

Integrated Chip–Package–System Simulation

The Complete Electronics Solution from ANSYS and Apache

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The pace of new product development — especially of meeting new design requirements — has never been more demanding. Historically, the rise in product development effort has been incremental, but the bar is now much higher for producing new and compelling products with better performance and at lower cost. Such heightened expectation has disrupted industry development and market planning patterns.

To meet these challenges, consumer electronics and other electronics manufacturers need the proper tools to design future generations of smart, energy-efficient products and meet time-to-market demands.

With electronic systems evolving at a rapid pace, chip designs become increasingly complex, even for mundane tasks. The challenge is managing design specifications (performance) and margins (price) while meeting the demands of a rapidly changing market.

Consumer electronics — tablets, smartphones and e-readers — is now leading the industry in growth. For system manufacturers and integrated circuit (IC) suppliers, the challenge involves keeping pace with rapidly evolving market needs while managing margins.

Other industries face these same design challenges, including aerospace and defense, medical devices and automotive. Today, an estimated 30 percent of a car's value is in on-board electronics; this is expected to climb to 40 percent of the total vehicle cost in the next few years, providing automobile manufacturers with a unique opportunity to differentiate their products.

Opportunities are wide open, all across the board. Smart technologies enable countless new applications, driving a range of end-use market sectors and boosting semiconductor sales. The number of networked devices is growing exponentially and globally. R&D teams rapidly pair devices with services, applications and content. At the same time, private companies — not just government agencies or military services — are playing a larger role in developing cutting-edge technology and products.

To meet the demands of both consumer and enterprise markets, electronics systems incorporate increasing complexity. Solutions to these engineering challenges rely on accurate, predictive simulation software.

Meeting Next-Generation Goals

How will you design your next generation of products and meet all of these goals?

In 2011, ANSYS, Inc. acquired Apache Design Solutions, the leading simulation software provider for advanced low-power IC design. IC and system designers use Apache tools for power-efficient electronics found in mobile devices, data center equipment, consumer and computing devices, and automotive systems. Apache Design technology complements and expands the breadth, depth, functionality, usability and interoperability of ANSYS® simulation products. More importantly, the acquisition opens the door to more comprehensive systems simulation so that engineers can predict product behavior much earlier in the design cycle.

With electronic systems evolving at a rapid pace, chip designs become increasingly complex, even for mundane tasks. In most design environments, ICs work within the context of a reference system that the IC vendor provides as a guide to the system designer. The challenge for system designers is meeting these guidelines and managing design specifications (performance) and margins (price) while addressing the demands of a rapidly changing market.

To meet these requirements, ANSYS and Apache Design together offer electronics customers a simulation-driven chip–package–system (CPS) development methodology that is multiscale, multiphysics and multiuser.

The methodology is multiscale in that it provides simulation technologies that range from the nanometer scale, used in IC and other chip designs, to the meter scale, found in servers, unmanned aerial vehicles and other designs. Multiphysics gives developers the ability to simulate various physical phenomena across chips, packages and systems, including power optimization, signal integrity, electrostatic discharge (ESD), electromagnetic interference/electromagnetic compatibility (EMI/EMC), heat transfer, fluid dynamics and structural mechanics. The multiuser aspect provides the simulation platform and collaboration tools that enable electronics, electrical and mechanical engineers — along with managers and executives from different divisions within the organization — to collaborate in designing increasingly complex products.

There are three differentiating points that translate into key benefits for electronics customers. The first is enabling innovation. The combined ANSYS and Apache Design CPS methodology provides simulation tools that span a large variation in scale while incorporating a variety of components and subsystems into a single simulation. This enables engineers to simulate and optimize signal and power integrity (SI/PI) for the entire CPS channel as a single system, rather than a collection of parts and components.

