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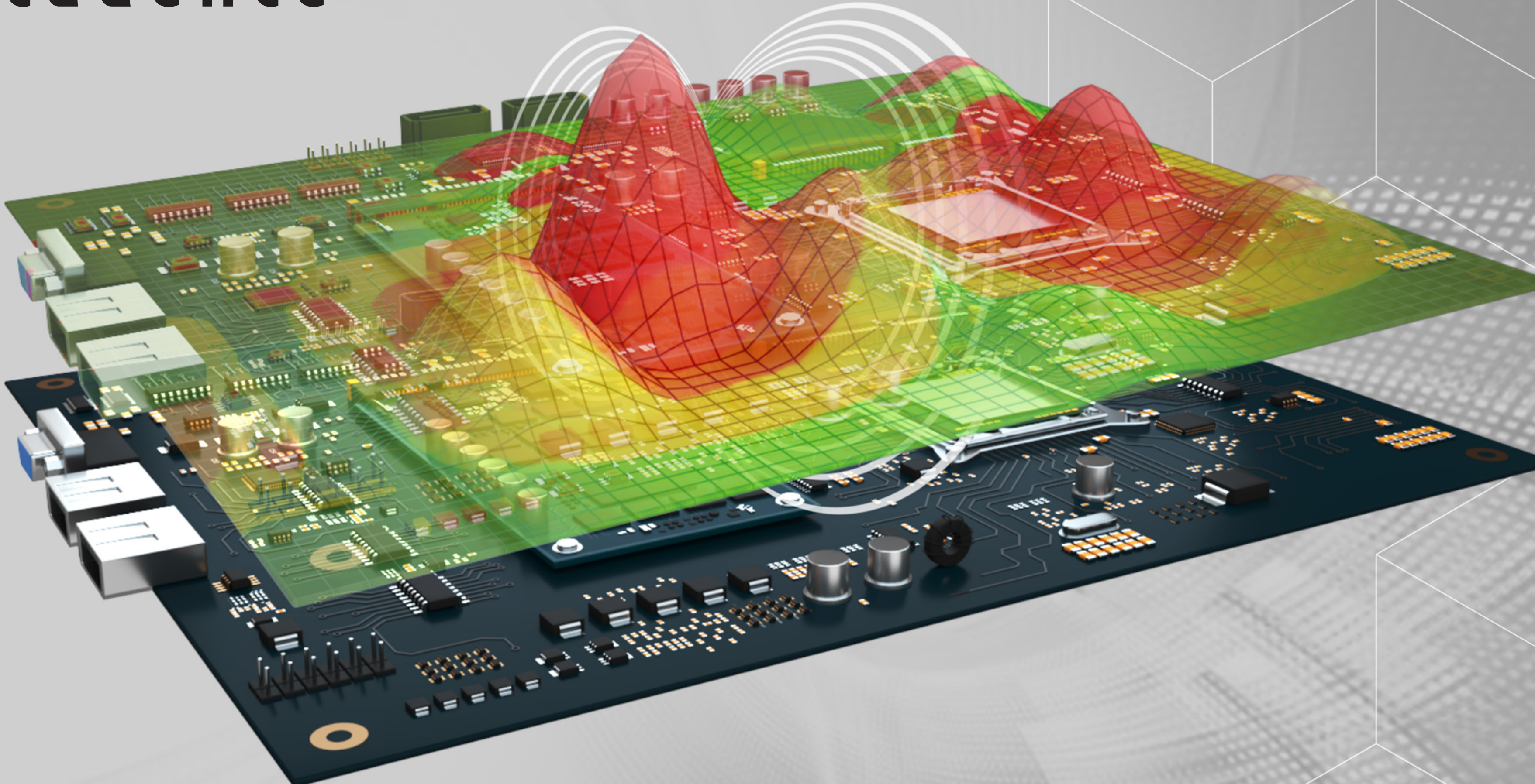

SYSTEM ANALYSIS EBOOK

# WHAT'S AT STAKE IN SYSTEM DESIGN?

CADENCE DESIGN SYSTEMS, INC.

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# WHAT'S AT STAKE IN SYSTEMS DESIGN?

When engineers refer to system analysis, they are referring to tool functions for improving an overall electronic design. Typically, these analysis options are focused on: power, signal, electromagnetic (EM), thermal, mechanical optimizations, improvements, or security. It can also be performed on RF/microwave designs.

