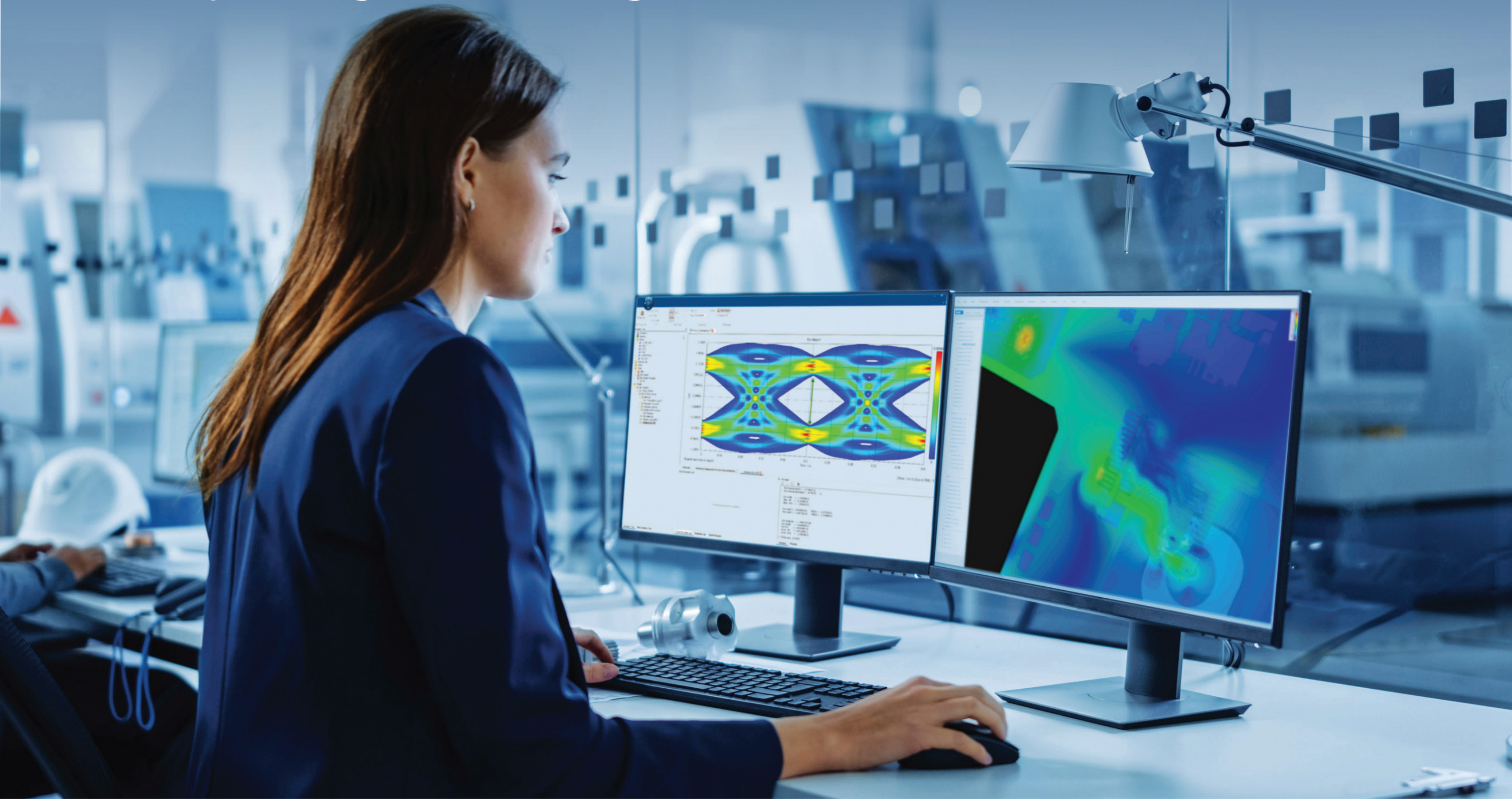
HIGH-TECH

SIMULATING THE VIRTUAL TWIN

Empowering "First-Time-Right" Electronic Product Innovation



As consumers, workers and citizens, we rely heavily on electronic products, which can be found everywhere. With increasing complexity and communication speed, designers and engineers must now modernize their processes by leveraging the full scope of simulation.

Electronics refers to a combination of integrated circuits (IC) placed on a printed circuit board (PCB) to process, for example, sensor signals or to control actuators and motors. Since signal processing is critical for the final device, there is a need for a highly accurate PCB design, which can be achieved with physical simulation.

