

#### **DIGITAL INDUSTRIES SOFTWARE**

## Digital transformation: How Siemens EDA helps you **engineer a smarter future faster**

#### **Executive summary**

We are living in an age of ever accelerating digital innovation, where world-wide knowledge, commerce and communication are broadly accessible and literally at our fingertips. Over the past six decades, thousands of companies in the tech sector have worked diligently to bring new, ever-more sophisticated electronic innovations to market daily, culminating in today's age of digitalization, which is rapidly changing how we live, travel, conduct business and communicate. This pace of digital transformation will accelerate even more rapidly as more companies begin to incorporate artificial intelligence (AI) and machine learning (ML) into their systems to leverage and even monetize the exponentially increasing amount of data produced by seemingly "everything digital." Siemens EDA is dedicated to helping more companies advance in their digital transformation and engineer a smarter future faster.

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### Introduction

With the 2017 acquisition of Mentor Graphics by Siemens AG's PLM (product lifecycle management) business, the newly formed Siemens Digital Industries Software (Siemens PLM plus Siemens EDA) became the first tech company to tear down the barriers between engineering disciplines to facilitate the design of entire digital ecosystems. Siemens recognized that to develop tomorrow's digital innovations more rapidly, the most successful companies and their suppliers either have adopted or are in the process of adopting a system of systems mindset, in which "the system" is no longer just the IP core your team is developing, or the IC, PCB, the embedded software, the ECU, or even automobile your team is developing. Rather it is all those electrical, software and mechanical systems and the network connecting all those systems integrated into smart business environments, smart factories, smart infrastructure and smart cities it is the whole ecosystem your enterprise or your customers' enterprises are building (Figure 1).

To deliver optimal, safe, secure and truly innovative products to market requires not only designing, verification/validation and testing the functionality of each of these systems individually but also testing them running together virtually in the context of the end-system or entire ecosystem before committing to manufacturing. And after manufacturing, the data from the design end-product running in the field and the manufacturing processes can be analyzed to ensure safety, build better next-generation products, and optimize manufacturing and business processes.

Mirroring what is happening with customers, Siemens, with its Siemens Xcelerator business platform, is also adopting a system-of-systems mindset by building the industry's most compressive, integrated product design ecosystem to enable more companies to design with the end-system/ ecosystem in mind and deliver tomorrow's innovations to market today (Figure 2).



Figure 1. The most successful companies and their suppliers design with the end-system ecosystem in mind.

Siemens' acquired Mentor to help its customers make their digital transformation faster. Siemens' acquisition of Mentor came at a time when a growing number of the largest and most successful systems and ecosystems customers – many of which were already customers of Siemens PLM software – started to bring not only electrical system development but even chip development in house.

Many systems and ecosystems companies today are finding that developing their own ICs or, alternatively, hiring semiconductor companies to develop custom ICs or application-specific ICs (ASICs) specifically for their end-systems are far more preferable than using off-the-shelf generic systems. These ASICs deliver better power, performance and area (aka, PPA) optimization while offering competitive



Figure 2. Siemens EDA is the first, foundational step for companies and their suppliers designing with the end-system ecosystem in mind.

differentiation from those that purchase the same off-the-shelf chips to create easily cloned products that commoditize once hot markets.

Apple and Tesla are two ecosystem companies that exemplify how internal IC development and scaling has reaped many benefits. For example, rather than going with an off-the-shelf, self-driving computer system (announced at CES 2019 1/2019), Tesla developed and announced at Tesla Autonomy Day (in April of 2019) its own book-size, self-driving computer product that reportedly outperformed an off-the-shelf, trunk-size product by 2.5x while also conserving 10x more energy. This computer has become a key differentiator, which has helped Tesla maintain its dominant 79 percent market share lead in the electric vehicles market.

Likewise, Apple has increasingly brought more chip development in house to achieve new levels of functionality, performance and profitability, while better guarding their trade secrets and upcoming product specifications. Roughly a decade ago, the company developed its own system on chip (SoC) processor architecture for its iPhone line. Building on that success, the company has more recently built its own SoC architecture to power its Mac PCs and tablet lines – all of which are tightly tied into its many subscription services.

