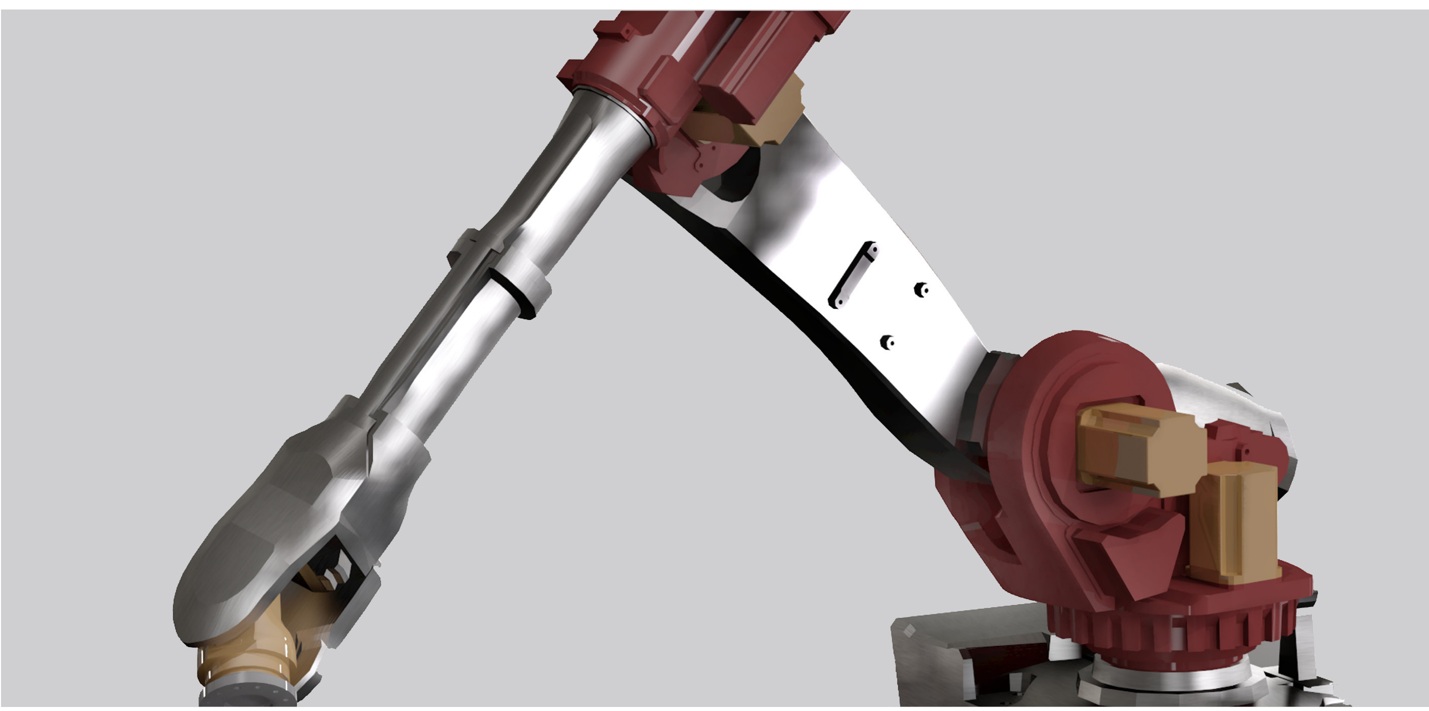
WHITE PAPER

INCORPORATING MECHATRONICS INTO YOUR DESIGN PROCESS

Overview

Designers of mechatronics products must create highly complex mechatronics systems that successfully integrate electrical, mechanical, and information-processing components. SolidWorks® Premium, integrated with our partners' products, can help you meet the unique challenges of mechatronics design, enabling you to use digital modeling to reduce physical prototypes, improve product quality, and streamline your entire development process.



Introduction

The days when mechanical systems and products were strictly mechanical are rapidly coming to a close as products continue to become more capable and more complex. To some degree, these increasingly sophisticated products are virtually guaranteed to employ "mechatronics." Depending on the product industry, mechatronics can be defined in several different ways. Generally, mechatronics is the integration of electrical and electronic components into mechanical enclosures and/or mechanical subassemblies.

