White Paper

The Race to 6G — Faster Networks and Devices Promise a World of New Possibilities

Collaborative Multiphysics Simulation Shortens Time to Market, Increases Reliability and Lowers Costs

Electronics Are Transforming Our Lives

The importance of electronics in the modern world is hard to overstate, touching every aspect of life. A good example is the telephone. For the first century of its existence, the telephone was strictly a voice communication device. Today's smart phone has a wide range of functions that have nothing to do with voice, including email, web browsing and personal entertainment. Tablets are another example. In just a few short years, they have become not only highly popular consumer devices but productivity tools for enterprises, healthcare institutions and governments, enhancing communications and providing a mobile communications work platform.

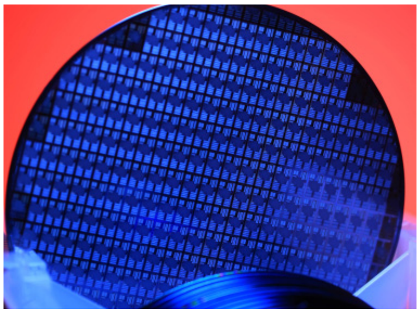
The impact of electronics is being felt in every industry. Thanks to powerful computing platforms and high-speed networks, financial transactions that once took days now take milliseconds to execute. Consumer products such as automobiles and appliances are more connected and computerized than ever before. Even traditional industries such as transportation and manufacturing are embracing large-scale automation and integration. From digital homes and super tablets to cloud computing and paperless healthcare, electronics are literally reshaping our lives.

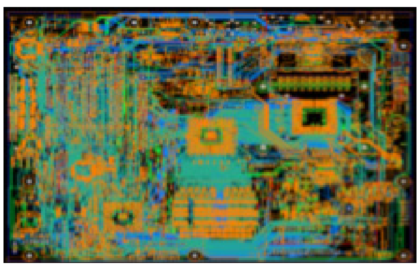
Telecommunications offers a striking example of the rapidity of the electronics revolution. The move from 1G to 4G took a full decade. The pace of new technologies is accelerating, meaning that the time to 5G and 6G will be much shorter — it may be a little as three years until 6G is a reality.

Many simulation tool vendors continue to focus on a single discipline such as thermal analysis or electromagnetic simulation. While these point products can perform well for their intended functions, they are difficult to integrate with other tools. They tend to foster the "local" thinking that masks system-level problems — until it's too late.

Higher Speed, Lower Power, Smaller Packages — and Increasing Demands on System Designers

What are the driving forces behind this revolution? One key factor is the continuing evolution of the integrated circuit (IC) toward higher speeds and lower power consumption, providing the ability to make products of all kinds smaller and more powerful. Today, ICs are the brains of a wide range of consumer products, from personal computers and smart phones to entertainment devices, automobiles and home appliances. They are at the core of industrial products such as industrial machinery and equipment, medical devices, renewable energy equipment, oil and gas exploration systems, digital homes, networking components, process control equipment, aircraft, and construction equipment.





At the system level, designers are being asked to pack more and more capability into devices and electronic systems with ever-decreasing dimensions. The designers of the today's smart phones have to introduce new products that are lighter and thinner — and more frequently than before, on an annual basis. At the same time, the telecommunications equipment industry must continue to make faster and faster networking devices to accommodate the increasing traffic caused by these next-generation smart devices. In such an environment, every design decision, from the choice of components to the location of ports and switches, affects every aspect of the product.

The Challenges of Increasing Frequencies and Shrinking Geometries
These smaller, more feature-filled products create a range of new challenges for designers. In the semiconductor arena, transistor features continue to shrink — currently as low as 28 nanometers. The packages themselves are much more complex, taking advantage of die stacking, greater numbers of substrate layers and other techniques to pack more into less real estate. The implications for IC designers are profound — local hot spots that can impair reliability and degrade performance, increasing potential for electromagnetic interference (EMI) at the IC level along with greater electromigration[1] and thermomechanical stress on the materials in the device.

As consumer products such as cell phones and tablets handle ever-growing amounts of information at higher speeds, system designers face their own set of problems. Faster signal transmission can lead to EMI problems at the system level. Demand for lower power consumption — key to battery life in mobile devices — poses signal integrity and noise challenges. The race to have the smallest, lightest package requires highly optimized designs, which only exacerbate these problems by packing more functionality into tighter spaces. Specific needs such as multiple antennas for today's 4G and WiFi-enabled devices contribute to the ever-increasing complexity of product designs — and add to the pressures on designers.