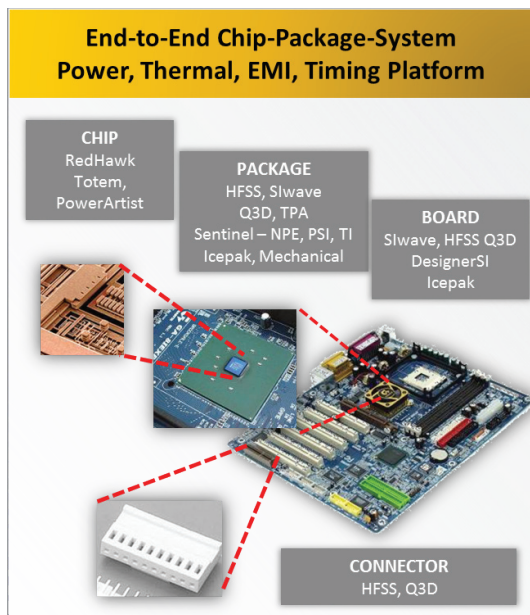


Figure 1. Chip-package-system solution resulting from the combination of ANSYS and Apache Design products

Another critical point is reducing cost and time to market. ANSYS tools offer a high level of visibility into SI/PI/EMI design; comprehensive mechanical and thermal simulation capabilities provide an early and more complete understanding of CPS design behavior across the systems' physics.

The third differentiating benefit is the increase in cross-functional collaboration. This improves productivity and provides engineers and management teams with a deep and real-time visibility into the CPS design cycle. It also improves the coordination and understanding of design trade-offs across departments and disciplines.

The tools that ANSYS provides now cover the breadth of simulation for a full CPS design flow, as shown in Figure 1. ANSYS is the simulation leader in package and board extraction using electromagnetics, system-level signal and power integrity, and mechanical/thermal simulation for electronics. Its tools (ANSYS HFSS™, ANSYS SIwave™, ANSYS Icepak® and ANSYS DesignerSI™) are used throughout the industry, while RedHawk™, Totem™ and PowerArtist™ complement that capability with IC design solutions in mobile device low power, reliability and chip-package-system simulation. The combination allows for a full end-to-end solution.

CPS Sign-Off

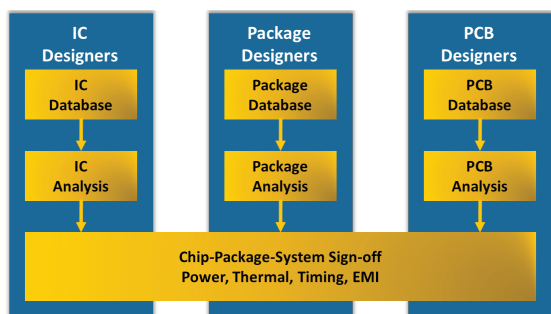


Figure 2. Chip-package-system sign-off involves IC, package and PCB design.

With the Apache Design acquisition, ANSYS offers new solutions that solve chip power delivery problems, package/board thermal/electromagnetic extraction, system enclosures and time-domain circuit analysis, all in a single simulation platform. The source of electrical signals in an electronic product is its integrated circuits. How those signals propagate and couple to other portions of a system, either intentionally or unintentionally, is governed by physics. Designing the system requires that organizations implement a method to analyze and control the signals while simulating both integrated circuits and the underlying physics. Engineers can accurately predict electrical noise, electromagnetic interference and high-speed electrical interfaces when they take these factors into account.

Figure 2 depicts how an organization can leverage a chip-package-system approach for design sign-off. A large electronics design organization may have at least three design groups, including IC design, package design and printed circuit board (PCB) design. Engineers in each of these disciplines often work in isolation using independent design flows. Ultimately, all design disciplines must deliver their parts to converge into a single working system. It is at this convergence that the CPS flow and design sign-off method becomes a distinct advantage.

The Apache products produce compact models that describe IC high-frequency signaling and power consumption behavior. Likewise, electromagnetic simulation created physics-based models for IC packages and PCBs to characterize their full electrical and physical behavior. It is possible to monitor and validate an entire design chain — from specification planning to system acceptance — by sharing models among teams and performing full systems simulations, which can be carried out by both IC and package/PCB designers within their own design flows. This approach allows for a package/system-aware IC design and an IC-aware package/system design. Engineering design trade-offs for system behavior, noise and EMI can be performed throughout the design process to avoid costly problems at integration. A similar model-based flow exists for mechanical design, including thermal effects, shock and vibration, allowing for full CPS sign-off.