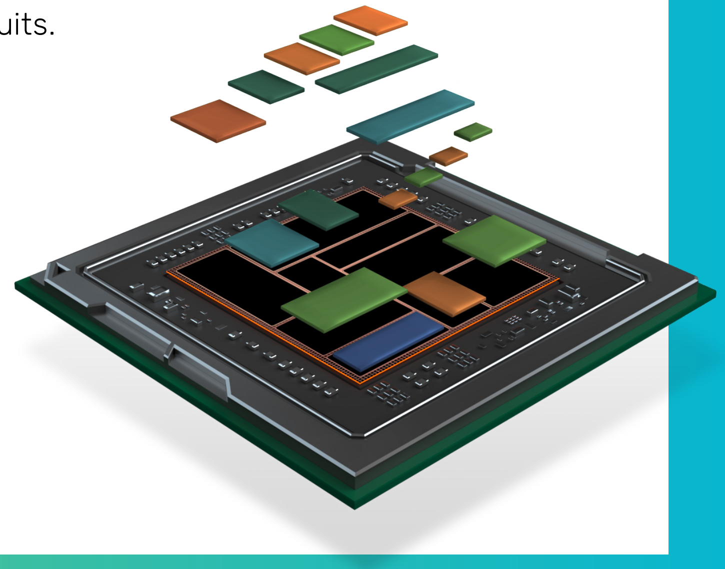
Improvements can be anything from increased runtime/ longer battery life, the ability to transmit data or power longer distances, the durability to withstand challenging environments, to sending more significant segments of data in more communicable formats.

These improvements can be project-defining optimizations. In the case of multi-million or multi-billion-dollar designs, completing a project within specifications is paramount.

Coming across the idea of system design or trying to understand it can be difficult. When the topic of systems is discussed, it is particularly about electrical systems: the PCB, IC, packaging, chip, cables, and connectivity.

The PCB and IC themselves require analysis and simulations as well as smart layouts to function properly. Putting things together is where difficulties like interference, crosstalk, and overheating into play. Individually these factors still challenge; however, when multiple chips are combined with unique signal necessities and multiple components are commingling with unique heat transfer properties, the overall circuit and system can become tremendously complex.

Packaging, cabling, and connectivity become a matter of how well the materials can match the device's functions. These materials then also have to undergo rigorous simulation, modeling, and analysis to determine how they interact with signal and power systems in other chips or circuits.



# INDUSTRIAL CONCERNS, SYSTEM SOLUTIONS

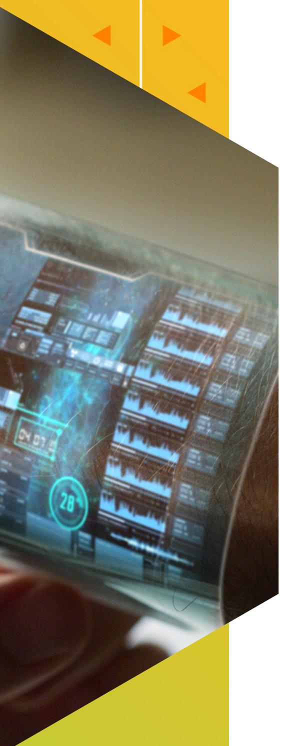
Despite technologies being widely applicable across industrial borderlines, the way new technologies are adapted into various industries differs and this is what makes the creative, artistic work of an engineer so thrilling. A systems solution is both a tool capacity and a philosophy: electronics is an industry where engineers constantly collaborate in inventive ways. One of the most challenging circumstances that a designer may face is being isolated for too long from outside-of-expertise feedback or knowledge.

Familiarizing with what other industries, engineers, and technologies are working on is something to be encouraged. This e-book examines the challenges that are most prevalent within some large and wide-spanning industries.


## Consumer Electronics

Some of the biggest challenges in consumer electronics are in data transmission speeds and form factors. Rigid-flex designs have brought forth the capacity of internet of things (IoT) devices everywhere, but how can the materials be pushed to even smaller size and greater reliability?

Data transmission rates, durability, and design miniaturization are all compelling challenges for any technology; however, consumer electronics designers face the difficult task of addressing all three in any new product or innovation. With more technology coming online to 4G and 5G speeds, signals engineers are already looking to push frequencies to 5G LTE and 6G bands. But data transmission cannot come at the cost of power efficiency or bulkiness.



To manage these demands, EM simulation software is necessary to find interference between devices and within rapidly changing networks and manage radiation emissions as they affect power delivery networks, impedance, and component integrity.

Between wearable technology, portable electronics, and the ever-increasing need for high-powered processing in consumer electronics, there's more heat being generated by what is being used day-to-day than ever before. To combat this, dynamic thermal management techniques are being applied to consider innovative ways to counteract the forces that can degrade electronics before their desired lifetime has come and ensure that heat never becomes a factor in any user experience.

The ever-present challenge in consumer electronics is how to provide better performance in products while making them last longer and take up less overall space. Microelectronics and specifically, the trend towards nanoelectronics, are requiring massive leaps in the accuracy of analytical results. But beyond that, improving wireless network bandwidth and data transfer rates require electronic collaboration between the power systems at work as well as the transmitter-receiver matrices responsible for data processing.