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Some examples of this definition include multifunction printer/scanner/fax machines, digital music players, GPS devices, laptop and desktop computers, digital cameras, cell phones, home appliances, and industrial machines. All these products include electronic systems that are a synergistic integration and packaging of electrical and mechanical subsystems. Although mechatronics is typically represented in the consumer electronics industry, it also is employed across a broader cross-section of industries, including industrial machinery.

A second way of viewing mechatronics is as a subset of the electronics industry, where mechatronics systems are composed of a systematic integration of mechanical, electrical, electronics, and embedded software components. When all these various components are combined, the result is an electromechanical system. Within this context, mechatronics is characterized by software and electronics that control electromechanical systems. This definition is best exemplified by modern automotive engines and other automotive systems, aerospace equipment, and complex production machinery.

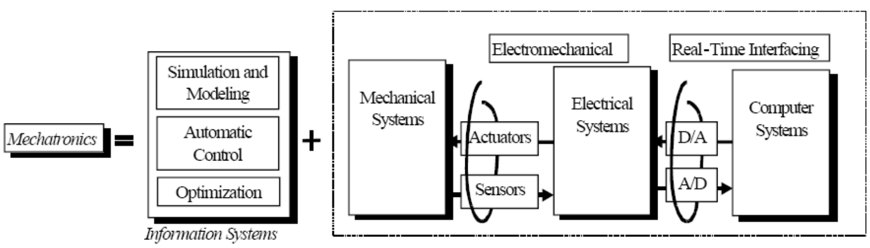

Figure 1: The key elements of mechatronics (Illustration courtesy of National Instruments)

Mechatronics is also known as a way to achieve an optimal design solution for an electromechanical product. Key mechatronics ideas are developed during the interdisciplinary simulation process, which provides the conditions for raising synergy and the catalytic effect for discovering solutions to complex problems. This synergy arises from integrating mechanical, electrical, and computer systems with information systems in order to design and manufacture mechatronics products. Machines that manufacture a wide range of products, from automotive tires to food processing, are good examples of this method.

Regardless of how mechatronics is defined, all mechatronics products exhibit performance characteristics that were once difficult—or even impossible—to achieve without a synergistic approach. The key elements of this synergistic approach are shown in Figure 1, which illustrates how mechatronics is the result of applying information systems to mechanical, electrical, and computer systems.

Mechatronics systems are excellent candidates for design process optimization, due to the high complexity of their designs and their high degree of integration among electrical, mechanical, and information-processing components. For the design team, the biggest challenges are how to integrate all of these components successfully and then choose the right design tools to create complex mechatronics systems.

The challenges of mechatronics

A number of critical business issues associated with mechatronics affect the engineering and design team as well as the management team. These issues range from improving product quality to reducing costs to maintaining sustainability; from complying with the Restriction of Hazardous Substances (RoHS) directive to shortening the product development cycle with faster time-to-market. As a result, your design team is under constant pressure to produce more complex products that not only top your previous designs, but also outperform your competitors' products—in less time and at less cost. One of the most effective ways to reduce costs is by reducing the number of physical prototypes during the product development cycle. You can achieve this by simply making digital test and simulation an integral part of the digital design phase.

As mechatronics systems become more complex, the challenges associated with successfully executing them also become more demanding. Greater end-user functionality and capability, for example, require greater numbers of electronic components, which in turn necessitates denser electronic component packaging. As electronic component density increases, cooling requirements also increase. Heat transfer becomes more daunting as packages become denser, thereby causing more heat failure. During the design phase, denser packaging becomes a critical system issue due to the interoperability requirements between electronic CAD (ECAD) and mechanical CAD (MCAD) software applications. Ultimately, this becomes a quality issue that must be addressed.