CPS Benefits

With smaller, lower-power, more portable devices, designing components in an isolated manner is no longer a valid approach. Engineers cannot work from the abstract of a schematic for individual components; they must consider the geometric description of the actual system to include all physical effects. This means being able to visualize the entire physical design, insert appropriate components (such as surface mount devices, connectors and ICs), and run frequency-domain and transient simulations with all electromagnetic effects included.

Engineers need a solution that is flexible, allowing the appropriate solver technology, including hybrid techniques and circuit simulation, for the task at hand. These requirements are not just related to signal and power integrity, however. Systems designers must also account for RF and EMI effects, as most modern electronic devices contain both digital and RF. Engineers must perform comprehensive analyses to determine thermal, stress, shock and vibration effects. A new design flow is needed to support design from layout, inclusion of signal integrity, power integrity, EMI, and 3-D integration. It must accommodate early-system design exploration and prototyping to help designers understand the various components needed and to predict system behavior and cost very early in the design cycle. These goals are achieved through a CPS design flow.

There are a number of benefits of the CPS approach: It is possible to import a package/board layout, add components including ICs, and run circuit and system simulation from within that environment. This physical approach provides a more scalable and usable framework compared to the traditional schematic- or netlist-based approach. Rather, engineers can populate the layout just as is done in production and test. Of course, the schematic is there if needed to link to abstracted subsystems, drivers, receivers, etc. Once assembled, any arrangement of chip + package + board can be inserted into a 3-D design (such as a housing or full 3-D product) for full 3-D system analysis. Wireless antenna patterns, EMI, electrostatic discharge (ESD) and full-system integrity can be performed. The 3-D integration now happens during simulation, not downstream in the lab.

The CPS approach benefits the entire electronics supply chain, especially IC suppliers and system integrators, providing a more robust and reliable design with greater predictability.

CPS Ecosystem

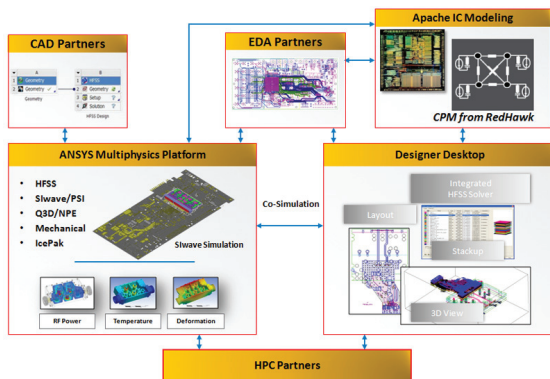


Figure 3. ANSYS CPS ecosystem incorporates multiscale, multi-physics and multiusers.

ANSYS has built a design and simulation ecosystem for high-frequency and signal integrity engineering, depicted in Figure 3. It consists primarily of a 3-D multiphysics platform for model extraction and the ANSYS Designer system/circuit simulation platform. The addition of the Apache Design products adds IC modeling and extraction, extending the solution in electronics. All simulations are accelerated by high-performance computing (HPC) to enhance fidelity and throughput of modeling.

Extraction Using Multiphysics

The ANSYS multiphysics platform allows rigorous modeling of complex physical structures. From IC packages on a PCB to coupled physics of a high-power RF filter used in a satellite, ANSYS Workbench™ and ANSYS Designer tools extract models based upon detailed physical simulation using methods such as finite element, boundary element and method of moments. Such detailed analysis is used in its own right to predict component performance in the electrical and mechanical domains. Models for 3-D components, such as antennas, RF filters and connectors, verified and optimized with ANSYS software can be sent back to the original CAD environment for downstream manufacturing and documentation. ANSYS tools link with EDA partner products to bring electrical CAD (ECAD) models into the multiphysics platform, enabling simulation and extraction of models for printed circuit boards, IC packages and IC back-end layouts. Again, component-level simulations are valuable in that they offer insight into ECAD component behavior such as signal degradation (signal integrity), EMI radiation and power integrity.

The ANSYS multiphysics platform is very powerful, and this class of rigorous physics modeling represents the bulk of ANSYS applications. It can be even more powerful when combining components into a system. Simulation is accomplished by models (extracting models) that can be used in circuit- and system-level simulation simulations in Designer.