In addition, simulation is proving more necessary than ever before as consumers find inventive, more challenging environments to test the durability of their devices. What good is a smartwatch if it can't send the picture captured of a mountain peak sunrise to the cloud because the network couldn't be found? How can someone train for a marathon which they've always wanted to run if their Bluetooth headphones run out of battery after four miles or their signal becomes completely distorted if it's sprinkling outside?

# Automotive

Comprehensive hardware virtualization enabling complete system design is vital for automotive designers. How do the advanced driver-assist system (ADAS) radar signals interact with Bluetooth and Wi-Fi? What about during temperatures when the encasing is particularly cold and thermal sensitivity increased?

Signal and power demands continue to evolve in automotive systems. Updating wireless network interaction capabilities for ADAS, as well as converting vehicular powertrain systems into more electric power systems, each comes with a unique set of problems, between having frequency spectrum targets reaching into and interacting with millimeter-wave (mmWave) potentials or utilizing higher current power networks to improve system efficiency.

The simulation of multigigabit networks (MGN), significantly as signal frequencies increase, posses a constant problem for managing noise and electromagnetic interference (EMI). Finite-difference time-domain (FDTD) calculations are beneficial in the necessary rigid-flex boards and packages within automotive systems. Finite-element modeling (FEM) simulations are practical with system-level electromagnetic compatibility (EMC) tests like direct power injection (DPI) and managing ADAS systems like long-range radars and ultrasonic sensors. They are also helpful in handling sensitive capacitive coupling on high-ohmic sensors and identifying critical current paths with additional computational methods like partial element equivalent circuits (PEEC) and 3D transmission line matrix (TLM).

The push to electric vehicles (EV) is yielding increasing thermal demands on the automotive systems therein.

As always, there is a need to strike a delicate balance between power, efficiency and safety with any automotive design; however, moving to a fully electric vehicle places immense current demands on the powertrain system. Determining electro-thermal reactions within power systems, as well as innovating to inspire the next generation of efficiency and power in vehicles, are unique and concurrent demands. Wireless power transfer (WPT) is definitively an attractive prospect for electric vehicles, and electric performance optimization is only projected to increase.

Finally, there are many electronics standards for automotive design to track and adhere to, which require the system design software to offer a robust design-rule check (DRC) or constraint management tool. Applications like design reliability and failure mode and effects analysis (FMEA) is evergreen.

## Digital and Network Solutions

Effectively, what cloud providers require are network synthesis and simulation to diagnose and resolve any problems that arise in deployment, accelerate computing capacities, reduce overall interference in data transfer, and yield comprehensive network monitoring.

Additionally, they need network-wide system verification. This means chip verification, operating center verification, and robust testing environments. Protocols like remote direct memory access (RDMA) and RDMA over-controlled Ethernet (ROCE) require more fine frequency measurements and planar solving for potential sources of EMI. For the future of network monitoring, more and more technologies are working together, driving the need for quicker and more accurate finite-element analysis (FEA).

Furthermore, more robust server loads and sizes are needed to work through increasing challenges like in-band network telemetry (INT) and neural network optimization.

As the demands for data increase, whether from virtual storage, transfer rates, or power management, data centers require more extensive processing, hardware, and software capacities. With virtual nodes and virtual links allowing access to many new levels of data access and transfer, power demands are soaring like never before. DC networks of data centers consume well over 70 billion kW, and that much energy is managed, examined, and improved through smart hardware and system design. But with that much energy being used, the thermal tradeoffs are immense.

Additionally, working through optical networking and quantum computing are thorough challenges for any engineer; however, new design challenges like power data transfer and virtual network embedding continue to add layers of difficulty to data networks' expanded capabilities. Virtual problem testing and fault awareness, remote direct-memory access (RDMA), and in-band network telemetry (INT) adds additional technology hurdles. With signal integrity (SI) and power integrity (PI) analysis options, designers can trust any design stage to be reliably optimized for power and signal demands. Furthermore, with in-design analysis capacities, they no longer have to worry about determining how to best proceed with design optimization instead of focusing on more dynamic design challenges.

## Aerospace

Commercial airlines are always looking to reduce maintenance downtime, improve product lifecycle, and reduce total air traffic quality violations. Virtual prototyping and design environments, as well as extensive multiphysics solvers, can certainly, augment these needs.

Whether in the air commercially or for security and defense-related reasons, the chips, boards, packages, and systems involved throughout designs will require highly accurate analysis results. Improving power efficiency of key components and power distribution networks throughout an aircraft, as well as systems that control the environment or enable wireless network access, is of vital importance. Furthermore, enabling sensor networks and communications systems allow for access to the most up-to-date information available to make informed decisions regarding flight path, as well as potential maintenance, avoiding costly errors or degradation-determined failures.