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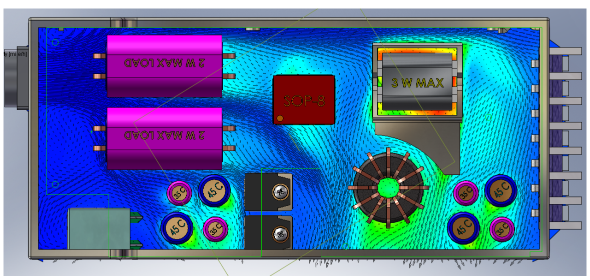

Figure 2: SolidWorks Flow Simulation is used on this power supply to analyze heat dissipation as cool air enters the box on the left and to examine the effect that has on the power supply's discrete components.

Because mechatronics systems are becoming more complex and functionality demands are increasing, designers are often replacing or supplementing hardware with software and firmware. One benefit of transitioning from hardware to software is called "postponement," or the ability to include major functionality features during the final stages of production, as a result of the embedded software system.

Another critical issue is the safe disposal of hazardous materials that are generated when electronic products are produced or retired. If treated properly, electronic waste can be a valuable source for secondary raw materials; if not handled correctly, however, it can become a major source of toxins. This is becoming a fast-growing global problem due to rapid technology change, low initial cost, and even planned obsolescence. Although technical solutions are available, in most cases a legal framework, a collection system, logistics, and other services must be implemented before a technical solution can be applied.

During the 1990s, some European countries banned the disposal of electronic waste in landfills, which in turn created an e-waste processing industry throughout Europe. Early in 2003, the European Union (EU) presented the Waste Electrical and Electronic Equipment (WEEE) and Restriction of Hazardous Substances (RoHS) directives. Since then, the EU, Japan, South Korea, and Taiwan have demanded that sellers and manufacturers of electronics be responsible for recycling 75 percent of these products. Many Asian countries have legislated, or are about to legislate, for electronic waste recycling.

Designing and producing a mechatronics system requires a well-orchestrated effort by many people across a wide variety of job roles and functions—from industrial design to PCB layout to control logic design to production planning.

In the United States, Congress is considering a number of electronic waste bills, including the National Computer Recycling Act. In the meantime, several states have passed their own laws regarding electronic waste management. Gradually, this ongoing problem is receiving deserved attention worldwide.

The mechatronics design process

Because mechatronics systems must integrate many different types of physical and digital firmware, processes, and personnel to create a successful end product, they present major design and production challenges. Designing and producing a mechatronics system requires a well-orchestrated effort by many people across a wide variety of job roles and functions—from industrial design to PCB layout to control logic design to production planning.

Although mechatronics systems differ, they all share six basic process elements that take an idea through design to production and ultimately into the marketplace.

1. Defining preliminary costs and performance specifications

Before any product is designed, several criteria must be established, including market feasibility. This ensures that the proposed product fulfills a genuine need. Once feasibility and need are determined to be worth the risk of product design and marketing, the anticipated preliminary costs and proposed profit margin are defined.

When upper management is satisfied with the product's potential financial success, the functionality and performance specifications are defined, along with the functional system requirements. Going forward, this will serve as a general blueprint for all functional levels. To assure that the functional requirements are met during this phase, the components and materials are specified, and the manufacturing processes are then defined.

2. Optimizing packaging design via modeling and simulation

The principles and challenges of mechatronics are first encountered in the packaging design phase. By using digital modeling and simulation techniques up front, you can minimize the cost and time required to produce the final physical end product.

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At this stage, a diverse group of design professionals works cohesively as a collaborative team in their respective disciplines. These areas may include industrial design (conceptual and aesthetics); mechanical engineering (conceptual, functional, and manufacturing considerations); interaction design (software-hardware control interface); and electrical/electronic engineering (functional, power requirements, and insulation/shielding).

Simultaneously, a preliminary printed circuit board (PCB) layout and a rough 3D mechanical CAD model are generated, with the major components and interconnections defined. To reduce costs, all collaborative team members must constantly check the availability of standardized 3D components.

Historically, this stage has encountered problems due to a lack of interoperability between ECAD and MCAD, which often results in the duplication of efforts. Using digital modeling and simulation from the outset, however, can enhance both interference detection and the routing between the various mechanical and electrical subsystems. In the packaging design phase, design optimizations are performed for all components—including mechanical, electrical, electronic, and software.