Both Apple and Tesla represent system companies that became ecosystem companies by whole-heartedly embracing digitalization to consistently introduce disruptive innovations to the world and become iconic leaders. They are fortifying their leadership positions and digitalization dominance by creating their own SoCs. And with the aid of Siemens Digital Industries Software, a number of other companies are following their formula for success.

### Digitalization, big data and AI

When people in the high-tech industry hear "digitalization" or "digital transformation" referred to as "emerging trends," they may be quick to dismiss them as something they accomplished 20 years ago. However, today there are still a vast number of companies that are not fully digital - prime examples being the myriad of small businesses and larger enterprises in the factory sector that Siemens serves. Further, with the pace of innovation producing more digital systems annually and in turn generating exponentially more data to be analyzed and potentially monetized, digital transformation is a perpetual journey, as even those companies that have been digital for decades recognize. To stay viable and competitive they need to continually update and improve their digital transformation and partner with likeminded companies in their supply chain.

Indeed, the realities of the COVID-19 pandemic have laid bare the frailties of businesses that do not have a robust digital presence or that partner with companies and manufacturers that are not digitally robust. The disruption the pandemic created have made evident the value and even necessity of investment in new digital transformation technologies (Figure 3).

"Digital transformation is the integration of digital technology into all areas of a business, fundamentally changing how you operate and deliver value to customers."



Figure 3. The COVID-19 pandemic has made evident the benefits of having a robust digital enterprise.

# Semiconductors at the heart of digitalization

The integrated circuit is the heart of many generations of modern electronics innovations and everything involved with digitalization. Every two years, in step with Moore's Law (devised by Intel co-founder Gordon Moore in 1965), the many companies involved in the design, development and manufacturing of ICs work together (though competitively) to deliver a new silicon process technology, which engineering teams can leverage to deliver new ICs with greater hardware functionality and faster performance to power newer and better electronic innovations.

Today semiconductor industry growth is driven by key digitalization trends mostly centered around

data, the worldwide volume of which is expected to skyrocket from 897 exabytes in 2020 to 392,540 exabytes by 2030, due in large part to more businesses becoming digitalized and thus consuming and generating more data. Tech industry analysts point to dramatic demand growth in the sensor and actuator market used for collecting data, a 10 percent CAGR for connected devices consuming and producing data, and continued growth in demand for the various devices used to more efficiently store this ever-growing amount of data (Figure 4) as key indicators that growth in data, supercharged by growth in digitalization, translates to dramatic growth for semiconductors.



Figure 4. Digitalization will further accelerate the creation and consumption of data and drive new uses of AI/ML to find ways to leverage and ultimately monetize data.

VLSI Research predicts digitalization adoption by businesses worldwide will become the prime revenue driver for the semiconductor industry the foreseeable future, vaulting the semiconductor industry to new highs. Meanwhile, research firm IBS predicts the semiconductor market will become a \$1 trillion market with a 9.9 percent CAGR by 2030 (IBS, January 2021).

Underlying collecting, transferring and storing data, an increasing number of semiconductor, software and system companies are turning to artificial intelligence and machine learning to help filter, sort, interpret, and analyze that data faster to speed business processes and derive new ways to monetize that data.

In fact AI/ML is quickly becoming pervasive as it is finding its way into an increasing number of points in the ecosystem (and all the key markets predicted to drive semiconductor growth), from embedded accelerator and pattern recognition blocks in ICs in edge devices and ADAS and autonomous vehicles, to new generations of wireless infrastructure transferring data, to datacenters storing the data in the cloud, and throughout the software running across all those systems as well as the software to design all the components of those systems.

To stay ahead of the game, the companies at the heart of digitalization are constantly looking for new ways to increase compute power. And for this, they are increasingly turning to Al/ML and extraordinarily complex architectures and manufacturing technologies. As an example, in a keynote at the Samsung SAFE (Scaled Agile Framework) event in October of 2020, Raja Koduri, senior vice president of Architecture, Graphics and Software at the world's largest semiconductor company, Intel, outlined how after innovating the 1980's era of "digitize everything," the 1990's era of "network everything," the 2000's era of "mobile everything" and today's era of "cloud everything," we are today readying "the emerging era of Intelligent Everything," where AI-enabled ICs will be at the heart of 100B intelligent, connected devices worldwide. "Today, with the world generating close to 175 zettabytes of data a day, we are generating data faster than our ability to analyze, understand, transmit, secure, and reconstruct it in real-time," said Koduri. The way to address this explosion of data growth is for the tech industry to work together to enable "exascale compute performance for everyone," said Koduri. To make that a reality by 2025, Koduri said it would require a 1000X improvement in AI computing, which would need to be aided by advancement in three areas, which can be summarized as: scaling of IC process technology, IC design, and systems.