Taken together, these trends create challenges for designers in a number of areas:

- **Signal integrity (SI) and electromagnetic interference:** Signals are closer together in chips, on printed circuit boards (PCBs), inside product enclosures and in cables. Therefore, it is more likely that electromagnetic fields from one signal could interfere with and distort an adjacent signal, resulting in product failure.
- **Thermal performance:** Higher current densities in chips, PCBs and cables can create hot spots, influencing signal timing and potentially leading to component failures. In some cases, a component fails because the temperature exceeds the limit of the materials. But even temperatures below the threshold can produce failures due to electromigration.

[1] Electromigration is the transport of material caused by the gradual movement of ions in a conductor running at high current densities. The material moves due to the momentum transfer between conducting electrons and diffused metal atoms. The effect is more pronounced as the dimensions of an integrated circuit shrink.

Mechanical integrity: Thermal cycling (the heating and cooling of specific locations on a chip or PCB) can create stresses that lead to material failure. Typical failure mechanisms include delamination of copper traces inside the integrated circuit, joint fatigue in the solder bumps near a PCB via and high mechanical loading due to vibrations or dropping.

Complexity — and Market Pressure — on the Rise

In recent years, a number of factors have changed the nature of electronic design in a fundamental way. Products are much more complex, leaving little or no room for error. And there's less time to complete the task: The design cycle is being compressed to beat competitors and bring products to market faster. Adding to the challenge, heightened competition and tight budgets create enormous pressure on engineering managers. Management's message is clear: "You can't make a mistake."

What about the designers themselves? For one thing, the engineering profession has become increasingly specialized. Recent years have seen the spawning of new disciplines such as signal integrity and power consumption. Unlike the early days of the integrated circuit — when a single engineer could, and often did, create the entire design — the typical design group today requires a larger number of engineering specialties.

And those groups are not located in one place anymore. It's not unusual to have engineers in three or four countries — or even continents. A typical electronic enterprise can have programmers in Moscow, hardware engineers in San Jose and manufacturing engineers in Taiwan — and they all have to work together to ensure success.

Design Methodology Hasn't Kept Pace

While the demands on designers have increased almost exponentially, the basic methodology and workflow for designing electronic products has strayed little over the last 25 years. First, system architects develop the overall architectural design of the product. Then the architecture is partitioned into modules, which are assigned to individual engineers. These engineers design their own modules, build prototypes and test the prototypes to module specifications. After the modules meet module specifications, they are integrated into a system prototype that is tested to system specifications.

This approach worked well in the past but is inadequate to support today's designers. Problems that show up at the system level require changes at the module level, a time-consuming and resource-intensive process. This iterative methodology leads to unacceptably long time to market and consumes far more resources than necessary. The need is to identify system-level problems earlier in the process — when changes can be made efficiently and quickly.

The Crucial Need for What-If Testing

In today's highly competitive marketplace, it is vital that design engineers be able to optimize designs in terms of variables such as cost, size, weight, power consumption and functionality. Optimization requires the ability to run a number of what-if cases, changing a single aspect of the design and assessing its impact on the overall system. Highly successful companies use this approach to gain an edge over their competitors.

However, analyzing multiple what-if cases poses practical problems. Building and testing a large number of physical prototypes is time consuming and expensive. Simulation offers a faster, more accurate and less expensive alternative.

Multiphysics Simulation Tools Speed Design Process

Over recent years, engineers have been turning to simulation as a way to shorten the design process and pinpoint problems earlier. However, these tools were usually specific to one aspect of the product design, for example:

- Circuit simulators model signal propagation within electronic circuits and devices.
- Computational fluid dynamics (CFD) tools predict temperatures on a chip or PCB.
- Electromagnetic simulation tools help engineers design RF components and antennas, conduct compliance analyses, and analyze digital signal propagation in high-speed channels.

With today's more complex products, design decisions in one discipline often impact other aspects of the design. For example, the thermal engineer could recommend rerouting a signal on a chip to reduce the current load at a hot spot. The signal integrity engineer might recommend against this change because the proposed new signal route increases RF emissions and compromises FCC compliance. Each engineer is working with a simulation tool, but the tools cannot take into account both factors at once.