3. Refining the PCB Layout

Initially, the PCB layout is constrained by mechanical considerations related to the Intermediate Data Format (IDF). In 1992, IDF was developed as a neutral format for exchanging PCA (printed circuit assembly) information between PCB layout design (ECAD) systems and mechanical CAD systems; since then, IDF has continually evolved. An IDF file is actually two files: the first file contains information about the physical characteristics of the PCB, while the second file holds data on the size and shape of each PCB component.

Since digital prototypes greatly reduce the number of physical prototypes, they generate savings in both time and costs.

Once the ground rules have been established with an ECAD system, a preliminary circuit trace layout is created that indicates the "keep out" areas, as well as the locations for plated and nonplated holes for component placement. Electrical and electronic design optimizations are performed to confirm component selection and placement, circuit traces for power and ground considerations, and general circuit logic. After one or more iterations, a refined layout with components is transferred back via IDF to the mechanical engineers, so they can check against the preliminary packaging design for proper fit.

While MCAD software is getting easier to use, ECAD software ironically is becoming harder to use. Due to the rapid changes occurring in the semiconductor industry, it is also becoming more specialized.

4. Saving time and money via digital prototypes

The digital modeling and simulation that occur during the prototyping stage provide many major benefits. Since digital prototypes greatly reduce the number of physical prototypes, they generate savings in both time and costs.

After determining and confirming as much information as possible through digital modeling and simulation, a physical, functional breadboard model is built. The design team can create a prototype of an electronic circuit and then experiment with circuit designs. A modern breadboard consists of a perforated block of plastic with spring clips located under the perforations. Integrated circuits (ICs) in dual inline packages (DIPs) can be inserted into these perforations. To complete the circuit topology, you can insert interconnecting wires and discrete component leads from capacitors, resistors, or inductors into the remaining free holes.

Figure 3: Using SolidWorks Premium, you can describe all the components and cabling of an electronic enclosure in 3D. This greatly increases accuracy and decreases errors in assembly manufacturing.

Product lifecycle optimization brings product development full circle, as a successful product will begin the cycle again as a new-generation product.

The combined breadboard and mechanical packaging design now becomes a working prototype that can be scrutinized by a number of parties, including technical, marketing, and manufacturing. Regardless of whether digital or physical prototyping techniques are used, the prototypes are reiterated to refine the initial concept and prepare it for the final design stage and manufacture.

5. Finalizing the packaging design

This last stage includes finalizing and documenting the mechanical and electrical design. Although the primary vendors for various product components and manufacturing processes have been in place for some time, second sourcing will minimize or eliminate the flow of components, especially the most crucial ones. Final product cost and performance analyses are performed to ensure that regulatory requirements will be met for all aspects of the product design and production. Previous to declaring the design "final" and freezing it before release to manufacturing, final design optimizations must also be performed.

6. Releasing the design to manufacturing

Prior to releasing the product design to manufacturing, drawings and formal specifications for all aspects of the mechanical and electrical and electronic subsystems are required, in order to produce the first fabricated article. Because design changes for optimizing product functionality can be made up to the last minute, embedded software is deployed.

Once the first article has been verified and validated, all drawings are finalized and released to the manufacturing vendors. Final tooling is built, production machines are programmed, quality assurance is put in place, and sustained production can begin.

For comprehensive lifecycle optimization, however, production is only an interim step. New issues, such as product retirement and recycling, can arise. Therefore, product lifecycle optimization brings product development full circle, as a successful product will begin the cycle again as a new-generation product.

Integrating controls and mechanical simulation into the mechatronics design process

Much is being made of the positive effects of integrating digital simulation and modeling into mechatronics design, and for good reason—it saves time and money, reduces risk, and results in more innovative and higher-quality products. An example of how this works is seen in the mechatronics synergy that Dassault Systèmes SolidWorks Corp. has fostered with one of its partners, National Instruments. Because of the synergy between these two companies, customers have realized great value when moving from mechanical to electromechanical machine design. By integrating National Instruments' graphical system design platform for controls using LabVIEW and NI SoftMotion software with the 3D modeling and mechanics of SolidWorks software, this synergy is driving product, process, and business improvement through simulation and modeling.