An optimally designed PCB ensures that the IC receives the right power at the right time (power integrity) and reduces the signal distortion when propagated through the board (signal integrity). Higher component integration and an increase in communication speed can cause an IC to emit electromagnetic signals, which can interfere with other ICs or even propagate outside the board.

Any radiation into other devices or cross-coupling within the PCB itself can adversely affect the reliability of the electronics and must be avoided. For this reason, electromagnetic compatibility and interference (EMC/EMI) are the most important issues that PCB designers have to address today to avoid the risk of last-minute failure.

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DASSAULT SYSTEMES

HOW TO BREAK THE COMPLEXITY AND SIMPLIFY COLLABORATION?

The complexity of PCBs is increasing. The number of components is growing, while the space to place these components is shrinking. Furthermore, PCBs are no longer rigid and can be printed on flexible substrates to save space or fit adjustable connections.

As a result, PCB development is – as in most products – a team effort. The electronic engineer collects the requirements, defines the schematic and validates its functionality with circuit simulation. The PCB designer (or ECAD designer) is responsible for routing signal traces and placement of components in layout, while the MCAD designer creates housing and fixtures. Throughout the entire process, the team usually refers to the electromagnetics engineer for EMC/EMI assessment, using physical simulation.

To support these tasks, Dassault Systémes® offers a collaborative platform, where everyone can work on the same dataset. This eliminates the time-consuming and error-prone process of exporting and importing data and using models from disconnected file servers.

The ECAD designer can start in the "home" environment by using Cadence® Allegro® or Altium Designer®, for example. This data is directly uploaded on the **3D**EXPERIENCE® platform through a connector, without having to leave the ECAD tool (see Figure 2). The electromagnetics engineer can then easily find the PCB on the platform and directly open it for simulation (Figure 3).

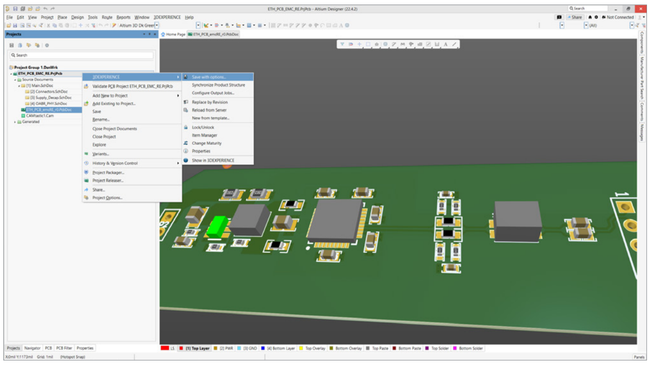


Figure 2: Connection of the ECAD tool to the **3D**EXPERIENCE platform

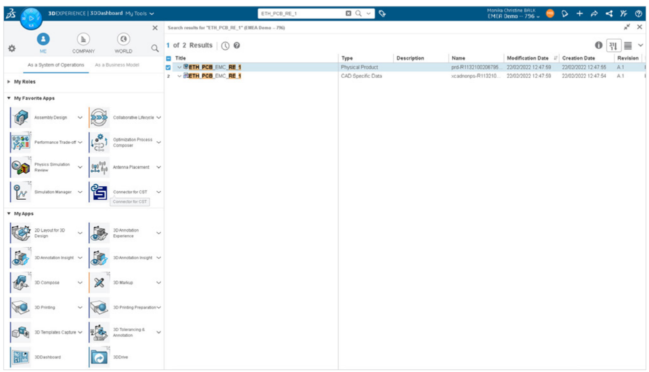


Figure 3: Access to common data set within the **3D**EXPERIENCE platform

The platform will load the board right into the appropriate application from SIMULIA CST Studio Suite®, which is CST PCB Studio, a dedicated tool for signal and power integrity analysis of PCBs. The board will automatically be populated with components. To describe the components' electromagnetic behavior (resistors, capacitors, inductors and more), simulation analysts can either specify them manually, load them via a database or load them from the **3D**EXPERIENCE platform.

In any case, it is possible to store and manage the used components, including their electromagnetic behavior, on the **3D**EXPERIENCE platform (see Figure 4). This will help speed up the simulation setup for subsequent verification tasks.