Additionally, emissions regulations and energy efficiency are becoming increasingly more demanding for airlines. As such, power and thermal analysis are vital. There are many concurrent systems at work within any aircraft. Environmental control systems, engines and power systems, and braking systems, to name a few, all have many factors that can potentially disrupt steady activity. Accounting for vast changes in temperature like cold flows, simulating heat exchanger profiles and optimizing their performance, and examining the micro-and nano-scale materials flowing through any system can be some of the issues a thermal aerospace engineer must address. Trust in powerful, quick, and accurate thermal analysis software is critical.

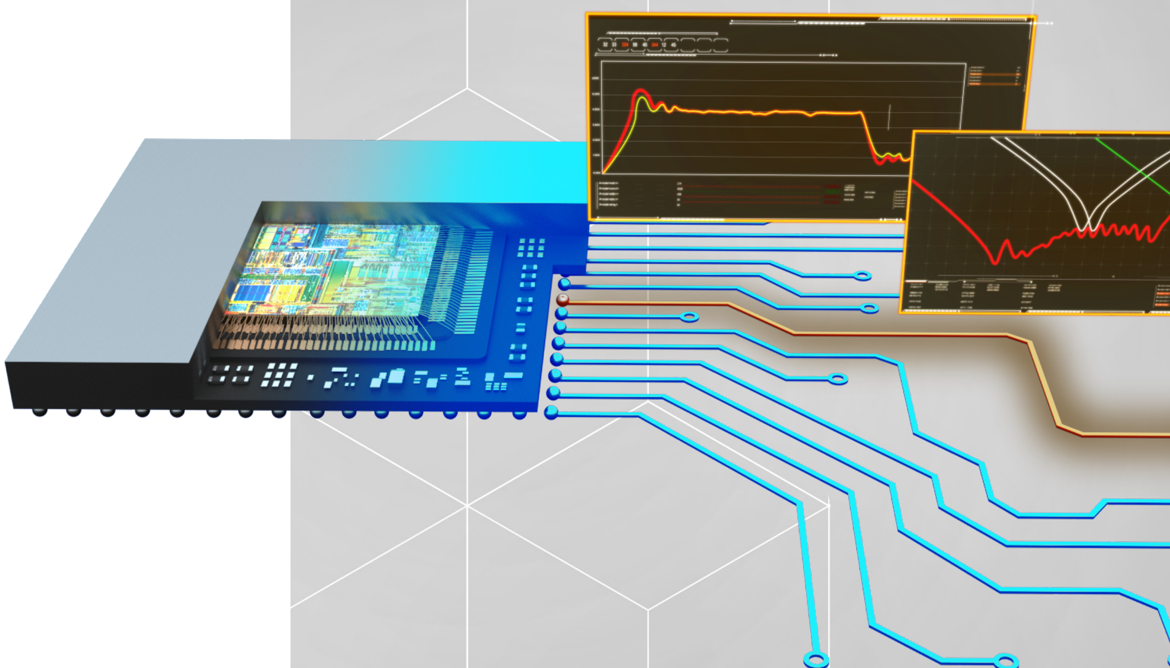
Defense operations need intense and highly sophisticated SI tools to manage communications needs. Still there are many pieces of military equipment throughout the world still operating on old communications standards, tools need to have access to interpret and communicate on multiple spectrums of frequencies.

Accuracy, as well as security, are of utmost importance for signal management. Ensuring the least disruption of communication between weapons systems or radars for accurate detection modeling is particularly valuable. When transport and attempt missions at faster speeds, higher accuracy, and greater power efficiency ratios than ever historically accomplished are required, of course, there will be many parallel challenges. At the surface level, more-electric aircraft (MEA) and all-electric aircraft (AEA) have inspired some of the greatest design innovations in the last few years. Improving mission accuracy is a task that requires both optimal electronic system design as well as a keen eye for cost management. And utilizing new EM devices in aircraft are enabling unique design innovations like electromagnetic brakes.

# POWER & SIGNAL INTEGRITY

Power integrity checks desired current or voltage from source to destination. On a system scale, this can involve simulating power distribution networks (PDNs) on chips, utilizing physics equivalent PDN models to analyze current loss or voltage noise, and optimizing PDNs.

Signal integrity manages noise, distortion, and loss of electrical signals. In systems and IC design, crosstalk by coupling capacitance or mutual inductance as well as mixed-signal and ultrawideband signals all pose unique and consistent difficulties.