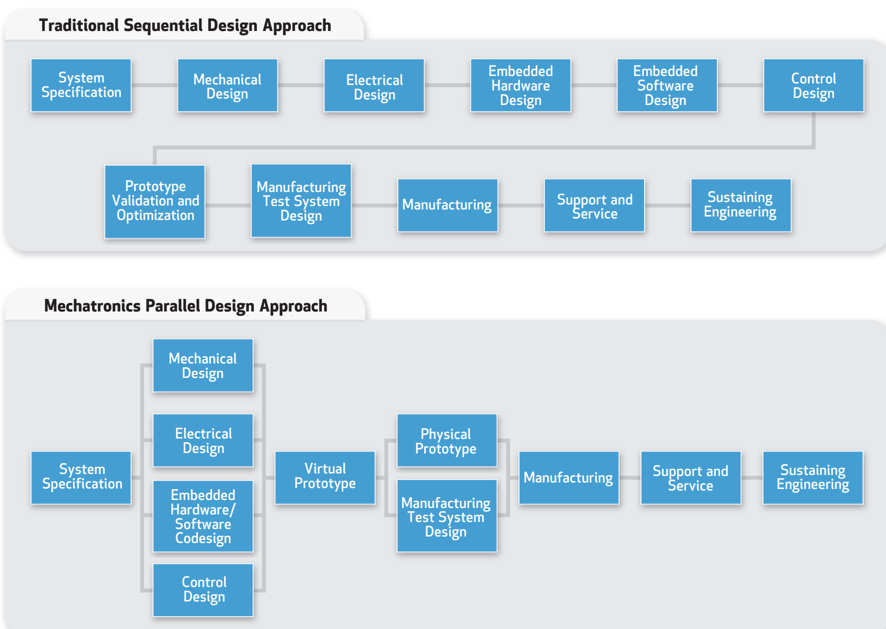

Figure 4: Mechatronics design has evolved from the traditional sequential approach, with the physical prototype used to validate and optimize, to the modern parallel design approach, leveraging the virtual prototype for validation and optimization thereby leading to faster and more efficient product development cycles. (Illustration courtesy of National Instruments)

In the past, simulating the performance of a machine that contained both mechanical and electrical components was a difficult and time-consuming sequential process that required highly skilled "specialists." Today, mechatronics design tools from National Instruments and DS SolidWorks are bringing together the electrical and mechanical worlds to simplify simulation and subsequent design. Before a single physical part is even ordered, electromechanical simulation can bring a digital machine to life. When the design is transitioned from prototyping to production, the same software that was used for simulating the machine is reused and implemented in the final product.

With integration between mechanical and control development environments, designers can help drive better design decisions for both the mechanical and control aspects of a design earlier in the product development cycle.

As machine builders implement new technology and replace yesterday's gears, cams, and shafts with servo actuators for precision motion, sensors for diagnostics, and cameras for inspection, they are embedding more electronics functionality—as opposed to mechanical components—in the machine's controls.

What was once purely mechanical is now electromechanical, adding an extra dimension of complexity to the design process. To achieve efficient machine design, engineers need to simulate the integrated mechanical and control design in software before moving to the prototype and production stages.

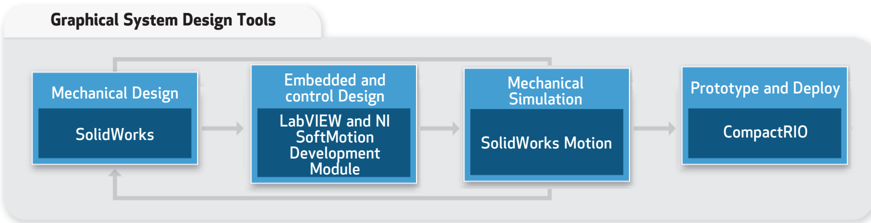

Figure 5: The integration of SolidWorks 3D CAD and mechanical design validation software with National Instruments' Graphical System Design platform for motion control design, simulation, and deployment provides a feedback loop to design mechatronics products virtually. (Illustration courtesy of National Instruments)

With SolidWorks software, you can design machine parts and assemblies using a familiar interface with 3D visualization. SolidWorks Motion, an integrated feature, utilizes mechanism dynamics to help simulate mechanism motion.