To maintain a single source of truth, the complete setup (and simulated) model is also stored on the **3D**EXPERIENCE platform, from where it can be loaded to resimulate or modify the simulation settings. Any modification can be incorporated into a new version of the simulation object that is under revision control.

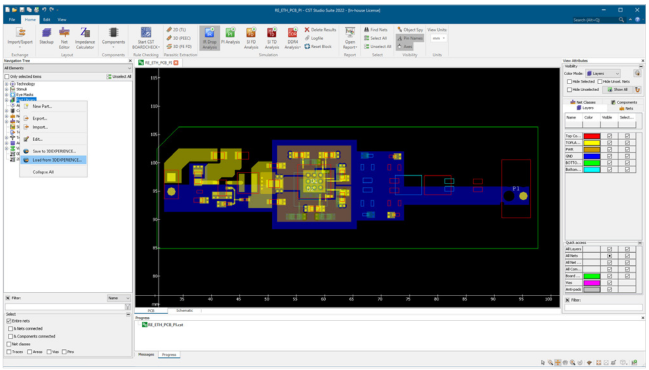


Figure 4: Managing component models on the **3D**EXPERIENCE platform

VALIDATING THE PCB WITH THE VIRTUAL TWIN

The verification and validation of the PCB can take place on different levels of abstraction. The quickest check is validating the layout against predefined design rules. For example, slot-crossing nets or nets near the edges of the reference planes are unfavorable and can effectively act as antennas (see Figure 5).

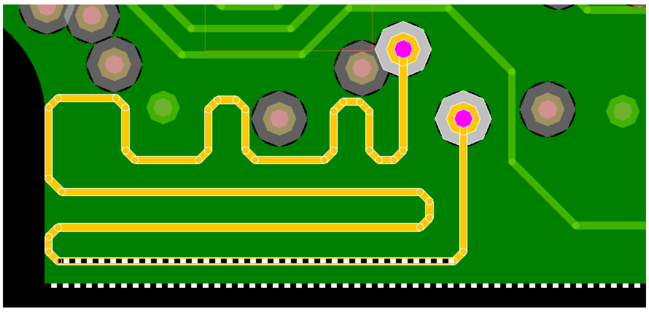


Figure 5: CST boardcheck

Due to the complexity of modern PCBs, performing manual checks is often not feasible. Dassault Systémes offers a PCB design rules-checker (CST boardcheck) that can perform an automatized check. The checking criteria include preset rules that the user can further customize.

Another important point to verify is the power integrity of the PCB. This requires the power delivery network (PDN) to supply a constant current to active devices on the board (e.g. chip), even at very high switching frequencies. Furthermore, the PDN is responsible for providing a constant reference for active devices. It also should not produce unwanted emissions. CST PCB Studio offers tools to tackle all these tasks.

Figure 6 shows an exemplary DC IR-drop analysis, which tells users how well the power supply works for eventual consumers on the board. Depending on the tolerance of the consumer, the tool provides direct visual feedback about potential consumer failures (see Figure 7).

The analysis is very quick and it is based on a Partial Element Equivalent Circuit (PEEC) method, which divides a selected 3D structure into a mesh of short conductive segments and small conductive and dielectric areas.

The analysis can also be extended to a frequency domain, which provides the user with the input impedance seen from the active device. With this information, users can either manually place capacitors to improve the power integrity behavior or use the decap optimization tool to reduce the overall impedance, while simultaneously minimizing the cost. However, this analysis is not performed in the context of this paper.

While the power consumption of modern electronics keeps increasing, the size of electronics keeps decreasing. Both of these factors lead to increased power density, which makes the thermal management of electronics a very important topic.

Overheating can destroy components and lead to deformation, delamination or melting of connections. In addition, the performance of devices placed close to a heat source may change - for example a temperature-sensitive sensor placed close to an amplifier.

Also, thermal design requires effective simulation tools. Dassault Systèmes offers such a tool that is accurate and easy to use. Based on a previously simulated power integrity (IR-Drop) analysis, a thermal simulation can be set up with literally one to two clicks. This automation uses geometry with already simulated components and heat losses on traces (see Figures 8 and 9).