## SI/PI Analysis Resources

### Understanding Passive Intermodulation in Wireless Communication Systems

PIM products become problematic only when they start interfering with other signals and other components in the system. The order of the PIM products is crucial when it comes to wanted signal distortion. The signals that mix with second-order and higher-order harmonics are the main problem makers in PIM products. As the order of the PIM products gets higher, there is more spread of interference, affecting the system performance.

Read more

### Calculate Loop Gain Using the Voltage Injection Method

The stability of voltage regulators in electronic circuits and DC-DC converters in PhotoVoltaic, fuel cell or battery-powered systems reflect on the output performance of the complete system. The traditional methods of analytical models and plots become obsolete, as they neglect parasitic effects and disturbances.

Read more

### Benefits of Wafer-Level Packaging for Board Designers

The overall benefits of using wafer-level packaging fall into two areas: signal integrity and verification processes (reliability, testing, and traceability). The former benefits make it easier for board designers to work with these products, while the latter set of benefits make it easier for semiconductor fabs to ensure high yield without increasing costs.

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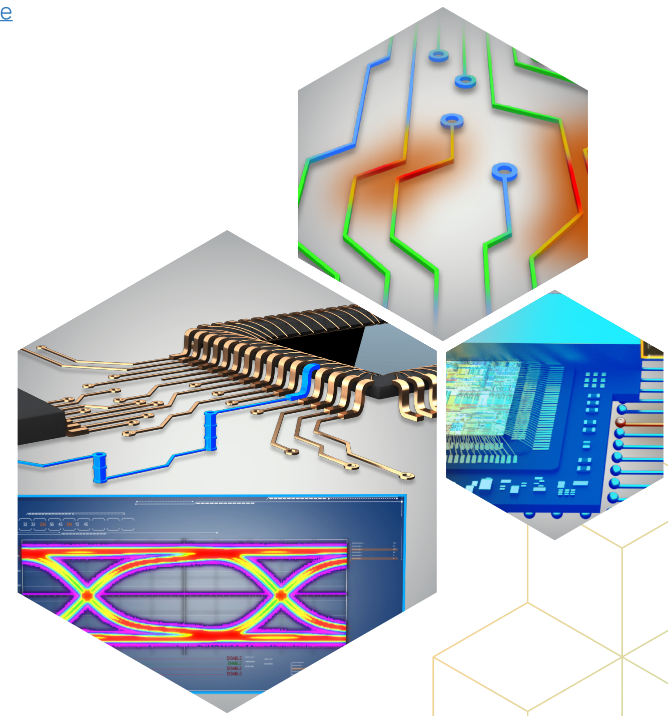
### Power-Aware Analysis Solution

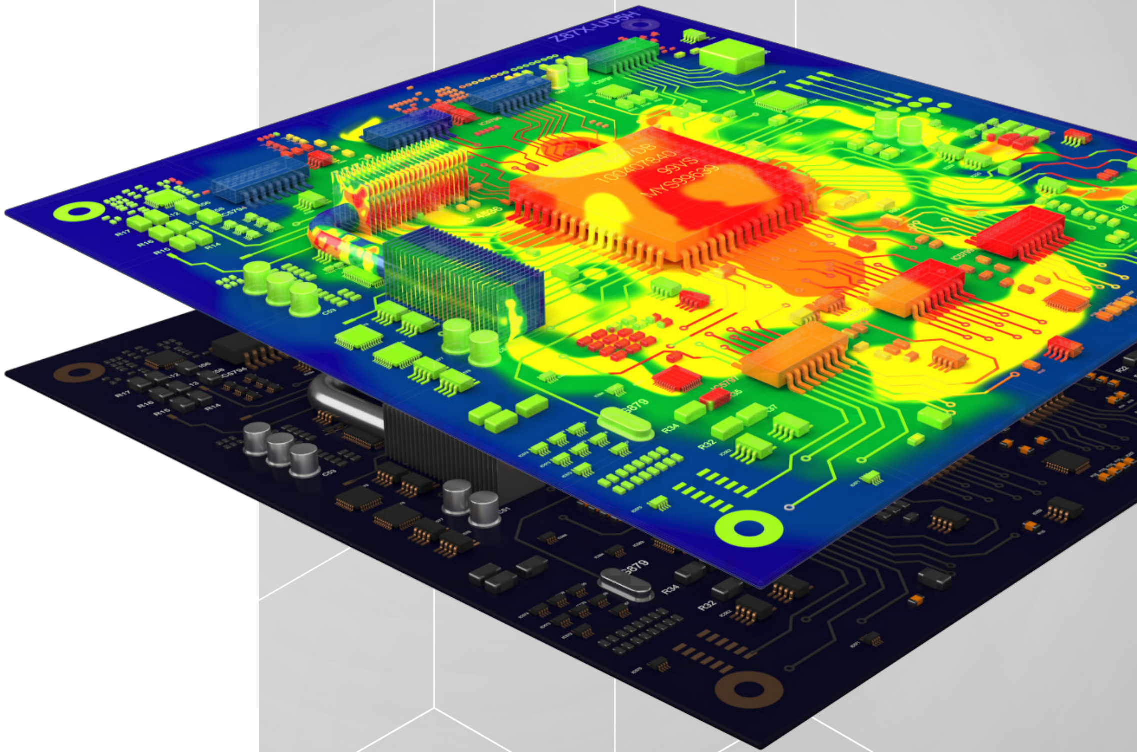
What can we do to make the design power aware? Since the power-aware requirement describes power and signal coupling, can we use a formula-based estimation to set up rules to check power and signal coupling? Because crosstalk estimation restricts the application to two parallel conductors only, it leaves estimating signal and power coupling out of the question. The reason is that the majority of power nets have large metal shapes, so there is no analytical solution to calculate the coupling between shapes and traces.

