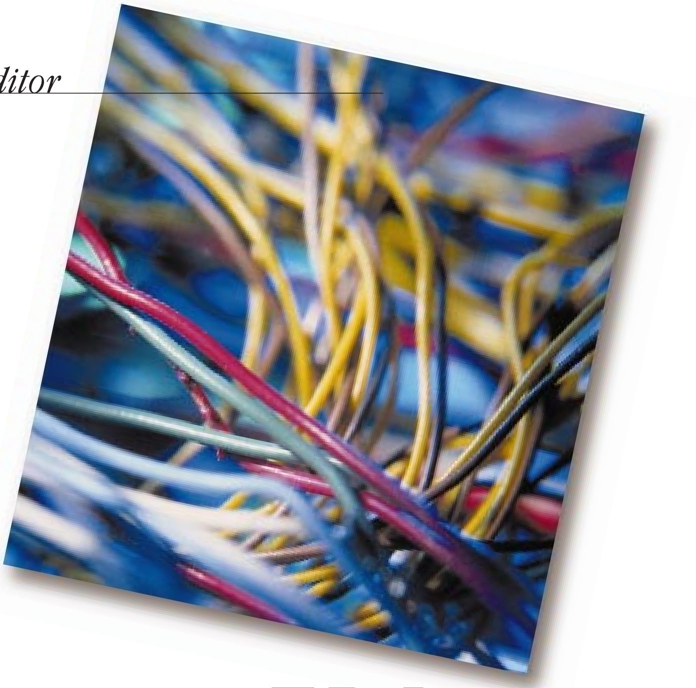

WIRING IS SO FUNDAMENTAL THAT WE FORGET THAT IT IS A SYSTEM UNTO ITSELF.

Cable and harness EDA enables advanced electrical-system design

Engineers who design and implement ICs have the attention of the EDA vendors and can choose from various tools targeted to every facet of their jobs. Developers of pc boards enjoy almost the same quality and amount of support. Yet, in almost every case, ICs, pc boards, and the systems they are part of are useless without cables. But few EDA vendors provide software to help designers and manufacturers develop and build cables. Until now, no one has needed sophisticated development and analysis tools for cables. With the exception of few companies dedicated to high-volume production, small companies and consultants design and develop most cables. These designers achieve reliability by employing conservative design rules and guidelines they learn through on-the-job training.

However, this situation is quickly changing. Many subsystems that once employed mechanical controls now use electromechanical controls. Each generation of cars and planes have more electronics subsystems, and the integration requirements among those parts are also growing. Cables must carry more signals at a higher frequency and with more power. The conservative rules that once kept engineers out of trouble are no longer applicable because the design margins have decreased. Stringing a wire between two points is no longer just a matter of measuring its length and selecting a gauge. The federal government has turned its attention to the reliability problems inherent in cables and wires, unfortunately only as a reaction to a couple of recent air-traffic disasters. In November 2000, the government issued a report covering the maintenance of wires and cables systems but acknowledging the importance of new technologies for designing such systems as a way of minimizing maintenance problems (**Reference 1**).

AT A GLANCE

- ▷ Smart products call for sophisticated cables.
- ▷ Both electrical and mechanical engineers have had to learn new terms.
- ▷ Electromechanical-design automation is a new discipline with a promising market.
- ▷ Few vendors and high entry barriers characterize the cable market.

THE PROBLEM

In any large system, two or more development teams are likely to use cables to connect their subsystems. Yet, developers designed and located each subassembly in the system with little consideration of the physical and electronics constraints of cabling. Even a clear example of leading-edge design, a Formula 1 race car, falls prey to the tradition. Designers of suspension systems, for example, know that they have to accommodate sensors that carry signals back to the engine-control computer. Yet, these designers often fail to consider the physical characteristics of the cable during suspension design, and they likely determine its precise routing and length through trial and error on the test track. The common approach to cables seems to be: If they do not get in the way, they are good enough. The rapid increase in semiconductor-fabrication technology and the Internet are forcing changes. The Internet supports a move toward global design and manufacturing with the goal of reducing costs. Manufacturers have to maintain many variants and options for each design and accommodate the special circumstances of regional manufacturing and design. Many products have long active deployments, requiring designers to consider the certainty of field upgrades during the life of the product. Electrical systems are evolving: Cars will soon have 42V batteries, flexible cable is becoming a viable alternative and possibly a preferred medium, and designers are using multiplexing as a way of increasing bandwidth.