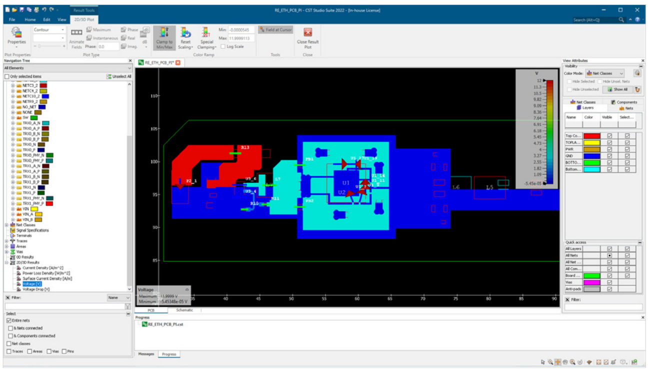


Figure 6: DC IR-drop voltage

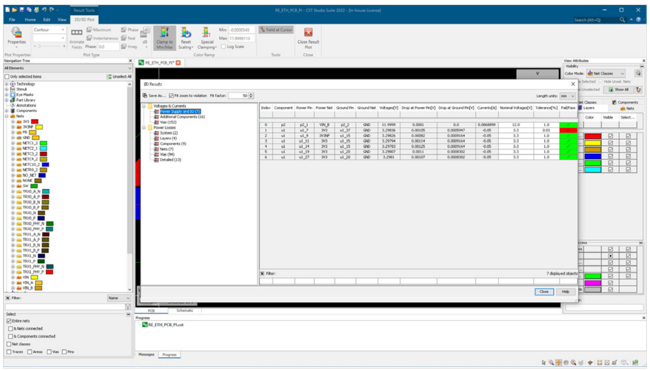


Figure 7: Power supply check

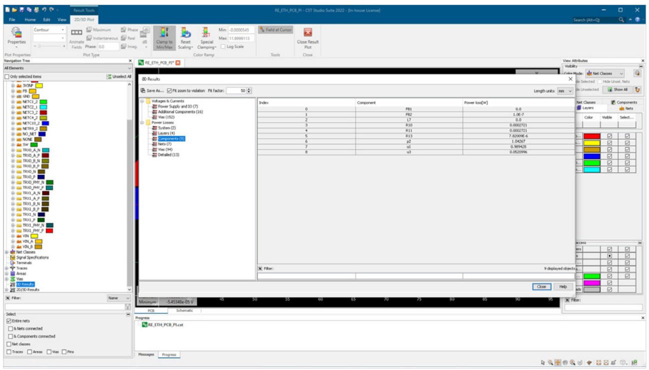


Figure 8: Component losses

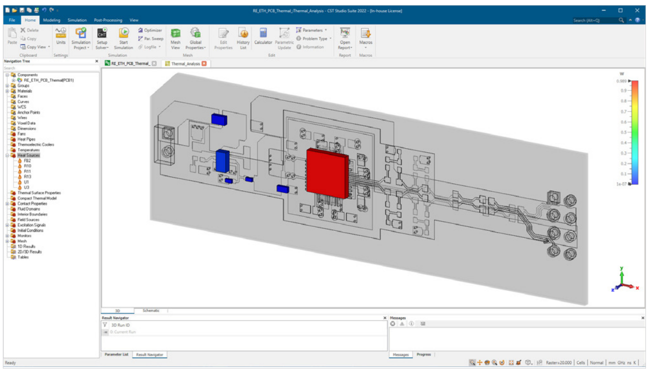


Figure 9: An automatically generated thermal model based on previously simulated heat losses in components and on traces

A conjugate heat transfer (CFD-based) solver then calculates temperatures for either a situation with only natural convection (as shown in Figure 10) or with forced convection by fans or liquid cooling. In our example, the chip would become quite hot and would need additional cooling measures. Just adding a simple heat sink would already reduce the temperature by 13 degrees (see Figure 11). The simulation facilitates optimization of the heat sink or additional cooling measures without any physical prototype. Insights into the device will also increase the base knowledge for further developments.

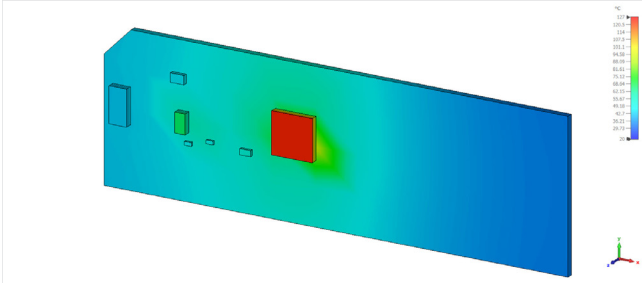


Figure 10: Temperature distribution on the PCB with natural convection only (maximum at 127°C)

For every communication, it is important for signals sent from the transmitter, via a communication channel, to be received at optimal quality at the receiver. To enable the assessment of channel performance, the simulation model consists of a PCB attached to both sides of the twisted pair cable (as shown in Figure 12). The PCB can act simultaneously as receiver and transmitter, therefore the same PCB is used at each cable end.