Multiphysics simulation tools represent the next stage in the evolution of design methodology. They model interactions between structural mechanics, heat transfer, fluid flow and electromagnetics behavior. Using multiphysics tools, engineers and designers from various disciplines can collaborate to create virtual prototypes of designs operating under real-world multiphysics conditions. This new generation of simulation tools accurately predicts how complex products will behave in real-world environments — in which multiple types of coupled physics interact. The software gives designers the tools they need to collaboratively optimize designs and take advantage of the full capabilities of components and materials in the product.

Multiphysics simulation tools offer significant benefits to both engineers and engineering managers in time to market, production optimization, cost control and business implications.

Time to Market

The legacy design process created “design silos.” Engineers focused on their own disciplines as they created their module designs and did not — in many cases, could not — assess the impact on other modules. The result? Complex products often failed at the system level due to interactions that could not be predicted at the module level.

Discovering these problems at the system prototype stage of the design process can be costly. Such a process introduces delays in product introductions, which result in missed market windows, delayed revenue and competitive disadvantage. Simulating system-level interactions before the completion of the module design phase leads to fewer system-level failures and reduces redesign time, which in turn shortens time to market.

Reliability

Virtually every major manufacturer today has a horror story about a product failure that led to expensive recalls and negative publicity. These incidents almost always revolve around failures at the system level — interactions between components that are difficult or impossible to identify with conventional tools and processes. Multiphysics tools offer the ability to more accurately simulate real-world conditions and interactions, reducing the likelihood and severity of after-market product problems. Companies that invest heavily in multiphysics simulation tools see a significant payback by reducing the costs of recalls as well as the adverse impact on the corporate brand.

Product Optimization

When they lack precise system-level analysis tools, engineers often compensate by building in safety margins to reduce system-level failures. For example, a thermal engineer might “pad” his calculations by 5 degrees due to uncertainty in the actual behavior of the circuit. That strategy can work, but it results in suboptimal designs. Getting that extra 5 degrees of safety could involve moving components farther apart than they need to be, resulting in a product that has a size disadvantage compared to others on the market.

With accurate simulation, engineers can design more aggressively, resulting in smaller, faster, more reliable products that are optimized for size and other key competitive factors.

Cost Control

When design engineers have access to multiphysics simulation during the module design phase, they can address potential system-level problems much earlier, before the system integration team begins building prototypes. Solving problems at the module level is usually easier, less costly and — most importantly — less likely to impact time to market or lead to missed opportunities in the marketplace. Sophisticated simulation tools also enhance the skills of engineers, leading to more robust and functional designs and less need for expensive consultants in specialized areas such as FCC compliance and signal integrity.

Business Implications

Multiphysics simulation is usually thought of as an engineering tool, but it has business implications as well. The kinds of problems identified by multiphysics simulation often have a direct effect on product specifications such as product size, battery life, regulatory compliance and mean time between failures. Identifying problems early in the design cycle also broadens the domain of possible solutions.

Take a case in which early simulation shows that the overall power budget for an integrated circuit will exceed design specifications. If this problem is found close to product release, the only option may be a costly and labor-intensive redesign of key parts of the circuit. However, discovering it early would allow the company to qualify a different IC manufacturer whose process brings the power budget back within specifications.

The ANSYS Approach

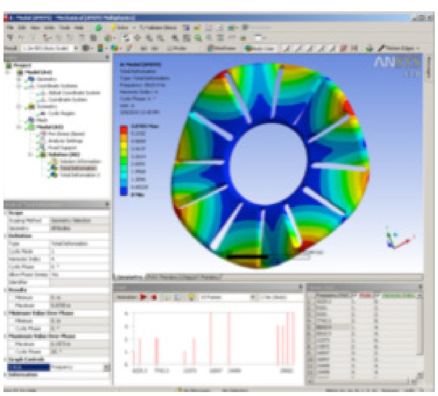
Many simulation tool vendors continue to focus on a single discipline such as thermal analysis or electromagnetic simulation. While these point products can perform well for their intended functions, they are difficult to integrate with other tools. They tend to foster the “local” thinking that masks system-level problems — until it’s too late.

ANSYS has taken a more comprehensive approach that focuses on providing the best-in-class simulation tool in any given discipline. ANSYS also provides a simulation platform that integrates these various products, enabling true multiphysics optimization and testing. Furthermore, ANSYS offers integrated simulation data and process management tools that enable an efficient and collaborative design process. Table 1 shows a sampling of the ANSYS portfolio of multiphysics simulation tools for electronic design.