A commercial wide-body jet has more than 150 km of wires; technicians likely determined the wires' individual lengths and routes by running a rope through the airplane. A helicopter electrical system contains an average of 20,000 wires. Fiber optics will most likely replace many of the wires in both airplanes and helicopters. The designers of the B-52, for example, expected it to have an operational life of 16 to 18 years; however, it is now scheduled to stay in active duties for 50 years. No one ever considered the effect of aging on the copper and insulation materials in the aircraft's wires. In satellites and other space vehicles, the challenges are even more daunting. Radiation can be corrosive and generates electromagnetic interference. Such systems cannot tolerate slack design rules because every pound of extra weight adds around $70,000 to the cost of a launch. But exotic products are not the only ones that offer challenges. A typical car today has more than 20 microcomputers on board that need to communicate with each other and with sensors and actuators in all types of weather conditions and at extreme temperatures in certain cases. In a commercial vehicle, the weight of a harness and its cost is second only to the engine. Development times are shrinking

CAR MAKERS PUT THE PEDAL TO THE METAL

The AMI-C (Automotive Multimedia Interface Collaboration) is an organization of vehicle manufacturers worldwide that facilitates the development, promotion, and standardization of electronic gateways to connect automotive multimedia, telematics, and other electronic devices to their motor vehicles. After an initial meeting in 1998, the manufacturers formally formed the organization in 1999 as a nonprofit corporation. Members are Fiat Auto, Ford Motor Co, General Motors, Honda, Mitsubishi Motors, Nissan, PSA Peugeot Citroen, Renault, and Toyota. Volkswagen, BMW, and Daimler Chrysler, which were active in the establishment of the consortium, are not official members. The AMI-C objectives are to:

- provide a convenient method to enable consumers to use a variety of emerging media, computing, and communications devices in their vehicles;
- foster innovation of new features and functions in automotive media, computing, and communications electronics by creating a stable and uniform hardware and software interface in vehicles;
- reduce time to market and facilitate upgrades of evolving electronics in vehicles;
- support deployment of telematics by defining specifications for the telematics and information interfaces between the vehicle and the outside world;
- reduce relative costs of vehicle electronic components; and
- improve the quality of vehicle electronic components through reduction in variations, thus improving first-time capability.

The group has recently released a number of specifications covering architecture, functional requirements, interfaces, and physical specifications, as well as use cases and a common message set. The specifications are for informational purposes only. The group will refine, validate, and verify these specifications. Upon completion of the process, AMI-C will release final "build-to" versions. Although the German car manufacturers have declined to sign the membership agreement, they can still provide input to the development of the standards and deploy products that fully meet them. You can find the specifications at www.ami-c.org.

from 36 months just a few years ago to 18 months today. Formula 1 race cars go from design start to first competitive start in about six months.

Because cables are electromechanical devices, software to support their development must deal with both the electronics and the mechanical disciplines. System architects would like a tool that allows them to design an entire system and evaluate choices. You can find a tool that allows you to perform the task from an electronics point of view, and you can find a tool that allows you to plan a mechanical system. However, you cannot find a tool that allows you to concurrently do both.

Electronics engineers and mechanical engineers do not talk the same jargon and have different physical rules to consider. They need tools in their respective disciplines that can communicate relevant data and information to the tools in the other discipline while keeping track of the progress and status of the entire design as a unit. Even more important, the development flow is separate from the manufacturing and procurement flow, a situation that often leads to errors and delays. The challenges are many: Designers select wire gauges and create wire interconnects by hand, and the process is difficult to reuse. Many organizations within the company use the design data. Without an integrated computerized flow, designers must enter the data multiple times and store it in various databases. Modifying the design data is, therefore, an error-prone and a time-consuming task.

EDA companies do not develop or sell mechanical tools, and mechanical-tool companies do not sell EDA tools. To ensure that the interface between the tools is complete or at least sufficient, tool developers must implement functions outside the company's primary market. Development, maintenance, and support costs for each tool are much higher, and the engineering team responsible for development and maintenance must possess unique skills. As a result, few established EDA companies, including Innoveda, Mentor Graphics, and Zuken, address the market. All three vendors are bullish about the potential of this market and compare it with the pc-board market in the early 1970s.

