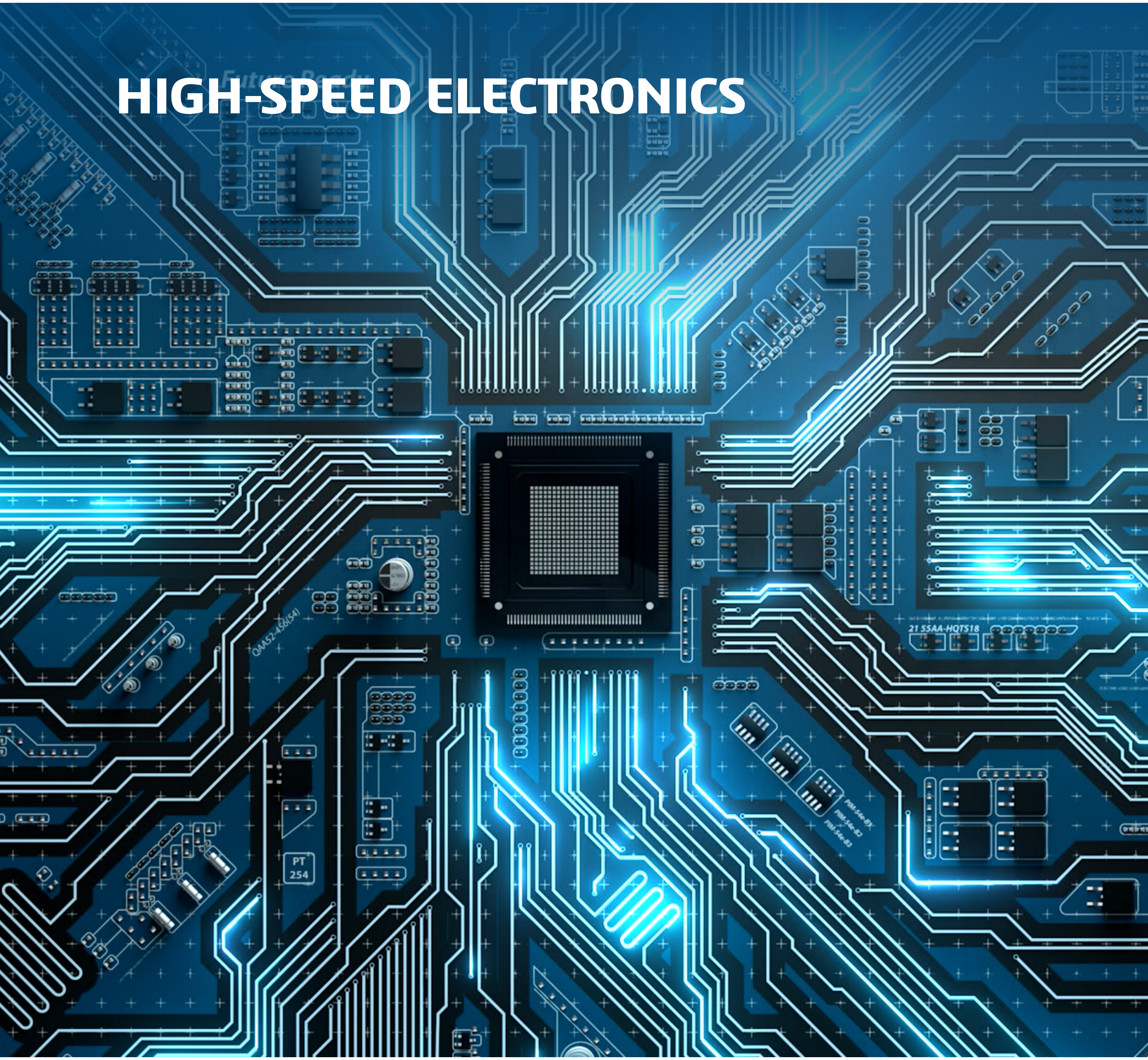
SIMULIA

3DEXPERIENCE

HIGH-SPEED ELECTRONICS



DASSAULT SYSTEMES

ELECTRONICS RUN OUR LIVES

The range of consumer electronics is wider than ever.