Table 1. Selected ANSYS Products for Electronic Design

ANSYS Product	Used for	Applications in Electronics
ANSYS® HFSS™	3-D simulation of full-wave electromagnetic fields	High-frequency, high-speed components
ANSYS® SIwave™	Signal-integrity and power-integrity analyses	PCBs and IC packages
ANSYS® Q3D Extractor®	2-D and 3-D parasitic extraction	PCBs, electronic packaging and power electronic equipment
ANSYS® Icepak®	Computational fluid dynamics	Electronics thermal management
ANSYS® Mechanical™	Structural linear or nonlinear and dynamics analysis	Mechanical behavior of PCBs
ANSYS® Workbench™	Export simulation results for use by other tools	Managing simulations
ANSYS® EKM™ (Engineering Knowledge Management)	Knowledge capture	Simulation data and process management

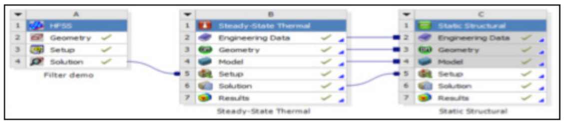
The ANSYS approach includes unique features not found in competitive offerings, including an integrated environment, automated simulation, seamless data exchange, bidirectional linking, what-if analysis and expert advice.



Unified Environment

The traditional boundaries between engineering disciplines are breaking down. In today's hyper-short design cycles, electrical, mechanical and thermal engineers must collaborate more closely — and earlier in the design process — than ever before. It's not uncommon to see an electrical engineer performing basic thermal or mechanical simulations to identify problem areas early, without having to wait for the more detailed analyses and simulations of the thermal and mechanical engineering teams. Signal integrity engineers can work with EMI and power integrity engineers to design the layout of a PCB for maximum speed and minimum interference.

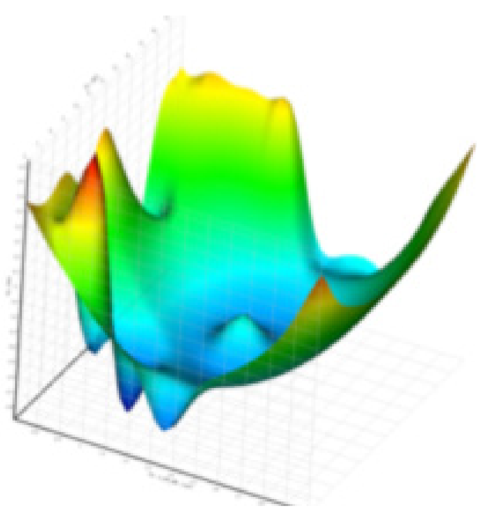
ANSYS provides a unique design environment in which engineers from a range of disciplines can work together. EEs, MEs and thermal engineers use a common interface from which they start their design simulations. The tools, the workbench and the multiphysics environment is the same for all. The ANSYS environment guides the team through the process of setting up and simulating the problem. It also allows engineers from different disciplines to display the simulation output in a way that is familiar to them, aiding the interpretation of simulation runs.



Seamless Data Exchange

Some companies rely on a mix of design and simulation tools from many different vendors. Often these tools cannot easily accept each other's results, meaning that engineers have to translate the information or even redraw designs for a different vendor's tool. ANSYS supports virtually all major CAD and simulation tools to allow engineers to reuse results by simply importing data files. The ANSYS tools exchange data with each other seamlessly so that simulation results can be easily passed from one tool to another.

The ANSYS environment features bidirectional linking, meaning that data passes automatically between all the simulation tools. Results from simulation runs can be exported to downstream simulation tools and back into the CAD environment so that engineers can modify designs to address specific issues that are identified in the simulation process. Table 1 shows typical uses of ANSYS simulation tools.

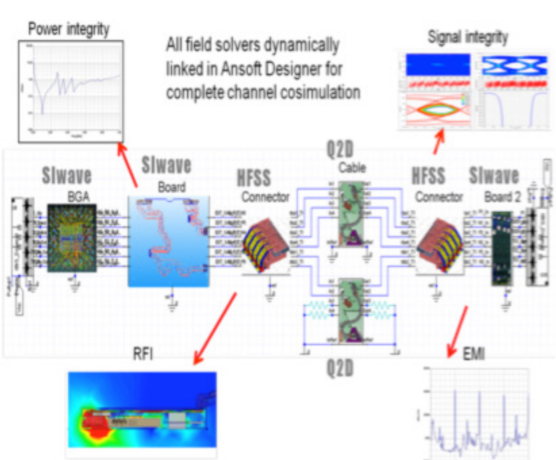


What-If Analysis

ANSYS tools streamline the simulation process by identifying particular areas of the design that need to be included in the simulation, effectively cutting simulation time dramatically, particularly for 3-D problems. Engineers can specify the level of accuracy, trading simulation time for precision. The net result is that ANSYS tools facilitate the multiple what-if analyses needed for design optimization without impacting time to market.