Read more



# THERMAL ANALYSIS

Thermal analysis looks at the impact of power across components of the electrical device. In systems, this means measuring heat flow and radiation between parts of the device and transients to inform the steady-state temperature simulation, which involves multiphysics simulations, finite element analysis (FEA), and computational fluid dynamics (CFD).



# Thermal Solvers Resources

## Contact and Heat Transfer Rates with Integrated Circuit Thermal Pads

The bulk production of integrated circuits leaves imperfect surfaces and micro-sized air gaps in the IC surface. The crests and troughs on the IC surface make its coupling with heat sinks improper and slows down the heat dissipation. To avoid the thermal conduction failures from uneven IC surfaces, Integrated circuit thermal pads and thermal pastes are used. They are thermally conductive materials sandwiched between the semiconductor package and the heat sink. The thermal conductivity of thermal pads and thermal pastes is greater than air and less than metal.

Read more

## The Basics of Steady-State Heat Transfer Analysis

A multiphysics field solver can be used to determine the steady-state temperature distribution in your PCB or IC package quite easily. These types of simulation utilities can include airflow, due to a fan or natural convection, in addition to conduction. A steady-state thermal simulation proceeds quite quickly compared to a transient thermal simulation in the same system. To determine the distribution of the heat transfer rate throughout the system, you need to use the following high-level procedure.

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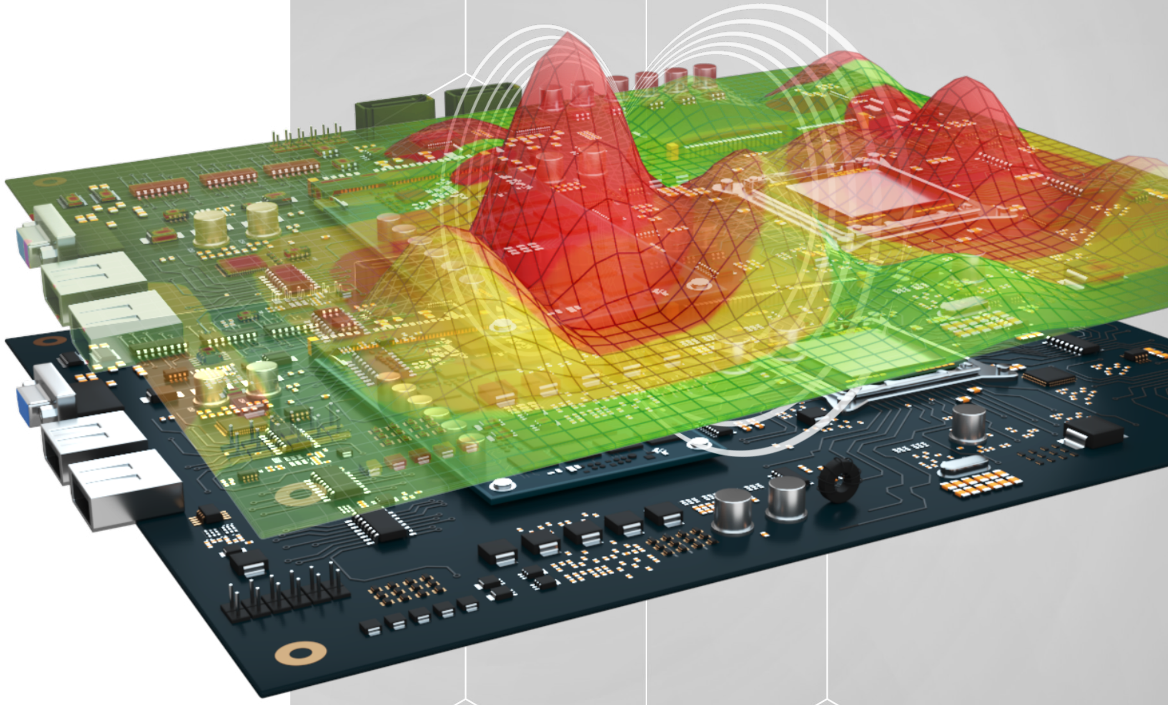
## Rising to Meet the Thermal Challenge