Electronics systems and networks power our businesses and consume our leisure time. At home, electronics enable our hand-held and wearable devices, our TVs, games and music systems. Electronics power our appliances, white goods, lighting, heating and internet. All these connected IoT devices and smart systems are increasing our home electronics footprint, resulting in a proliferation of the large datacenters that power our everyday apps and services.

When we travel, no matter the mode of transport, electronics and connected systems play an increasingly important role. Innovation in today's cars is driven primarily by electronics systems, and it's projected that 50% of the cost of an automobile[1] will be the electronics and associated systems by 2030. Mandates for electric vehicles and for more sustainable and renewable energy production will only increase the requirements for electronic systems over the next decade.

Data centers, smart factories and other industrial electronics require huge quantities of reliable, high-performance and interconnected devices.

At the office and in industry and manufacturing, electronics play a critical role, and it's hard to imagine any business operating without a computer or internet connection. Today's manufacturers rely heavily on complex electronic systems for production and communication and industry in general uses a diverse mix of on-premise and cloud computing and networking for a wide variety of business needs.

All of these applications and systems require and rely on the high-speed movement of data, albeit at different scales. **From the inside workings of a smartphone, a home network or factory to an internet connection spanning continents, there are rapid increases in the volume and speed that data is moved around.** And it's not just raw speed that's important. The reliability and inherent latency (delay) of connections is becoming critical.

The world relies on high-speed and high-volume data. Electronic systems have to constantly keep up and adapt to that demand.

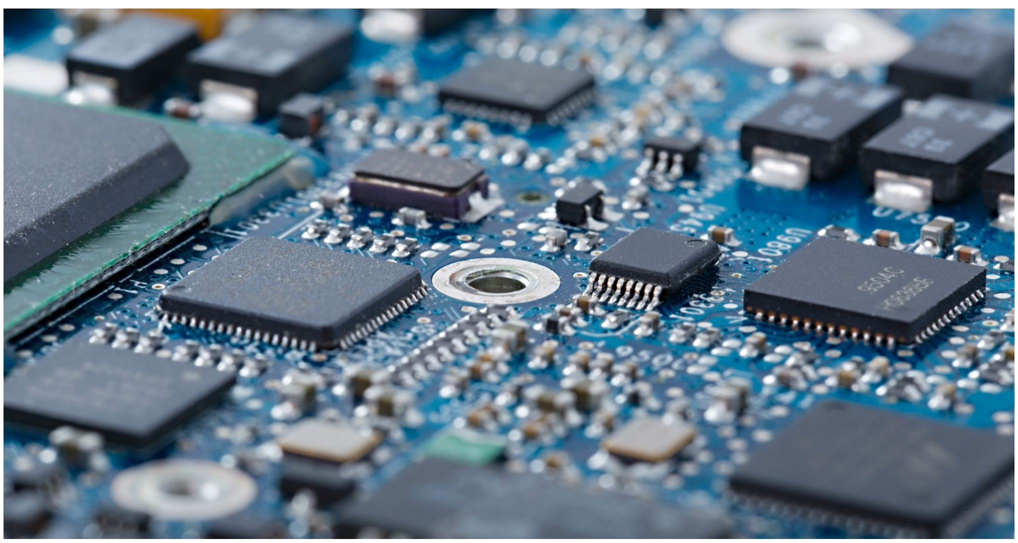
WHAT DO WE MEAN BY ELECTRONICS?

We all have an idea of what electronics is – from a nest of wires in the back of an old TV to the minimal and modular look of the inside of a modern smartphone. We might expect that semiconductors or integrated circuits are involved. We know that electronics perform a variety of functions such as data processing, computing, driving a display, mechanical control, amplification, network communications and so on.

So what constitutes electronics, and what do the various parts do?