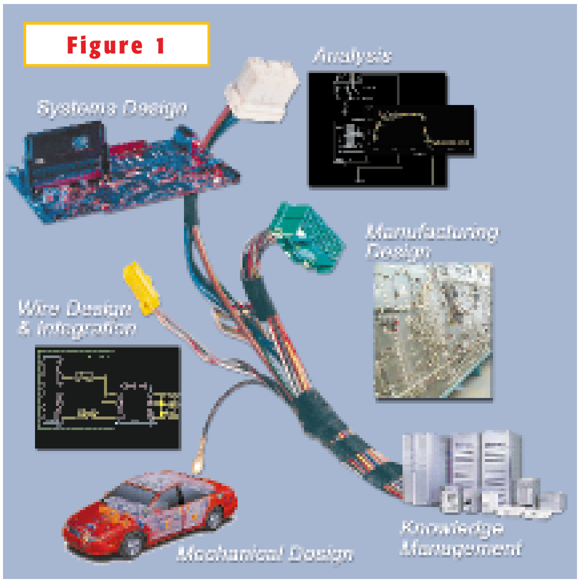

Figure 1

Design and development of cables present many challenges (courtesy Mentor Graphics).

HOW THE ELECTRICAL SYSTEM IS BUILT

A new discipline, EMDA (electromechanical-design automation), combines elements of electrical design, mechanical design, and manufacturing methods with the functions you need to design, engineer, and manufacture an electrical system. The electrical system in a vehicle or piece of equipment contains one or more harnesses. A harness is a group of cables that is fabricated together. To better illustrate the characteristics of EMDA as it applies to cable design and development, see **Figure 2.**

The development of the electrical system starts with designers drawing the logical representation of wires using a graphical editor. This tool may either be the same as the one used for electronics design but with additional functions enabled or a different one whose database is completely compatible with the schematic editor. The design team then begins to introduce electromechanical attributes in the design, converting the appropriate logical nets to wires and splices by assigning attributes to each net and connectivity point. Designers can then route wires between pins of physical components and splices created when multiple wires are connected. Designers can then assign wire sizes or postpone assignment until architectural layout. They need to insert multiple terminations when routing multiple wires to a com-

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mon pin. Wires are bundled together to form cables. If the cable is shielded, the designers must place termination pins to support grounding of the shield. Designers typically generate a number of variants for each design. Think of a vehicle platform that will find use in a number of car brands, and each brand can have more than 100 options. You will then understand the complexity of necessary design data management. And the process is truly global: For example, the manufacturers of the US Lincoln LS build the car on a British Jaguar platform. Of course, designers need to keep track of all the parts a design uses and assign a name and all appropriate attributes to each wire and cables. Most of these tasks are mechanically oriented with the goal of producing the logical map of the electrical system to be built. You also need to ensure that the design does not violate any electrical, physical-, or manufacturing-design. So you need a DRC tool that you can run at any time during this process. And, of course, the design must be associated with your pc-board design at all times. The electrical system schematics now becomes an integral part of the design database, associated with the electronic-design schematics, so that connectors can be associated with logical signals and common properties can be seen in both designs.