### Digital transformation begins with ICs designed with the end-system in mind

Siemens EDA is the electronics division of Siemens Digital Industries Software. Siemens EDA offers design flows for:

- IC design, verification and manufacturing
- IC packaging design and verification
- Electronic systems design and manufacturing

Joseph Sawicki, executive vice president of IC EDA, runs Siemens EDA's IC EDA business. AJ Incorvaia, senior vice president, Electronic Board Systems EDA runs Siemens EDA's IC packaging and verification as well as its Electronic Systems Design and Manufacturing businesses. Both report to Tony Hemmelgarn, CEO of Siemens Digital Industries Software.

In recent keynotes, Sawicki has outlined the vision for how Siemens EDA is enabling process technology, design, and systems scaling as fundamental steps to helping companies deliver IC innovations and accelerate their and their customer's digital transformation.

**Enable process technology scaling** The semiconductor and EDA businesses are unique in that with the introduction of new silicon process technologies every two years, the EDA tools and methods to design and manufacture ICs on these new silicon processes not only have to scale in capacity and compute power to handle much larger design files and exponentially more foundry design rules, they must also scale to address new complexities and the strained physics of new manufacturing processes. To address these increasing complexities, Siemens EDA has been a pioneer in the use of AI/ML technologies inside of EDA tools to enable those tools to produce more accurate results faster. Meanwhile, to better address growing capacity and compute power challenges, Siemens EDA offers high-performance computing configurations via on-demand fog and public cloud configurations for those verification tasks that are especially compute intensive.

To enable process technology scaling, Siemens EDA works closely with foundry partners and customers to deliver Calibre® signoff quality physical verification, design for manufacturing (DFM), lithography and Tessent yield and test tools for each emerging process technology node. These enable the foundries to bring up new process nodes quickly as well as help IC design teams ensure they are getting the highest PPA possible and that their ICs are completed as fast as possible.

For companies wanting to achieve "More than Moore" densities for their ICs, Siemens EDA has worked with foundry partners and design customers to deliver Xpedition<sup>™</sup> advanced packaging solutions, which enable customers to use chiplet and stacked die methodologies to develop 2.5D and 3D ICs and system-in-package products to achieve optimal PPA for their end-systems. To speed data on and off chip faster, Siemens EDA is also a pioneer in silicon photonic design tools, with its LightSuite<sup>™</sup> Photonic Compiler. Though not a main-stream technology yet, silicon photonics brings fiber optics directly onto the IC for IO speed hungry applications such as high-speed communications, high-performance computing, storage in data centers and LiDAR for military and autonomous driving systems.

Siemens EDA also offers full custom, analog, and analog/mixed-signal and MEMS design (Tanner™) and verification (Analog FastSPICE™) flows for companies developing custom, MEMS and analog IC designs and those developing AMS (Symphony™) high-speed IOs. It also pioneered AI-powered library characterization with its Solido<sup>™</sup> technology.

**Enable design scaling** As companies take a more holistic systems-of-systems view of their chip designs and integrate AI/ML into their SoCs, the chip and system architects who plan the system can develop mathematic algorithms representing the end-functionality they want their system or the AI/ ML functions in their system to accomplish.

Instead of jumping right into designing the silicon at the register transfer level (RTL), using a hardware design language, and perhaps going down a wrong path, they can transfer that mathematic algorithm into C code (using a tool from MathWorks). They can then run that C code on a standalone processor, SoC or FPGA-based prototyping system to see what functions of the algorithm run fast and what runs slow. To speed up the slow parts of the algorithm and achieve the goal of best PPA, they can use Catapult™ HLS to harden those parts by implementing them as logic gates in an SoC design and run the rest of the algorithm as software in the SoC's embedded processor. They can use Catapult HLS to synthesize the C code into RTL code and then use Catapult HLS to verify the algorithm's overall performance with one part running in custom logic and the other part running as software on the embedded processor. They can refine the hardware and software mix until they reach their desired PPA for the end-system specification and then advance the design to the rest of the IC design process, ensuring they are developing an optimal mix of hardware and software for their end system.