Basic Components: These are the building blocks of a functional electronic circuit. Active components such as transistors require a power source and provide a switching, or amplifying function. Passive components such as resistors, capacitors and inductors require no power source and they can only dissipate or store power. There are few types of basic component, but in combination and in large numbers they can offer advanced analog (amplifier) and digital (logic) functionality.

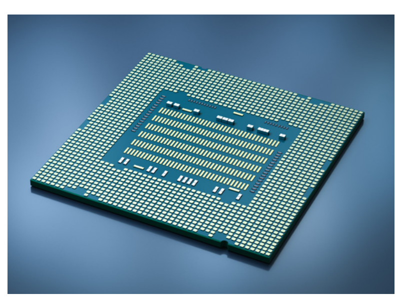
Printed Circuit Board (PCB): This was one of the earliest innovations and provided a simple and repeatable method of mounting and connecting smaller electronic components such as resistors and transistors to create an electronic circuit. The metal connections (or traces) are etched onto the board and the components mounted through holes in the board and soldered to pads connected to the traces. Connectors at the edge of the PCB provide connections to the rest of the system.



The increasing density and data rate of modern PCBs requires careful control of interference and signal noise.

PCBs these days support multi-pin integrated circuits and the routing through the PCB can be extremely complex, often requiring multiple layers and vias to facilitate the required connections. Signals and power distribution can take tortuous routes across the board in order to get where they are required. The system end-to-end signal and power channels can be even more complex as they travel through motherboards and subsidiary daughter boards and various types of interconnect.

Semiconductors: Semiconductors are at the heart of modern electronics and perform the processing, logic and memory functions required in modern applications. The processing core, or die, is built up from a silicon wafer to create highly miniaturized versions of the basic components mentioned above. A modern die comprises billions of transistors and components at a few nanometers scale. The die is bonded to a package and encapsulated in protective plastic and this is the typical flat black chip that we are familiar with. More



Much of a chip package is given over to the hundreds of pins and complex network of wires that connect the nanoscale silicon circuit to the rest of the device.

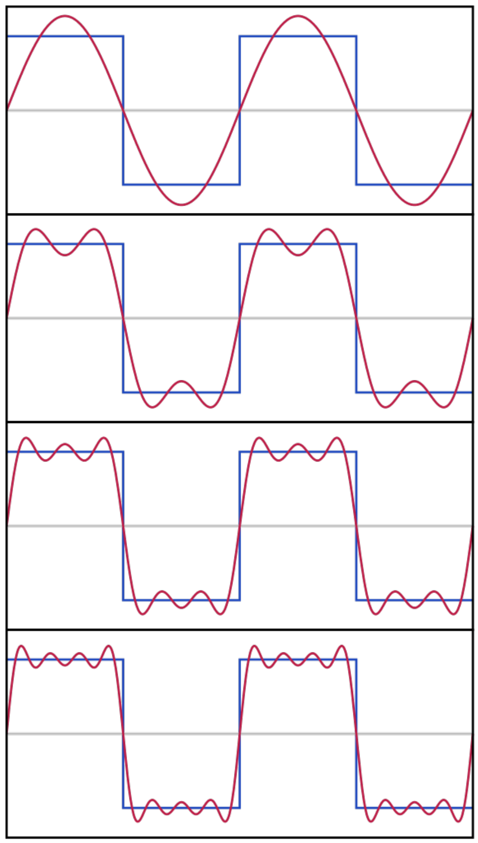
recently semiconductors are starting to exploit the third dimension by stacking dies vertically within a single package. This is enabling even higher levels of performance and integration of previously peripheral functions such as memory and graphics processing.

WHAT DO WE MEAN BY HIGH SPEED?

Let's start by comparing analog and digital electronics.

In analog electronics, we have a varying signal level and we often talk about a frequency of operation. Analog electronics are used, for example, in a signal amplifier or RFIC (radio frequency integrated circuit) found in the front end of a smartphone.