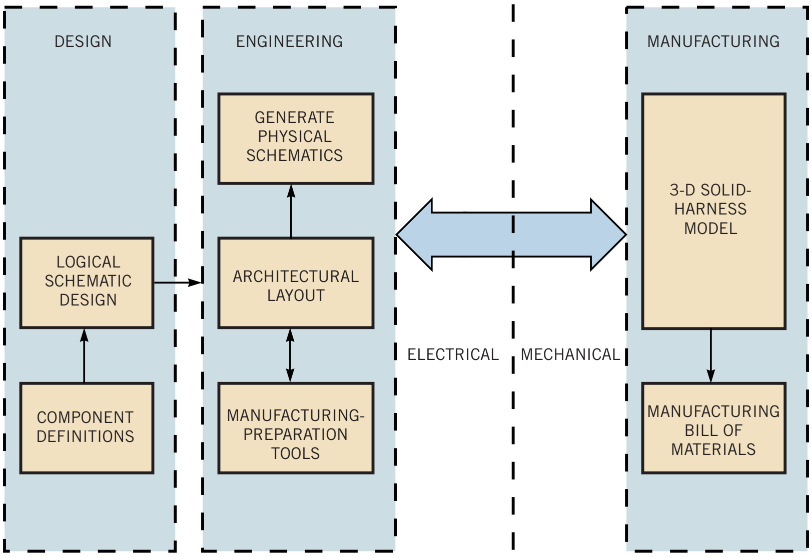

Figure 2

Designers follow a complex flow to complete a cable design (courtesy Innoveda).

After completing the design of the logical schematic of the electrical system, the engineering work to prepare it for manufacturing can begin. This phase of the process defines the harnesses, generates drawings to produce the fixtures used to build them, and a topological description of all the wires and cables mechanical engineers use to assign their final attributes. First, engineers must produce an architectural layout, a 2-D rendition of the electrical system showing its complete topology and attributes. Engineers place a symbol for each electronic module connected to the electrical system and route wires and cables using the logical netlist they previously generated. They must assign wire gauges, estimate the length of each wire and cable, and identify where connectors and fuses should be. The result is a more precise but still logical representation of the electrical system. They then partition the electrical system into harnesses. This step is time-consuming when done manually. For each harness, the designers must generate a 2-D design that includes manufacturing information, such as cable-covering and -retention devices, such as brackets and grommets. At this point in the process the design is not to scale but provides early information to manufacturing. Manufacturing begins to have an idea of how many harnesses it will have to produce, their degree of complexity, and the approximate amount of each part that manufacturing needs to order.

The design is now ready for the mechanical engineers. Each of the cabling-design systems from Innoveda, Mentor, and Zuken interfaces with at least one mechanical-design package. Two mechanical-design packages share this market. The French company Dassault Systemes developed CATIA, and IBM also distributes this product. SDRC (Structural Dynamic Research Corporation) developed a product called I-DEAS, although people often refer to it as SDRC. Both of these products take the logical netlist and the physical attributes developed using EDA tools and allow a true 3-D rendition of wires and cables, as they will be finally positioned in the finished product. At this stage, engineers determine the precise length of each wire and the location of the connectors and fasteners. **Figure 3** shows an example of the planning and routing of a harness**.** The designers then export the information about the electrical system to the EDA tool. Engineers update the drawings for each harness and the electrical-system bill of materials and produce the drawings and specifications for the form boards that are used to assemble each harness.

Once you design the system, you must ensure that it will operate safely, reliably, and according to the specification. Physical routing can have an impact on system-interconnect performance. The failure to account for voltage drops through the wires during the design phase can result in costly changes. In the automotive and aerospace environment, 12V dc at high currents is prevalent, and wire losses are not negligible. Engineers must monitor and analyze the effects of routing on their original design and provide routing rules to avoid the problem by, for example, restricting the gauges used for wires or setting a maximum cable length.

Electrical sneak paths can cause unwanted functions to occur or prevent desired functions from performing correctly even when all components are working properly. Sneak paths are usually the result of external asynchronous inputs that a circuit designer either could not foresee or could not control. To identify a sneak path, you must analyze the power switching circuitry from each source to each termination. Then, you must determine all paths that allow bidirectional current flow through components along the path. Any such path could potentially alter the system's functioning, creating glitches that could prove dangerous.