What's more, they can leverage PowerPro power analysis in Catapult HLS throughout the entire flow, from C-level design down to implementation, to ensure their designs do not stray from the intended power budget. They can then use the Questa<sup>™</sup> line of functional verification tools and Veloce<sup>™</sup> FPGAbased prototyping platforms to ensure the functionality of the RTL is correct. They can then use Veloce Strato+ emulation system to verify the functionality of the entire SoC running in the context of the end system and use Siemens Embedded to further develop software for SoCs, getting an early jump on further software development while the SoC design is moving through the implementation flow (with Oasys-RTL<sup>™</sup> logic synthesis and Aprisa place and route) and gets verified with Calibre, then manufactured and tested with Tessent<sup>™</sup>.

**Enable systems scaling** When EDA and semiconductor veterans hear the term digital twin floated as a new concept, they are typically quick to point out that companies have been creating "twins," "models" and "prototypes" of their ICs since the earliest days of semiconductors – with solutions evolving from breadboards to SPICE models to today's emulation systems digitally modeling multi-billion gate processors and SoCs. But semiconductor and conventional EDA companies typically stop there – at their IC system – when it comes to addressing a digital twin. With Mentor now a part of Siemens Digital Industries Software, Siemens is in a unique position to offer the industry's only true systemlevel, cross-discipline, comprehensive digital twin. As an example, in 2019 Siemens announced its PAVE 360, which ties Siemens EDA's IC tool flow with Siemens EDA's Veloce emulation system to a slew of Siemens PLM technologies to enable automotive OEMs and their suppliers to essentially verify automotive IC designs and validate related software in virtual driving scenarios before committing the silicon and the rest of the system to manufacturing.

While PAVE 360 is an automotive-specific implementation of a comprehensive digital twin, there are many other systems and ecosystem opportunities that will benefit from such cross-disciplinary, comprehensive digital twin environments in the not too distant future.

Siemens EDA also pioneered a silicon lifecycle management technology called Tessent MissionMode (released in 2017) and last year acquired UltraSoC, which enables companies to insert specialized IP blocks into their ICs. These blocks monitor, in real-time, on-chip faults, security, power and performance of ICs and potentially ECUs as well as the full systems they are built into. In an automotive configuration, companies can configure the blocks to report warnings to the vehicle's occupants, to the dealership for preventative maintenance and part ordering or to the tier-1 chip supplier or even the OEM to head-off recalls and improve derivative designs and even manufacturing processes. To deploy this technology to its full potential not only requires a partner, like Siemens EDA, with the right IP, but also the ecosystem software infrastructure, like Siemens Digital Industries Software, to interpret and take action on that data.

While Sawicki's group in Siemens EDA is innovating new IC design technologies for companies wanting to speed and optimize their digital transformation into digital ecosystems, AJ Incorvaia's group is extending digitalization from the PCB and interconnected electronic systems into the mechanical design sphere.

### Digital transformation for next-generation electronics systems design

Where IC design is constantly challenged by the complexities of new process nodes and the market's relentless demand for greater functionality and performance, PCB systems design is relatedly challenged with adequately powering and cooling these complex, faster ICs as well as routing and maintaining signal and thermal integrity of every highspeed signal between the ICs on a board. Rapidly, the challenges, and thus the technology to design and analyze them, must encompass all the boards on a system and be synchronized with related mechanical systems. Increasingly, design teams must deliver these ever more complex PCBs and interconnected electronic systems with best-in-class performance at the lowest power possible and do so within shrinking time to market windows. But the challenges are not limited to design complexity and time-to-market pressure.