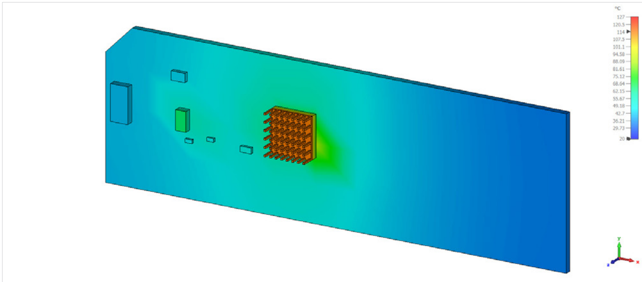


Figure 11: Temperature distribution on the PCB with an added heat sink (maximum at 114°C)

Presently, a design rules-checker, as well as signal and power integrity simulations at the PCB level, are commonly offered. However, the ultimate purpose of the printed circuit board designer is to prevent malfunction once it is mounted. This requires a more holistic view and a simulation assessment of the overall ECAD/MCAD system under working conditions. Through simulation, potential product failures can be detected early in the design phase, enabling the designer to apply countermeasures.

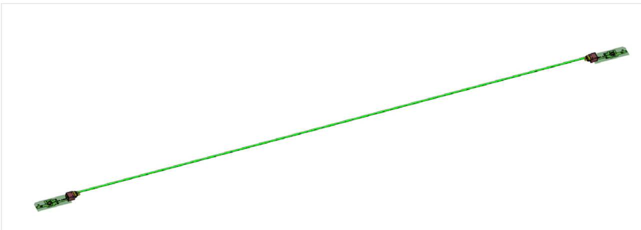


Figure 12: The PCB under test is attached to both sides of a twisted pair cable

Let us consider an Automotive Ethernet application. This is a specific communication technology, widely used in the automotive area, due to the low cost and weight of its communication equipment. In contrast to the Standard Ethernet, Automotive Ethernet uses a single, unshielded copper twisted-pair cable as the communication channel. For example, the data sent via the Ethernet connection is processed from a camera or a sensor.

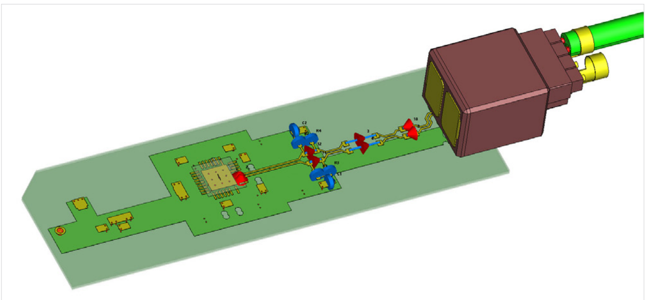


Figure 13: Zoom into the connection of PCB to cable

The electromagnetics engineer needs to perform the signal integrity analysis for the given ECAD/MCAD system. The excitation of the signals takes place at the ports attached to the chip (see Figure 13) in either common mode (both ports excited with the same amplitude and phase) or differential mode (one port excited with a 180° phase difference).

For good signal integrity, the excitation of one mode at the transmitter should not result in the occurrence of the other mode at the receiver.

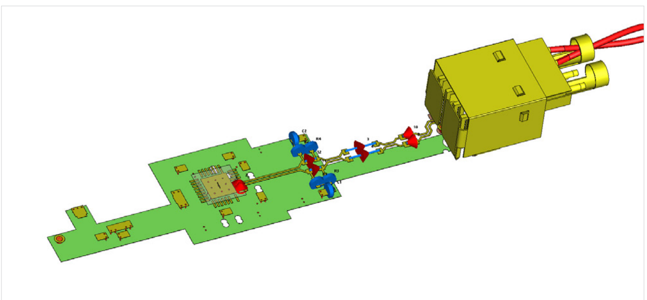


Figure 14. Zoom into the connection of PCB to cable, showing only electrical conductors

The simulation of the 3D model will reveal signal transmission quality and eventual cross-coupling. The actual 3D model is exactly as shown in Figure 12 (PCB-Cable-PCB), where the detailed PCB geometry is shown in Figures 13 and 14 and the length of the twisted pair cable is one meter. However, PCB traces unrelated to the signal transmission are neglected for this analysis. This can be easily simulated using a FEM solver in the Frequency Domain.