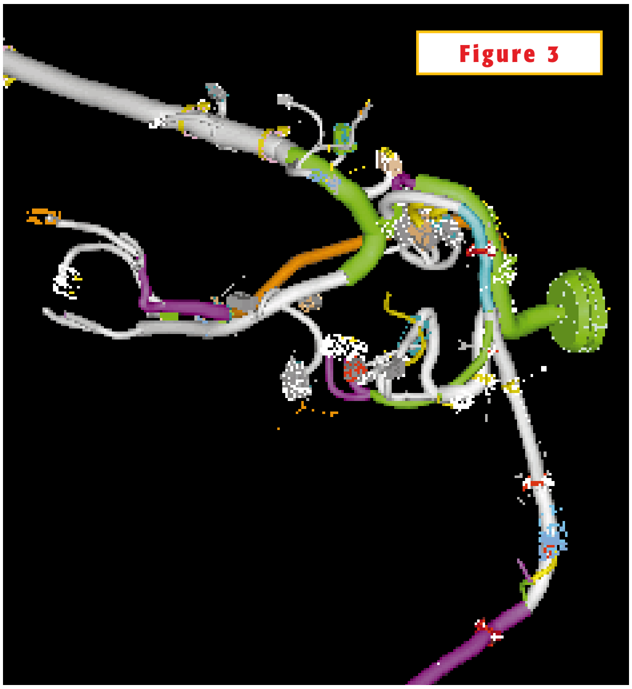
Figure 3

CATIA and I-DEAS help engineers visualize the electrical system in a vehicle to optimize performance and minimize costs (courtesy Zuken).

But even the most thorough analysis may not find all of the problems. During normal service life, all wire systems are subject to aging. Errors can occur during maintenance operations. You need a way to test the system while it is in the field. Just as many electronic systems perform a self-test at start-up, electrical-distribution systems need to test themselves when they are turned on. Engineers would like to be able to check the resistance through a wire to determine whether fatigue or rust has altered its operation. They would also like to check for electromagnetic radiation caused when a broken insulation turns a wire into an antenna. Deterioration of the electrical system or even revisions to components that are near but not part of the electrical system could turn a marginally operating system into a failing one.

AVAILABLE EDA TOOLS

EDA tools to support the development of an electrical system dramatically shorten a product's time to market. Whenever two or more engineering disciplines must interact to design, produce, and manufacture a system, the complexity of the problem increases dramatically. The car manufacturers are leading in the development of new standards for the specification, design, and development of automotive electrical systems. Toward that end, vehicle manufacturers have formed the AMI-C (Automotive Multimedia Interface Collaboration) to standardize protocols and to provide the critical technological mass for their development (see **sidebar** "Car makers put the pedal to the metal"). Although no architectural tool yet exists to allow the integrated design of the electrical system with the electronic system, BMW is working with Cadence using the Cadence VCC architectural tool to explore possible practical applications (**Reference 2**).

All three EDA companies in the cable-design market have active partnerships with automobile manufacturers. Zuken is working with Toyota, Innoveda is working with Ford, and Mentor has partnerships with Daimler Chrysler and others. All three are or will soon be working on Formula 1 cars. Zuken and Toyota have built a Formula 1 car, but it will not compete until 2002. Innoveda is with the Jaguar team, and Mentor is working with Ferrari, the current world champion. Both Innoveda and Mentor provide tools for designing, engineering, and interfacing with mechanical-design functions, whereas Zuken is in the final stages of developing its engineering-tool set. Although all three companies have initially targeted the automotive market, both Mentor and Innoveda are also active in the aerospace, shipbuilding, electronics-equipment, and even consumer-products markets. Zuken will address all markets when it completes its tool set.

Designers and technicians have addressed and for the most part solved the discontinuities and obstacles they have encountered. Mentor, through its Logical Cable product, provides a comprehensive approach to the design of electrical systems. It offers Manufacturing Cable and Capital H, a product it obtained through last year's acquisition of Harness Software Ltd. E3LCable provides the interface to the CATIA mechanical-design tool. Mentor has developed DC Analyzer to address wire-harness electrical-behavior analysis and also offers OEMs the Scat dc-loading and sneak-path-analysis tool from SoHaR of Germany. Innoveda also provides TransDesign, a comprehensive design, engineering, and manufacturing system that offers a built-in connection to corporate parts-information systems and connects to both CATIA and I-DEAS, depending on the customer requirement. Zuken's Cabling Designer supports the design, engineering, and manufacturing of automobiles. It offers bidirectional interfaces to both I-DEAS and CATIA mechanical packages. It is now developing more functions to make its offering the equivalent to those of its two competitors. Given the increasing contents of electronics in most systems, engineers can expect increased attention by EDA vendors to this area. Analysis and verification of electrical systems are becoming more important with each improvement in IC design and manufacturing. Competition will be higher, tool development will accelerate, and more functions will emerge, especially in the analysis, verification, and test of electrical systems.□

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