In digital electronics, we refer to discrete on or off states, 1s or 0s, as used in a computer or the back-end operation of a smartphone. Digital electronics is just a discrete, 2-level form of analog electronics, but has many advantages in terms of noise rejection, logic operations, security, transmission and encoding, as, even when the signal is partially degraded, you can still tell the difference between a 0 and a 1. Analog radio signals are used as the wireless carrier of digital information for systems such as WiFi or modern cellular.



Digital pulses as a square wave produced by adding sine waves at different frequencies. Including higher frequency components shortens the rise time, improving bandwidth and signal integrity[2].

As digital signals are analog at their core, they have an on and off state and critically, a rise and fall time between those 2 states. The faster we want to transmit data, the faster that rise and fall time will need to be. Through Fourier series, those transitions comprise a series of discrete analog frequencies and the faster the rise time, the higher the frequencies required. For example a 10 Gb/s wired data Ethernet transmission comprises frequencies up to 25 Ghz if we are to resolve the rise time and keep the digital signal intact. This means that the connection or data channel has to be able to support and transmit a wide bandwidth extending to that frequency.

So high speed or high data rate electronics is really broadband high-frequency electronics. Those high frequencies can create numerous design challenges, but the good news is that high-frequency electromagnetics can be simulated and solutions can be found very early in the design process.

STATE OF THE ART

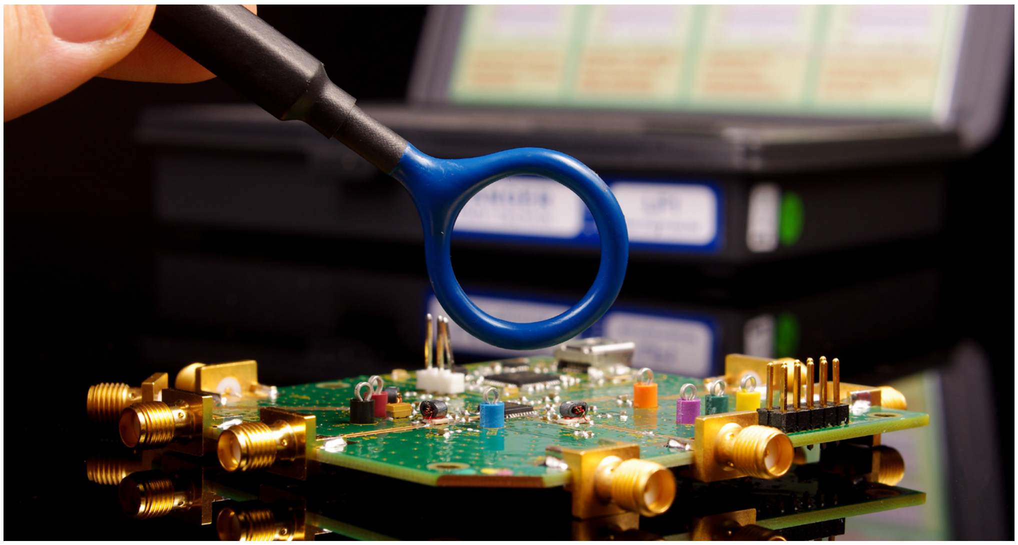
To understand the state of the art in electronics, you can open up a modern smartphone or view an online teardown. You'll see very few, if any, through-hole components, but you will see dense PCBs with very neatly mounted semiconductor packages and surface mount chip resistors and capacitors providing a variety of functions. You may see some flex cable connecting the screen or peripheral components such as the camera, antennas and battery. Although this can look like an exercise in system integration, many of the challenges around designing such a device are due to the high-density, high data rate requirements and lack of space. This combination can give rise to interference and thermal issues and difficulty in routing power and high speed data effectively. If not addressed, this can adversely affect the operation and end-user experience.

MODERN DESIGN CHALLENGES

Apart from advanced computing tasks such as simulation, machine learning or autonomous driving, challenges are rarely about lack of processing power. Most PC and smartphone owners use only a small fraction of the processing power available to them.

The challenges today come from the early-stage design of an electronic system to ensure its long-term reliability, robustness and performance specifications are met and that geo compliance and certifications are achieved. We'll have a look at these challenges in the next sections and offer a solution.