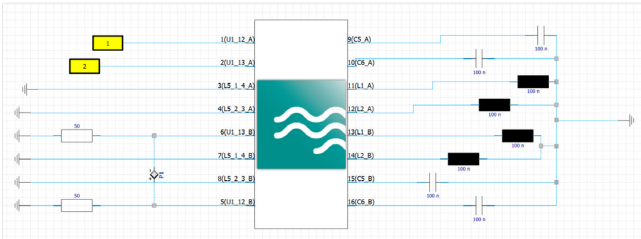


Figure 15: Schematic representation of the simulation model with the 3D block (middle) and circuit elements

To be more efficient, PCB components are represented in 3D by placeholders and added with their exact values in a schematic tool, which is fully coupled to the 3D simulator (see Figure 15). This approach allows quick tuning of the component values in the circuit simulator without re-running the 3D simulation. The probe (P1, shown in Figure 15) represents the connections at the receiver.

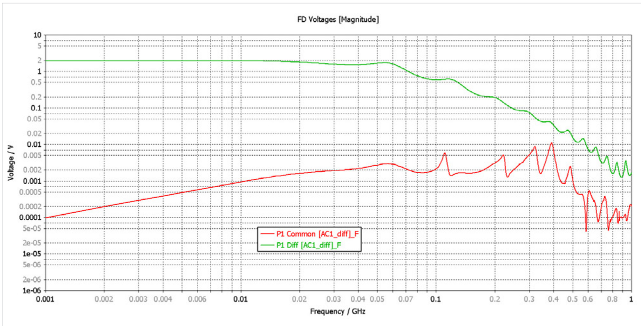
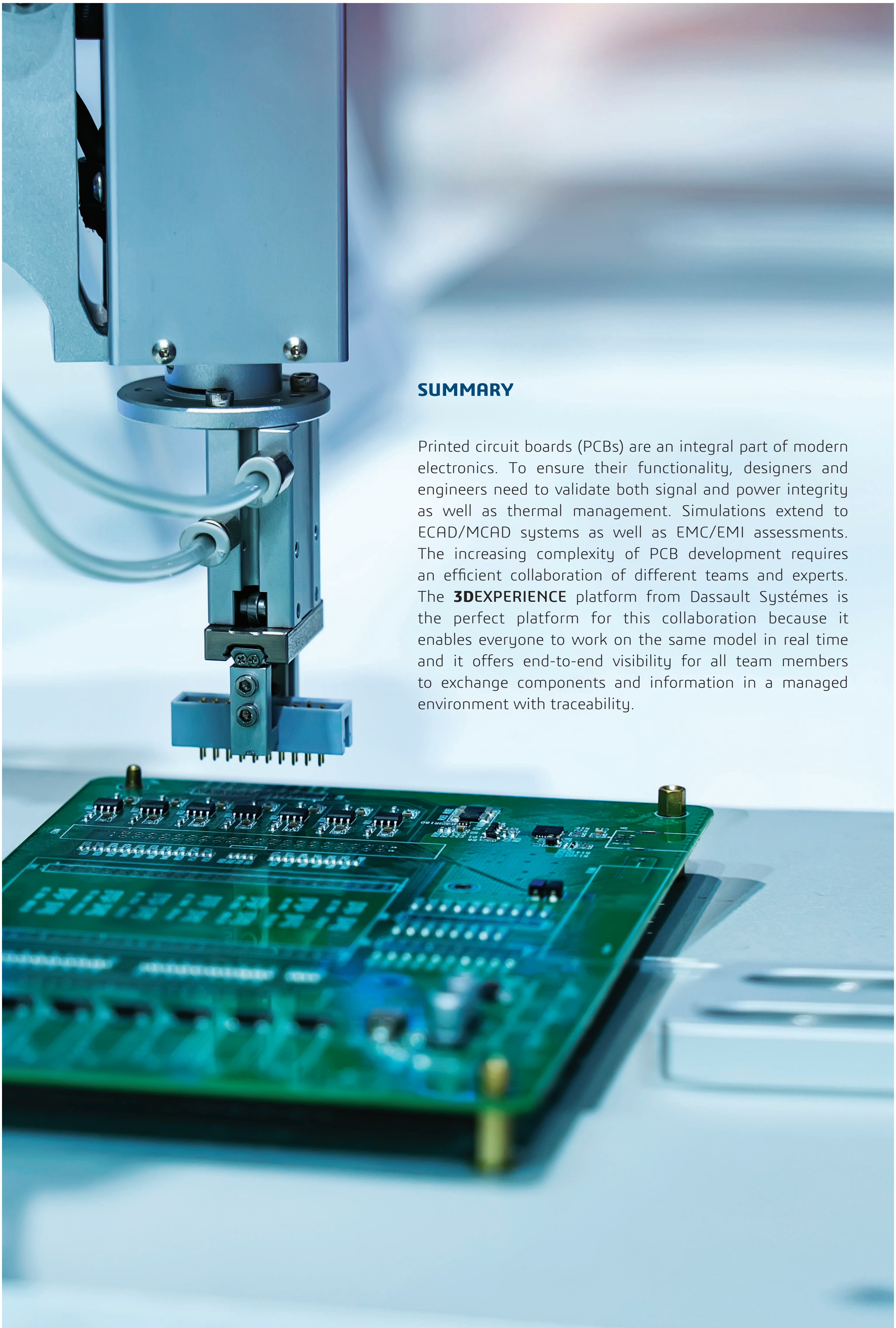