While SolidWorks Motion is well suited for open-loop motion simulations, a typical electromechanical system involves closed-loop control. For a true closed-loop simulation, engineers must simulate not only the dynamics of a mechanism, but also the controls that act on that mechanism in synchronization. LabVIEW graphical system design software is used to design the control system for machines. The LabVIEW interface for SolidWorks/software provides an interface between these two environments, so you can simulate integrated control of complex electromechanical systems. With integration between mechanical and control development environments, designers can help drive better design decisions for both the mechanical and control aspects of a design earlier in the product development cycle.

Making decisions about the mechanical and control design issues streamlines the machine design process, which results in fewer iterations and a reduction, if not elimination, of physical prototypes. Virtual prototyping of both mechanical and control designs helps you to develop proofs of concept before physical prototypes are even produced.

By having tight integration between a control design environment, such as LabVIEW, and a mechanical design environment, such as SolidWorks/software, you can accelerate the design process for complex mechatronics systems.

How SolidWorks software functionality addresses mechatronics

On its own, SolidWorks Premium provides a wealth of features and functionality for designing mechatronics systems. With partners such as National Instruments, the solutions become even more comprehensive and the possibilities endless. Below are just some of the solutions offered by DS SolidWorks and its partners to help you succeed when designing mechatronics systems.

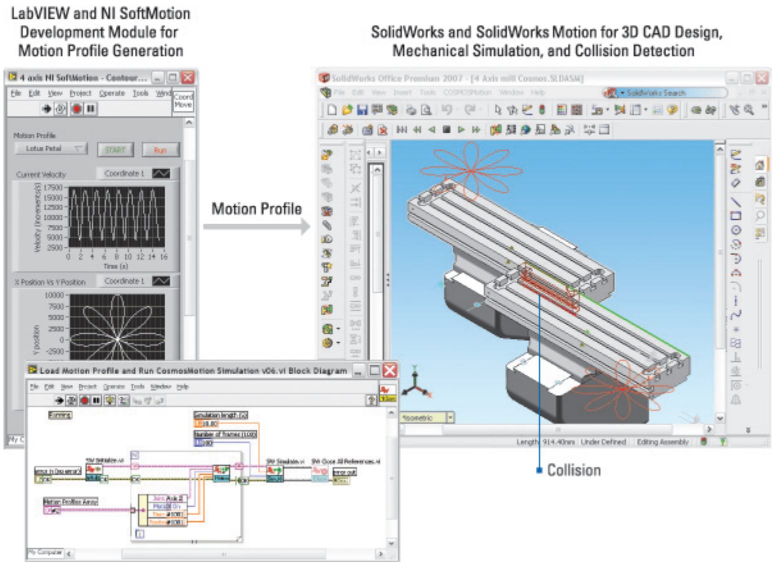

Figure 6: Example of motion profile generation and validation including checking for collisions and throughput optimization in a virtual simulation before building the actual machine. (Illustration courtesy of National Instruments)

A complete 3D product design solution, SolidWorks Premium equips product design teams with all the design engineering, data management, and communications tools they need in one package. For everything from consumer products to machine design, SolidWorks Premium helps you gain speed and flexibility in managing large assemblies. Since components can be designed and changed from within an assembly to ensure optimal fit, you get unparalleled performance when designing large assemblies with tens of thousands of parts. You can even drag and drop parts and features into place. Throughout the entire design process, comprehensive materials libraries specify the correct material with all physical characteristics and properties.