CHALLENGE—ELECTROMAGNETIC COMPATIBILITY AND INTERFERENCE



EMC testing to detect electromagnetic emissions from a PCB.

While a modern device often has various antennas to communicate high-speed data, it's less well known that the device can radiate unwanted electromagnetic noise externally and between systems internally. This unwanted noise can be caused by higher harmonics or intermodulation products from the intentional transmitters or by high-speed data flowing on traces or flex circuits which behave like unintentional antennas due to their high-frequency nature.

External or "radiated emissions" must be controlled sufficiently to meet local geo requirements and a device can fail certification if the compliance regulations are not met.

Internal systems can interfere with each other (known as "de-sense") by similar means, particularly where sensitive systems are in close proximity to higher power or high-speed systems. For example GPS antennas are typically very sensitive due to the lower power involved. If the connection to this antenna is placed without shielding close to a high-speed data route from a 4K camera for example, the GPS may lose sensitivity and fail to work correctly.

Finally, devices may be susceptible to outside interference affecting the correct functioning of the electronics. This could be a problem in the vicinity of other devices or other noisy electromagnetic environments and can cause a device or system to perform poorly. The electromagnetic spectrum is heavily exploited and shielding and high-quality filtering may be required to ensure rejection of this external noise.

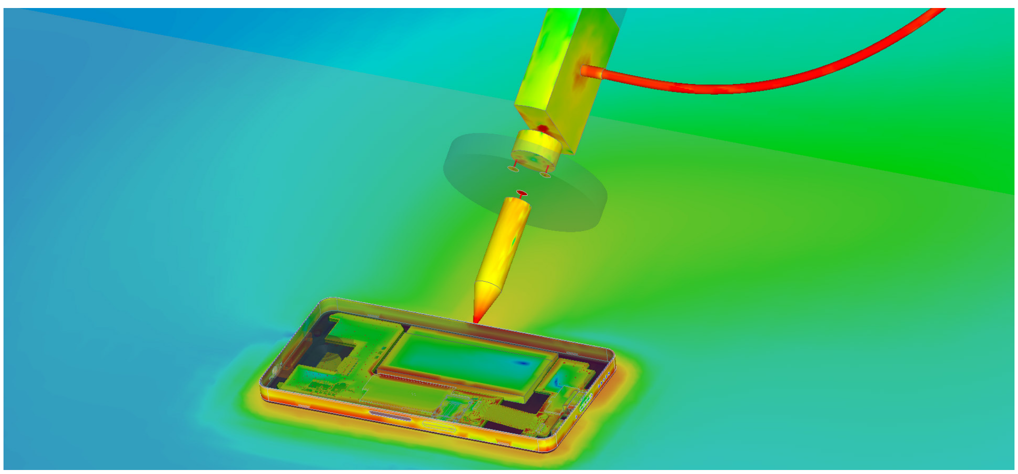
CHALLENGE—SIGNAL AND POWER INTEGRITY

Processing speeds and external communication speeds are constantly increasing. The advent of 5G has given rise to a significant increase in data speed requirements and data must be able to travel through a channel without degradation so that it can be recognized at the receiving end. A channel can comprise a connector or antenna, a flex circuit, one or more PCBs and associated interconnects and an integrated circuit. Within the PCB, the data may travel through various angles horizontally and 90 degrees between layers vertically. Each of the transition points in a channel has the potential to cause reflections and radiation, degrading or distorting the signal and the cumulative effect can be such that the signal is unrecognizable by the time it reaches the receiver. The higher the data rate of the channel, the higher the frequency content and the worse the potential effect. Proximity to other operating data lines or power lines may also have an impact.

Similarly, power distribution networks (PDNs) must be designed so that power is routed at the right level and at the right time to the components that need it. Degradation in the voltage level or bad timing may cause incorrect operation. PDNs can be noisy due to switching effects at the power source and destination and these transients have to be mitigated – often by reducing the PDN impedance with decoupling capacitors. The capacitors used also act as local charge reservoirs maintaining the required power levels even under switching conditions. However, introducing too many discrete components can be expensive, so optimization is required.