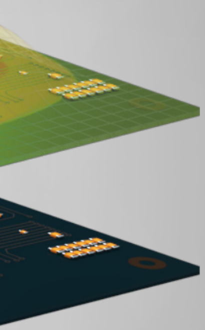
Traditional approaches to solving FEA problems have been unsuccessful in scaling up to the analysis requirements of today's advanced systems because of speed, capacity, and compute limitations. Speed limits were imposed by tools that were unable to distribute simulations over more than a dozen or so servers without running into the scaling limits typical of traditional simulation methods. Capacity limits were hit when the tools required too large of a memory footprint, so objects in a system had to be simulated separately to fit into server memory. Compute limits were imposed by the financial impracticality of purchasing enough superfast servers with vast amounts of RAM to run these traditional tools.

Read more

# ELECTROMAGNETIC ANALYSIS

EM analysis models the coupling of electric and magnetic fields primarily using Maxwell's equations. Between Faraday's Law, Lorentz Law of Force, Gauss Law, and Helmholtz equations, analysis tools determine wave propagation, waveguides, scattering, absorption, and oscillating fields which, involves looking at power and transmission losses and frequency disruption.





# EM Simulation Resources

## RF Antenna Design and Layout Tips for PCBs

Isolation structures are generally placed between RF elements to block noise coupling and power exchange between them. Determining which isolation structure should be used to ensure RF antenna SI is a complex design problem that has been thoroughly researched. Suppose the designer is not an expert at elliptical integrals. In that case, they will need to rely on an EM field solver to determine how these structures affect feedline/RF antenna impedance, as well as the level of isolation these structures provide.

Read more

## Aerospace or Automotive Radar Systems Design

Pulse-Doppler (PD) radars produce velocity data by reflecting a microwave signal from a given target and analyzing how the frequency of the returned signal has shifted due to the object's motion. This variation in frequency provides the radial component of a target's velocity relative to the radar. The radar determines the frequency shift by measuring the phase change that occurs in the EM pulse over a series of pulses. By measuring the Doppler rate, the radar is able to determine the relative velocity of all objects returning echoes to the radar system, whether planes, vehicles, or ground features.

Read more

## Fast and Simple Rigid-Flex PCB Bending EM Analysis

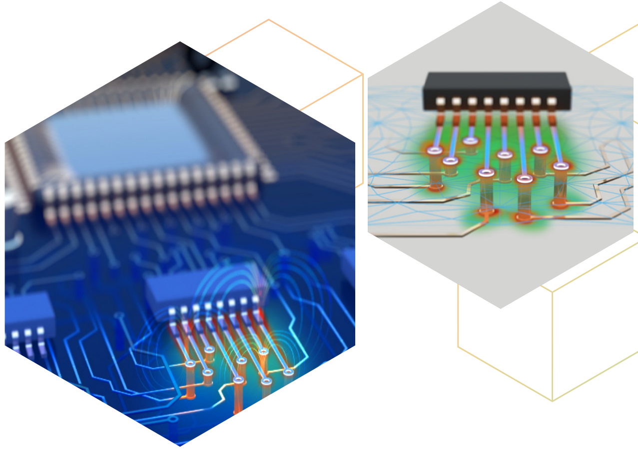
There exists a typical workflow for any PCB simulation where the flat PCB geometry is transferred into the 3D EM tool. This includes the layer stack-up information (material properties) and component definitions for resistors, capacitors, inductors, and chip/packages. The advantage of this typical ECAD flow is the automatic creation of ports based on the component definitions imported from the layout tool.