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SolidWorks Intelligent Feature Technology—or SWIFT™—streamlines the design and optimization processes. By powering a series of tools that diagnose and cure problems in feature order, mates, sketch relationships, and applying dimensions, SWIFT enables you to focus on design rather than on CAD.

Although 3D CAD provides tremendous power for the design engineer, it also creates more complexity. As a result, you are often forced to become an expert in order to leverage this power. SWIFT aims to eliminate the need to learn how 3D CAD software "thinks" by making you an expert from the start. With SWIFT, designers can focus on what they want to accomplish, not on the rules of 3D CAD software.

By providing the greatest number of translation formats in the industry, including IDF, SolidWorks software helps to move accurate data to and from other ECAD programs. The IDF data-file importing capabilities of SolidWorks software combined with those of CircuitWorks™, a Gold Partner add-in, provide a true interface as well as extensive interoperability between ECAD and MCAD designers. With a host of partners such as National Instruments, DS SolidWorks provides a comprehensive mechatronics design solution.

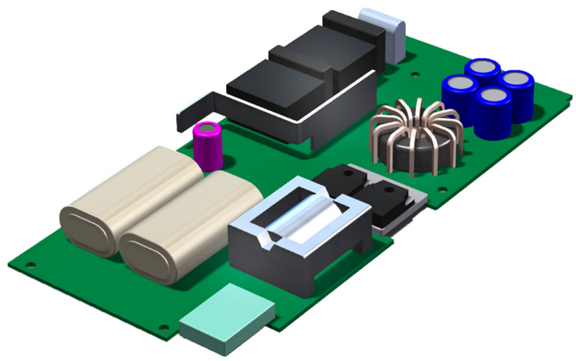

Figure 7: SolidWorks software users can take advantage of 3D ContentCentral, which provides access to thousands of free, downloadable electronic components in native SolidWorks software format.

With 3D ContentCentral®, you can easily download the latest vendor components right from within SolidWorks software. 3D ContentCentral offers you direct access to timesaving CAD models, in a number of formats, from leading suppliers and individual SolidWorks software users worldwide. Its purpose is twofold—to help customers find the components they are looking for in a vendor-certified format, and to provide engineering component manufacturers with a vehicle to deliver information and data about their products.

SolidWorks eDrawings® Professional software, included within SolidWorks Premium, helps design teams communicate concepts with users outside the SolidWorks Community, such as ECAD and industrial designers and manufacturing engineers. Intended primarily for CAD users who need to share product designs and coordinate design reviews, SolidWorks eDrawings Professional generates accurate representations of 2D and 3D product designs that anyone can view, mark up, and measure.

With the availability of valuable information early in the design process, SolidWorks Motion also enables you to consider more designs with less risk.

The most popular motion virtual prototyping tool for SolidWorks 3D CAD software, SolidWorks Motion ensures that your designs will work before you build them. SolidWorks Motion is the standard virtual prototyping tool for engineers and designers interested in understanding the motion performance of their assemblies. As a result, you can significantly reduce product development time and physical prototyping costs. With the availability of valuable information early in the design process, SolidWorks Motion also enables you to evaluate more design options with less risk.

Specifically tailored for designers and engineers who are not specialists in design validation, SolidWorks Simulation helps you improve product quality by indicating how SolidWorks software models will behave structurally before you build them. Fully embedded inside the SolidWorks software interface, SolidWorks Simulation utilizes the FeatureManager® design tree as well as many of the same mouse and keyboard commands. So anyone who can design a part in SolidWorks CAD software can also analyze it without having to learn a new interface.

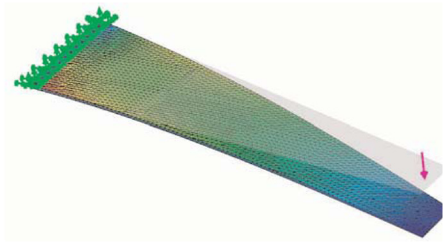

Figure 8: Using SolidWorks Simulation, you can quickly and easily analyze parts with loads applied to them to verify their structural integrity.