Figure 16: Voltages arriving at the receiver (probe P1)

As we can see from Figure 16, there would be no mode conversion up to 200MHz. This means the excitation of differential mode at the transmitter would not result in a common mode at the receiver. Since the Automotive Ethernet communication is in the range of 25-33MHz, this is more than adequate to validate the PCB for this application.

To better collaborate with other team members, users can now store the simulation model on the platform, where it is also possible to visualize the results in a web-based environment.



SUMMARY

Printed circuit boards (PCBs) are an integral part of modern electronics. To ensure their functionality, designers and engineers need to validate both signal and power integrity as well as thermal management. Simulations extend to ECAD/MCAD systems as well as EMC/EMI assessments. The increasing complexity of PCB development requires an efficient collaboration of different teams and experts. The **3D**EXPERIENCE platform from Dassault Systémes is the perfect platform for this collaboration because it enables everyone to work on the same model in real time and it offers end-to-end visibility for all team members to exchange components and information in a managed environment with traceability.

Inceptra supports engineering and manufacturing organizations with best-in-class solutions to digitally design, simulate, produce, and manage their products and processes, enabling enhanced innovation and productivity.

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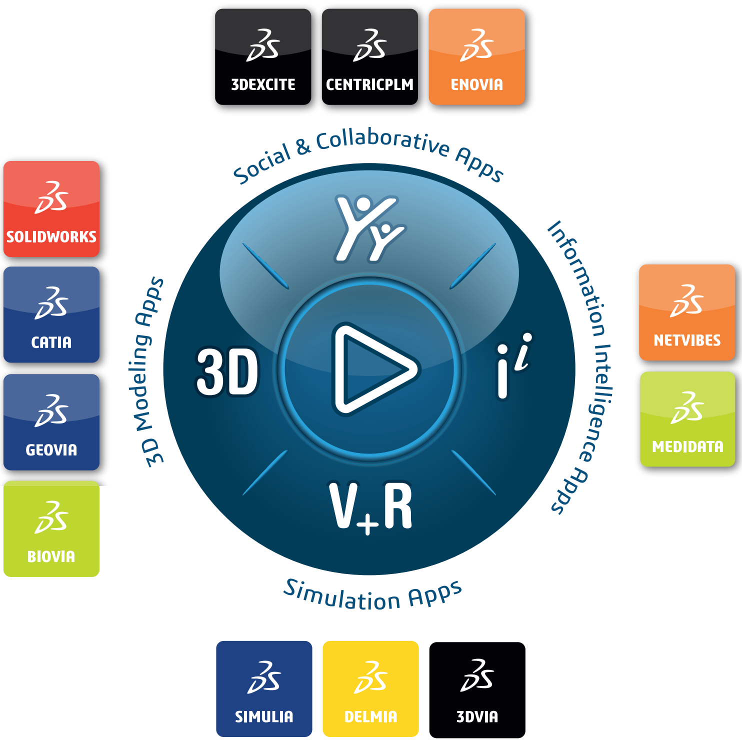

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