Read more

## Microstrip Antenna Design and EM Simulation

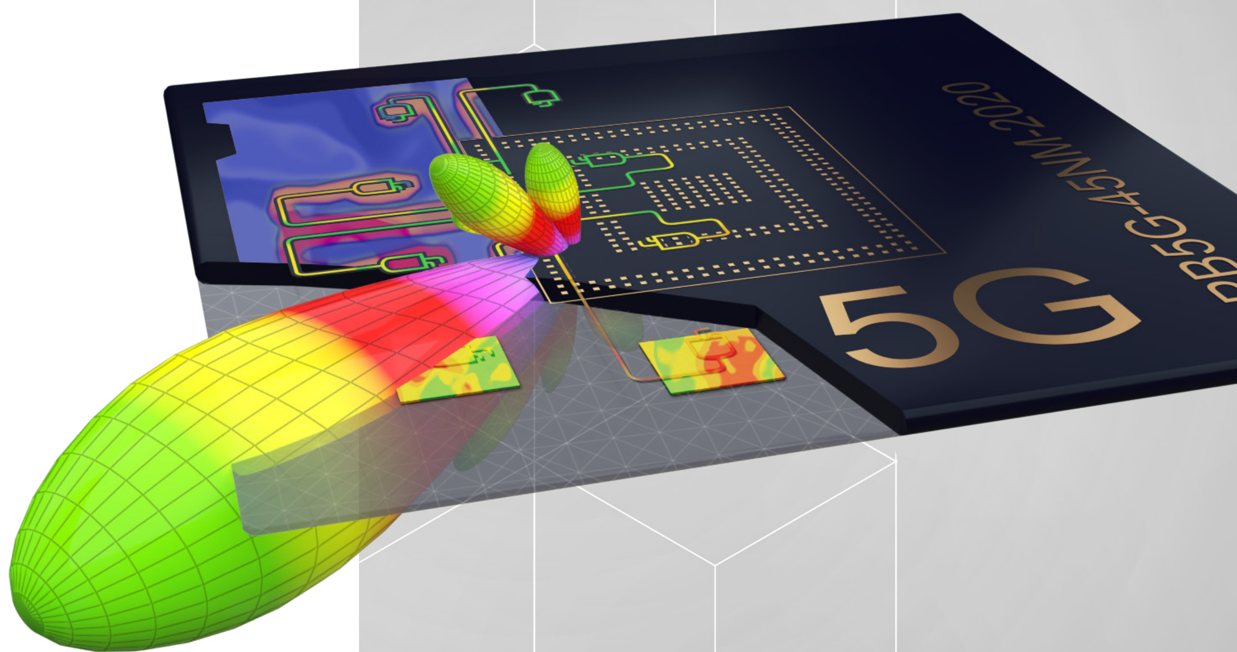
A significant performance element in communication and radar systems, as well as wireless devices, is the antenna, which may be defined as a transducer between a guided electromagnetic (EM) wave propagating along a transmission line and an EM wave propagating in an unbounded medium (usually free space) or vice-versa. The antenna is required to transmit or receive EM energy with directional and polarization properties suitable for the intended application.

Read more



# RF/MICROWAVE DESIGN

While RF/microwave is not a specific type of analysis, there are specific analytic functions for RF/microwave designs. Primary analytical functions include harmonic balance (HB) simulations in the frequency domain, transient analysis in the time domain, noise analysis, and array transmissions.



# RF/Microwave Design Resources

## Using an Infrared Phototransistor in Electro-Optics

Just like photodiodes, a phototransistor can be integrated into a 1D or 2D array, which is useful in a number of applications. A 2D phototransistor array is basically a CMOS sensor, which uses MOS phototransistors. To form images, the detector needs to be coupled to some optical and mechanical components, which will help direct and focus light onto the sensor.

[Read more]

## Analyze Microwave Integrated Circuits (MIC) with Lumped Element Models

As the microstrip width is comparable to the wavelength of the microwave, any dimensional change in the strip causes variations in the electric and magnetic field associated with it. The changes in the width of the microstrip transmission line are generally termed as discontinuities.

[Read more]

## Raising the Levels of 5G Millimeter-Wave Signals

Compared to 3G wireless networks, 4G networks achieved performance improvements by means of enhanced spectrum efficiency, typically through the use of advanced modulation and coding techniques. Antenna techniques such as multiple-input, multiple-output (MIMO) schemes also helped increased spectrum efficiency in 4G systems as well as the use of novel radio technologies, such as orthogonal frequency division multiplexing (OFDM), to make better use of the available spectrum.

[Read more]

## Predicting Critical Metrics for Wireless RF Links

What's happening to this link that is causing the discrepancy? The math was done correctly and entered into the spreadsheet, so the expectation is that the NF should be 4.68dB. The design was built, and the analysis is done, but the AWR VSS simulation does not return anything close to 4.6dB. Why? The AWR VSS tool is much more sophisticated than a spreadsheet and has many more capabilities and measurements, so the next step would be to try performing further analysis of the LO link.

[Read more]

## Conquer Radio Frequency

Transmission lines, as most of you will know, are all about delivering power from a generator to a load. The way we achieve maximum power transfer and maximum efficiency is, however, very different for high and low-frequency circuits. This is because, while at low frequencies (e.g. 50Hz), power is conveyed predominantly as voltage and current and is' quasi' electrostatic in a field form. At high frequencies, the power is predominantly conveyed as 'electromagnetic fields.'

[Read more]