In a series of keynotes, Incorvaia has outlined how the technologies (Xpedition Enterprise and PADS<sup>™</sup> Professional design flows as well as the tightly integrated HyperLynx<sup>™</sup> and Valor analysis suites) from Siemens Digital Industries Software uniquely enable customers to address product, organizational, and process complexities that have persistently hindered organizations from delivering PCBs and interconnected electronic systems on time with minimal revisions or respins. Incorvaia describes five core transformational capabilities that are required to deliver these keys to product differentiation, profitability and faster time-to-market:

 Digitally integrated and optimized multidomain design Enterprises must choose a PCB design environment that not only scales with the complexities of design, but also facilitates a digital thread that enables design teams and manufacturing to stay up to date on project status and collaborate worldwide across engineering domains.

A digital thread between design and manufacturing enables design and manufacturing teams to better collaborate to speed up the design process and minimize the respins. Streamlining the transition to manufacturing requires sharing a complete understanding of the product and enabling early downstream access to the data. Using a digitally integrated platform helps teams develop a complete and accurate multi-domain bill of materials that companies can easily integrate with a wide variety of other enterprise applications. Design teams can also develop templates that help teams enterprise wide to reuse best practices and enforce standards.

#### 2. Model-based systems engineering (MBSE)

To facilitate a system-of-systems mindset, many systems companies are turning to model-based systems engineering (MBSE), where sub-systems from the electrical, mechanical and software domains are each functionally modeled and brought together in a comprehensive digital twin at a systems architecture level, before design begins.



Figure 5. Choosing a multi-domain, trans-geography solution is imperative for digital transformation.

With an MBSE methodology, the architectures for the electronic sub-systems are extracted and communicated as a bill-of-functions, which are then used to drive the electronic system definition with appropriate configurations. At the beginning of the process, the systems architects define all the external interfaces for harness and cable design. The electronics are then placed into their appropriate logical and subsequent physical design implementations. The comprehensive digital twin allows engineers to start working on trade-offs in different domains from a functional level, earlier in the design cycle. Because each of these trade-offs may have an impact in each of the individual domains, the earlier it can be determined what tradeoffs work best for the overall product, the better the product will be. Furthermore, by looking at the entire system through a model-based systems perspective, teams can not only look at the electrical and functional trade-offs earlier in the design cycle, but also product trade-offs that might be based on such things as weight, cost, or even available components.

#### 3. Digital-prototype driven verification

To shorten time-to-market and maximize profitability, leading design teams perform analysis during the design process in iterative, short loops – rather than performing analysis only after the design has been completed or is in the lab after a physical prototype of the board or system has been assembled. Environments such as Xpedition allow design groups to perform analysis iteratively and create a digital-prototype of their systems for much earlier analysis.

What's more, having a comprehensive system not only allows for localized iterative loops for correct-by-construction design, but also facilitates broad system analysis. In today's environment, it is no longer viable to analyze only a few individual parts of a design outside the context of the entire system. Performance must be analyzed and verified at the largest system level – from 3D electromagnetic modeling of complex design structures to the creation of multi-substrate, digital, system-level models that feed poweraware system-level signal analysis. Heterogeneous silicon integration and advanced IC packaging require true, system-level thermal analysis along with concurrent analysis, where IC thermal effects on packages and the corresponding PCB are modeled in the context of the entire system.

- 4. Capacity, performance, productivity, efficiency The companies who have been most successful in making a digital transformation choose design environments that scale to their organization's size, challenges and design team expertise. In addition, the most sophisticated environments enable companies to catalog and leverage design reuse across their organization. In the IC design space, this has proven to have several benefits for reducing cost as well as design time by enabling development of derivative designs across an organization.
- 5. Supplier strength and credibility To embark upon a digital transformation and then continue to grow throughout that transformation to deliver generations of innovation to market requires partnering with reliable suppliers who not only offer leading solutions for today, but also are committed to formulating new ways to make companies more successful. Siemens is that supplier. It can help companies realize their digital transformation by offering not only the industry's most complete digitally integrated, next-generation systems design platform but also one that works seamlessly with manufacturing, PLM and enterprise flows.

### Conclusion

Digital transformation is a journey. The most successful companies that have built their systems into ecosystems understand that to obtain the highest levels of business success and deliver true value to customers, they must partner with companies that not only understand and share their larger vision but are equipped to help them achieve their goals. With Siemens EDA, Siemens Digital Industries Software is committed and uniquely positioned to help you in every stage of your digital journey.

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