Simulation Using Designer

R&D teams either build or buy product components to create a system. Complexity ranges from that of an aircraft or smart-phone to that of a thermostat or household appliance.

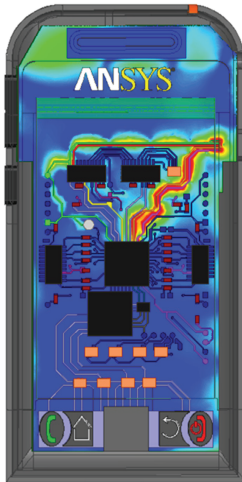


Figure 4. 3-D cell phone systems analysis
Model courtesy Juliano Fujioka Mologni, ESSS.

ANSYS has embarked on a program to integrate even more 3-D physics directly into the ANSYS Designer Desktop platform. This tool is geared toward electrical engineering design and associated layout-based models, such as IC packages and connectors. Figure 3 shows how Designer Desktop is connected to EDA partner products, allowing easy exchange of these layout-based models. New developments, such as Solver on Demand™ technology, enable electrical engineers to prepare models for rigorous 3-D physics simulation in a familiar layout-based environment. This streamlines design and model setup for component and systems-level simulations.

ANSYS Designer gives engineers the ability to model how components will operate within the system. Models extracted using detailed 3-D physics simulation are passed to the Designer Desktop, enabling engineers to connect them into an integrated whole. Full systems-level simulations via Designer help engineers to understand how electrical signals propagate through systems such as high-speed computer interfaces (ethernet, PCI Express™, DDR), or how microwave signals behave in a wireless communication system. In some cases, the signals are generated by behavioral models for drivers and receivers; in others, engineers can import SPICE netlist fragments to include transistor-level circuit detail using ANSYS Nexxim® or HSPICE® engines.

Figure 3 also shows a bidirectional cosimulation between Designer Desktop and the ANSYS multiphysics platform. As mentioned earlier, the circuit/system simulations use extracted models from tools such as HFSS and SIwave to account for real physics. The results of these analyses can be pushed back into the 3-D physics solver so that engineers can observe electromagnetic fields, resulting temperatures and stresses, and other true physical behavior that the components exhibit in the actual system. ANSYS is the only software vendor that delivers this capability with full multiphysics accuracy.

IC Modeling

The latest addition to the ANSYS simulation ecosystem is advanced IC modeling. The IC is the source of most electrical signals and heat in an electronic system; hence, adding Apache Design tools to the ANSYS suite helps to further the company's Simulation-Driven Product Development™ vision. Apache Design developed these leading tools for low-power design of integrated circuits so critical in today's mobile and computing markets. RedHawk and Totem software read the IC database produced by IC design engineers, who use the tools of major EDA and CAD vendors. Optimization to reduce power consumption can be performed, and compact models such as the Chip Power Model (CPM™) can be created and used in system-level simulations. As shown in Figure 3, these models are brought into the Designer Desktop and integrated with circuit- and system-level simulations of the extracted results. In many cases, it is possible to pass models directly between Apache Design tools and the 3-D physics software, such as SIwave, for signal, EMI, and thermal/mechanical analyses.

CPS Roadmap

ANSYS has built a strong roadmap to fulfill the CPS vision. The company has now put in place the underlying simulation technology for IC modeling, package/board extraction and systems-level simulation. Immediate integration plans concentrate on streamlining the flow for model exchange and cosimulation to enable high engineering productivity.

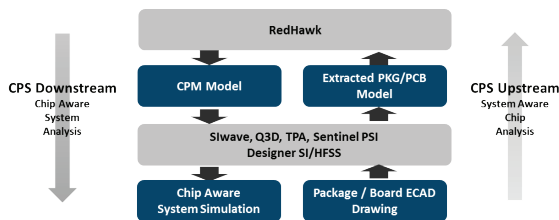


Figure 5. CPS downstream and upstream flows streamline integration of package and board models with RedHawk IC simulation.