Since SolidWorks Simulation contains the most frequently used design validation tools, you can easily compare alternative designs and then quickly choose the optimal design for final production. SolidWorks Simulation also allows you to study the interaction between different assembly components.

Unlike other computational fluid dynamics (CFD) programs, SolidWorks Flow Simulation combines a high level of functionality and accuracy with ease of use. Fully embedded inside SolidWorks 3D CAD software, SolidWorks Flow Simulation is suited for the engineer who needs flow analysis, but is not necessarily an expert in the field of fluid simulation. A goal-oriented approach allows you to gain insight into the performance of a design under real-world conditions. Designed to be extremely flexible, SolidWorks Flow Simulation can be used in a wide range of applications.

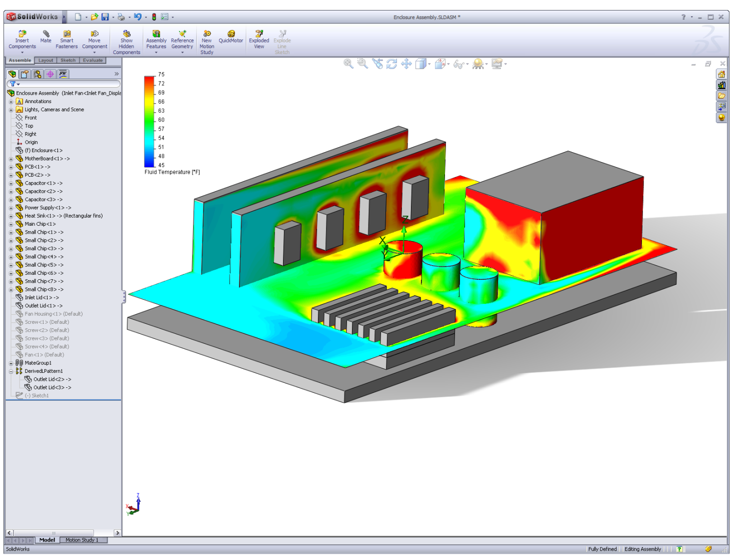

Figure 9: SolidWorks Flow Simulation greatly reduces multiple heat studies by first testing designs virtually, thereby eliminating costly prototypes.

With PhotoWorks™ software, you have the ability to quickly and predictably create photorealistic renderings for presentations and downstream (sales, support, marketing) reuse and repurpose. Additionally, you can present convincing design proposals quickly and effectively, produce virtual material studies, and reduce prototyping and photography costs, thereby bringing your products to market faster.

SolidWorks Routing enables you to quickly design pipe, tube, and electrical routes in mechatronics product designs. For designers of electrical and electronic systems, SolidWorks Routing provides additional timesaving tools for generating cable and harnessing manufacturing documentation. Because it uses the familiar SolidWorks 3D CAD software design environment, SolidWorks Routing is fast and simple to use. The routing application and fittings library is fully integrated with SolidWorks software, so your routed systems design can be done in the same package as your mechanical equipment design.

Conclusion

With SolidWorks Premium, you can bring superior mechatronics products to market in less time—and at lower costs. Working with the same software tools, the same geometry database, and the same user interface, your engineering and design teams can evaluate functionality at the concept stage. They can also generate continually improved digital alternatives before committing to a physical prototype.

As the unique challenges of mechatronics continue to evolve, SolidWorks software will continue to redefine the future of mechanical design.

SolidWorks Premium, integrated with our partner's products, provides you with advanced mechatronics technologies and development practices to deliver:

- Higher profitability through faster, lower-risk, lower-cost development
- Increased efficiency due to better understanding, communication, collaboration, and integration
- Greater innovation through increased design automation across engineering disciplines

The mechatronics challenges that confront designers today will become even more demanding in the future. To successfully address these issues, SolidWorks Premium provides a complete 3D product design solution. The SolidWorks mechanical simulation and modeling software integrated with National Instruments' graphical system design platform for motion control enables your design team to reduce physical prototypes, improve product quality, and accelerate the design process —while saving your company time and money. As complex mechatronics systems continue to evolve, SolidWorks and National Instruments software will continue to redefine the future of mechanical design.

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