Industrial 4.0 technologies including artificial intelligence (AI), robotics automation, and data analytics.

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Figure 1: Many factories regularly incorporating robotics and software-controlled automated equipment into their production lines.

Software-Defined Manufacturing

Still at its conceptual stage, SDM includes a layer of software that oversees all manufacturing processes, from initial building of parts to final assembly and testing. The necessary hardware includes sensors, cameras, and robots throughout the factory that feed back data into the control hardware and application software. The aim is to

optimize the manufacturing process, making it more flexible to support product changes and prototyping.

The critical difference between SDM and traditional hardware-centric manufacturing is the ability for operators to have a unified view of the entire production floor. Instead of optimizing individual hardware systems for a particular task, OEMs can now also optimize the entire production line, from build, to assemble, to test [2]. With SDM, much of the complexity transfers from the hardware to the software, with proponents arguing that this can simplify hardware and make it more resilient to supporting new products and innovation.

Some of the challenges of SDM include ensuring the safety, security, and repeatability of the systems inside the factory. A critical factor in this is ensuring low-latency connectivity, the use of AI, and rapid computation to ensure the operation is running according to standards. Companies such as VMware and Intel have partnered to create consolidated systems on a single edge-compute cluster, incorporating robotic vision and control as well as an edge compute stack to process vision and AI, motion, HMI, and control functions data [1], to address this need.

Value of the Digital Twin

A digital twin provides insight into some of the gains possible with SDM. It is a virtual representation of a component, system, asset, or process in a virtual version of the object's real environment. Over time, the digital twin is updated with the real object's lifecycle data (using sensors in and around the object), and then designers use simulation, machine learning, and analysis to make decisions. They run simulations based on possible scenarios, and they can optimize environmental conditions or the original design itself in order to improve efficiency in the original physical object. Using a digital twin differs from simulation in two key ways: a digital twin includes the object's environment, and it is updated with real-time data [3].

Some advantages of a digital twin include improved research and development, in terms of product lifecycle management (PLM); better efficiency in the manufacturing process, including minimizing downtime by tracking maintenance and field failures; and an understanding of what can be recycled from the product at its end-of-life stage [4].

It's important to recognize that a digital twin is expensive, requiring an exact virtual replica of the object/system and its environment, as well as the installation of sensors and processing equipment on the real-life original. Digital twins are most useful in extremely complex environments, such as industrial automation systems, automobile or aircraft production, or power utilities. In this paper, we focus on industrial automation systems. OEMs using a digital twin can benefit from a through sharing of data between engineering, operations, and maintenance, including notification of the conditions surrounding a field failure.

Benefits of an Open Automation Ecosystem

The complexities of industrial automation have led to a push to create an open automation ecosystem, allowing OEMs to combine best-in-class components and software from a range of suppliers rather than a single vendor. This has the advantages of allowing flexibility in choice of supplier, simplifying service and process automation, and implementing control logic across the factory—a key enabler for SDM and allowing IT services to track and trace throughout the factory [5].

In addition, standard interfaces enable OEMs to swap out existing components with new ones. This can shorten engineering and commissioning time, and modularity reduces costs during process scale up. All of these benefits can improve total cost of ownership for automation equipment in manufacturing facilities.

Available Standards

Successfully achieving an open automation ecosystem requires industry standards. The O-PAS Standard was developed by the Open Process Automation Forum (OPAF) with its first release in 2018 focused on interoperability. Version 2.0 introduced configuration portability in 2020 and was finalized as 2.1 in 2023. Now the group is working on physical platform and application portability in version 3.0, with expectations for the preliminary release in 2024 [6].

Working in conjunction with the efforts by OPAF, the Universal Automation Organization is an independent, non-profit, industry association that is working to enable portable, interoperable technologies for automation hardware and software. Founded in 2021, this effort leans heavily on a shared-source runtime engine based on the IEC 61499 standard with a goal to emulate the openness and collaboration present in other industries, such as mobile technologies, for industrial automation.

PICMG, a consortium for open hardware specifications, has partnered with OPAF to maintain an open modular architecture for process control systems, specifically for edge controller hardware. The standard, known as InterEdge, focuses on pluggable modules, detailing electromechanical interoperability and hot-plug capabilities (allowing replacements without disconnecting power from the backplane). It includes compute modules, switch modules, I/O modules, power supply modules, and their interconnection protocols through data and power buses in the PCB backplane [7]. InterEdge is compatible with IEC 61499 and IEC 61131 standards.

Rapid Prototyping in the Smart Factory

While there are many factors and approaches enabling the smart factory, a combination of them can improve product prototyping. For instance, in the design and production phases of complex products, operations teams can now have unprecedented insight into their manufacturing systems.