Expert Advice

Even the best tools are more effective when augmented with expert advice. The ANSYS support team consists of application engineers with extensive experience working on cutting-edge designs. They understand both the tool suite and the target applications and can offer guidance for design teams in any industry.



ANSYS Tools in Action

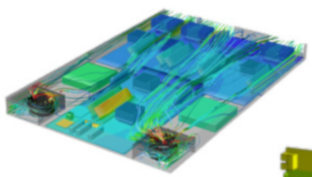
This section shows how ANSYS tools can be used in a typical workflow to simulate an electronic product. The product is a printed circuit board with several integrated circuits, an 802.11n antenna, RF components and connectors. It is intended for use in a network router that operates at speeds approaching 100 gbps.

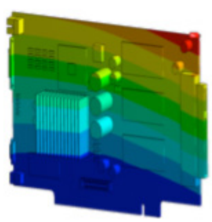
Electrical Simulation

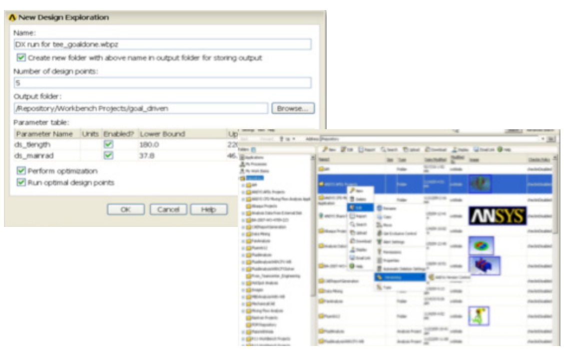
ANSYS SIwave is used to conduct detailed power integrity and signal integrity analyses for each semiconductor package and the PC board itself. ANSYS HFSS is used to design the RF components and WiFi antenna and simulate the behavior of connectors, vias and full chases. HFSS is also used to conduct a complete analysis of the behavior of the entire system as a high-speed channel.

ANSYS

The Race to 6G — Faster Networks and Devices Promise a World of New Possibilities







Thermal Simulation

ANSYS Workbench exports the joule heating losses in the PC board and connectors into ANSYS Icepak, which conducts a comprehensive thermal management analysis.

Mechanical Simulation

The results of the thermal simulation are exported through ANSYS Workbench into ANSYS Mechanical, which conducts stress and thermomechanical stress analyses as well as vibration and drop-test simulations.

Optimization

Engineers can optimize the design by performing EMI simulations of the final design along with thermal analysis.

Collaboration

ANSYS EKM allows all of these tasks to be conducted collaboratively by dozens of engineers in various disciplines, such as signal integrity, power integrity, mechanical, thermal and RF/microwave, across multiple companies and geographies. This collaboration saves time, reduces design mistakes and minimizes product recalls.

About ANSYS

Over the last 40 years, ANSYS has invested in developing best-in-class computational fluid dynamics, structural mechanics and electromagnetic solutions. Today, ANSYS offers a multiphysics solution that is unparalleled in the industry. For more information about ANSYS products, visit www.ansys.com/electronics.

ANSYS, Inc.
Southpointe
275 Technology Drive
Canonsburg, PA 15317
U.S.A.
724.746.3304
ansysinfo@ansys.com

Toll Free U.S.A./Canada
1.866.267.9724

Toll Free Mexico
001.866.267.9724

Europe
44.870.010.4456
eu.sales@ansys.com

ANSYS, Inc. is one of the world's leading engineering simulation software providers. Its technology has enabled customers to predict with accuracy that their product designs will thrive in the real world. The company offers a common platform of fully integrated multiphysics software tools designed to optimize product development processes for a wide range of industries, including aerospace, automotive, civil engineering, consumer products, chemical process, electronics, environmental, healthcare, marine, power, sports and others. Applied to design concept, final-stage testing, validation and trouble-shooting existing designs, software from ANSYS can significantly speed design and development times, reduce costs, and provide insight and understanding into product and process performance.
Visit www.ansys.com for more information.