CPS has both downstream and upstream flows, as shown in Figure 4. In the downstream flow, CPM models produced by RedHawk are integrated directly into the physics-based solvers, such as SIwave, DesignerSI, and HFSS. By automating this flow, package and board designers can include the true electrical signals from the IC in their system solutions. As indicated in the figure, this allows a chip-aware systems-level simulation of the package and board.

The upstream flow brings IC package and board models up to IC design, as shown on the right in Figure 5. ECAD artwork for the IC package and board are imported into one of several electromagnetic field simulators, such as SIwave, ANSYS Q3D Extractor® or Sentinel™ PSI, as appropriate for the particular model extraction. The upstream flow allows for a system-aware chip analysis that includes parasitic coupling and loading to produce accurate power waveforms from RedHawk.

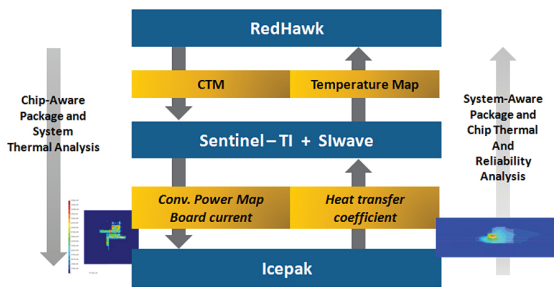


Figure 6. Downstream and upstream CPS flow for thermal analysis

Electronic product power consumption and the associated heat that develops are critically important to the industry. The source of heat and primary consumer of power are the ICs, so including an automated solution to link the IC die to the package and board is essential. Figure 6 depicts a downstream and upstream flow for thermal analysis. Sentinel-TI technology is a package-level thermal simulator that couples to RedHawk results using a chip thermal model (CTM). ANSYS Icepak is a system-level thermal simulator based on computational fluid dynamics that can include both conduction and convection cooling. Linking Sentinel-TI to Icepak provides the most accurate solution for IC packaging with the full system environment included in the analysis.

Including both Sentinel-TI and Icepak simulations in the flow offers two primary benefits:

Converged power/thermal: Coupling the solvers provides a true, converged power map and resulting temperatures. This is especially important for today's nanometer designs in 3-D IC or 2.5-D silicon interposer designs with through silicon vias (TSVs). The leakage power of nanometer IC devices is a major part of the power consumption in electronic systems, and that leakage power is a strong function of temperature. By linking Sentinel-TI with Icepak, ANSYS provides a converged power map and temperature essential for computing the actual operating point and leakage power of nanometer ICs. The converged temperature map provides an accurate and detailed reliability (electromigration and ESD) analysis for complex 28 nm and below ICs.

Accurate thermal simulation from IC die to full system: Icepak provides an electronics cooling solution for full systems with included components ranging from IC packages to printed circuit boards to full enclosed systems. With the addition of Sentinel-TI, the ANSYS solution includes high-resolution thermal and stress simulation at both die and package levels. The combination gives engineers the insight they need to understand thermal behavior across the full spectrum of geometry so that they can correct any thermal design issues.

These models provide a way for design teams to share information while protecting the IP of their individual designs. As chips operate faster at reduced supply voltages and with more functionality, accurate prediction of this noise level can determine whether chips will succeed or fail in the end market. The detailed thermal simulation enabled by CTM can be used in ANSYS Mechanical software to conduct a thermomechanical stress and current density analysis on the package and PCB. These models enable systems-level designers to understand the impact of their design choices (for example, removing layers of the PCB, adding an extra decap or modifying the heat sink) on the performance and reliability of the chip that powers the system.

Summary

The ANSYS simulation flow enables engineers to solve many of their toughest design challenges. The CPS solution is necessary to provide a fully coupled chip-aware and system-aware simulation for the chip/package/system. As a result of acquisition, the best-in-class IC dynamic power solution from Apache Design is now coupled to the best-in-class physical extraction simulators from ANSYS, providing full electromagnetic extraction, SI/PI/EMI analysis, thermal and mechanical stress, and solutions needed as 3-D IC technologies become mainstream.

ANSYS is committed to providing continued customer success through simulation innovation and world-class technical expertise in R&D and customer support, particularly in the areas of on-chip dynamic power and reliability, electrical extraction and system simulation, and thermal and mechanical stress for electronic design.

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