An example of this is the manufacturing approach taken in Samtec's cable factories, a strategy that combines the ideas of SDM and the digital twin with Evolutionary Operations Methodology (EVOP) to take full advantage of available data. EVOP is a proven design of experiments (DOE) process that introduces changes during a manufacturing process, ultimately helping to improve process performance.

By expanding their understanding of the physical phenomena required for high-speed cable construction, Samtec design and production teams are speeding time to market. Samtec's cable operations have found that SDM, digital twin technology, and EVOP enables continuous improvement to reduce variability (quality issues) and improve the manufacturing process (yield). By creating custom product models within a software-defined environment, Samtec can sharpen its competitive advantage by rapidly bringing up prototypes to full-production capabilities, such as with its proprietary Eye Speed® twinax cable used in Flyover® cable technology, allowing Samtec interconnects to offer design flexibility and low skew.

With this type of combined approach, production teams have a thorough understanding of their manufacturing process allowing them to define, measure, analyze, improve, and control it. By implementing machine learning predictive models, collecting real-time analytics, and combining them with real-time process variables, the production team characterizes interactions and gains detailed insight into their processes. As a result, they can improve process control, preventing defects from recurring.

Industrial Automation Advances in the Smart Factory

Industrial automation can arguably benefit from open systems, interoperability, and SDM, yet there simultaneously remains plenty of opportunity for innovation in the individual products, components, and software that power industrial automation.

Specific systems designed for industrial automation include programmable logic controllers (PLCs), human-machine interfaces (HMIs), sensors, actuators, and industrial communication networks. Connecting all of these hardware components efficiently and effectively can be challenging. High-performance interconnects, such as the ones from Samtec, are designed and rigorously tested to provide reliable and secure connections in industrial systems.

For example, many industrial automation system designers choose Samtec's Tiger Eye™ connectors, specifically series TFM/SFM, because they are proven for use in small, high-reliability, high-cycle, rugged applications [8]. Rated to 1,000+ mating cycles, these interconnects use a multi-finger BeCu contact that provides redundant points of contact for improved reliability. Available in 0.80 mm, 1.27 mm and 2.00 mm pitches, Tiger Eye connectors can be equipped with additional ruggedizing options such as screw down, weld tab, and solder nail. In addition to being part of Samtec's Sudden Samples program, TFM and SFM Tiger Eye products are available from Samtec's Reserve® program, shipping quantity orders in 1 day.
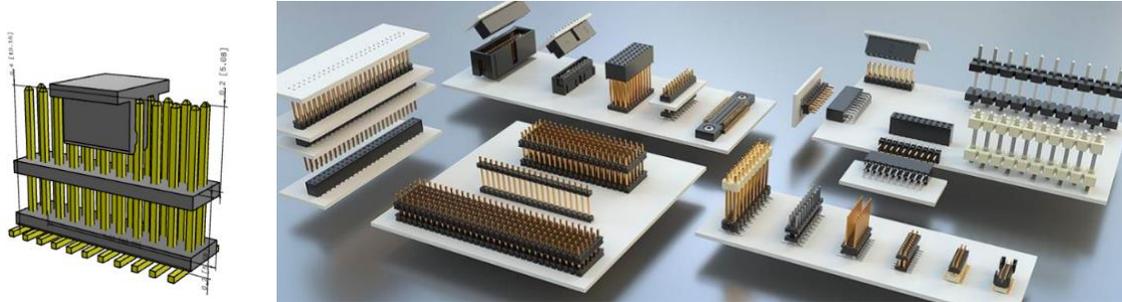
Figure 2: Image shows (left) FW-SM micro-board stacking header and (right) a variety of Samtec board stacking connectors. Customers can specify a wide range of board stacking heights as well as ruggedizing options.

Another popular product to support industrial automation systems is Samtec's board stacking connectors, where header and socket systems are available in a variety of pitch, density, stack height, orientation, and other standard or modified options [9]. For instance, post height and body positions are specified in 0.13 mm increments, as part of the standard ordering process. Series FW micro board stackers, for example, mate with CLP low profile, dual-wipe sockets with up to 50 pins per row.

Samtec's industry-leading expertise in rugged/power and high-performance interconnect systems, combined with on-going Extended Life Product™ and Severe Environment Testing initiatives, enables quick-turn, cost-effective options for the performance, reliability, and durability demands of industrial automation applications, including enduring high vibration, high power, and high mating cycle systems in small form factors.

For more information, visit https://www.samtec.com/industries/industrial/industrial-automation/ or contact SIG@samtec.com.

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