CHALLENGE—ELECTROSTATIC DISCHARGE (ESD)

ESD is an everyday occurrence typically caused by a combination of dry air, a nylon carpet and a door handle. A person builds up charge by walking on the carpet, which can rapidly discharge with a spark when their finger approaches a metal door handle. This is generally harmless, but electronics can be very susceptible to this type of high voltage discharge. For example, if your phone is in your hand it could potentially spark to the door handle as you approach.
Electronics manufacturers pay close attention to this effect and build in protection measures which they test for compliance using laboratory standard discharge devices. ESD can be simulated using an ESD generator model, enabling performance to be assessed prior to fabrication and compliance testing.



Replicating an ESD test virtually can identify potential issues long before manufacturing a physical prototype.

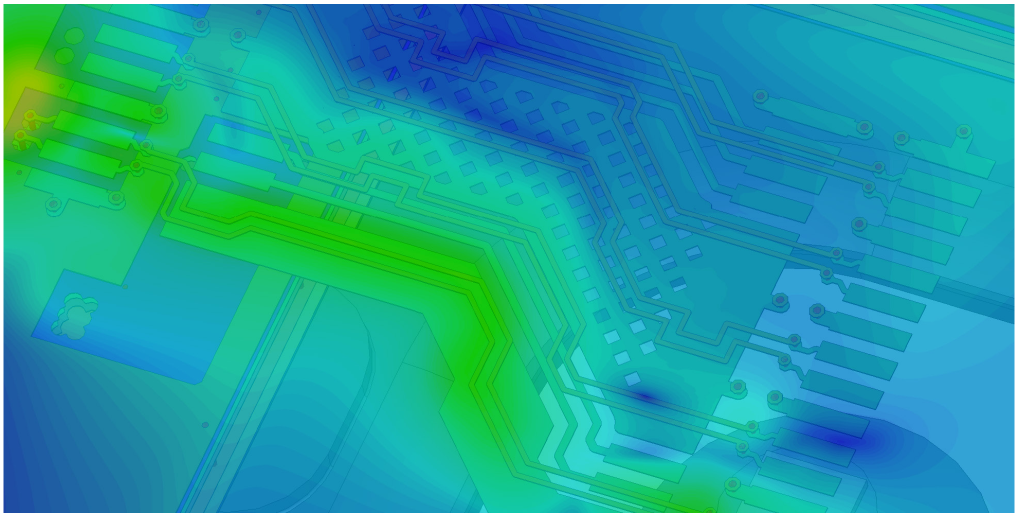
SOLUTION—EARLY-STAGE DESIGN AND SIMULATION

All of the above effects can be disastrous for a product in late-stage design or production. They are often very difficult to fix and, even if the problem can be fixed, the solution may introduce unnecessary weight, material and higher costs per unit.

Fortunately, early-stage solutions are available via design rule checking and 2D and 3D physics-based simulation. A virtual twin of the electronics design can be created and all of the above effects can be tested through a series of virtual tests. Key Performance Indicators can be collected for each virtual test and compared with built-in industry standards.

SIMULIA CST Studio Suite technology is the ideal solution for early-stage pre-compliance testing. It has been validated over many years and uses direct transient simulation to simulate all of these transient electronic effects. Advanced pre- and post-processing allow straightforward CAD and ECAD integration and KPI generation. Fully-validated contact and non-contact discharge generators are available for virtual ESD testing.

Full integration into the Dassault Systemes **3D**EXPERIENCE® platform allows full data management and traceability of CAD data and results, as well as easy cross-department collaboration.



Simulation models and visualizes how electric currents and fields flow through electronics, helping users to not just find problems, but understand and resolve them.

1 https://www.statista.com/statistics/277931/automotive-electronics-cost-as-a-share-of-total-car-cost-worldwide/

2 https://commons.wikimedia.org/wiki/File:Fourier_Series.svg (public domain)

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