REVOLUTIONIZING AUTOMOTIVE SERVICE WITH DIGITAL TWIN ELECTRONIC VISUALIZATION

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Introduction

Automotive servicing is a crucial part of the overall ownership experience, and rapid, effective service is a critical business metric for the entire automotive industry. But with the accelerating integration of electronic system functionality in the latest machines, servicing cars today requires understanding a complex, interconnected computer system. How do we equip technicians to identify and repair problems? This paper explores the changing nature of modern vehicle maintenance and how digital twin technology may apply to this and other industries whose devices are increasingly digitalized.

Every Link Counts in the Automotive Value Chain

For many automotive customers, the number one value proposition is reliability. Over the last thirty years, new technologies have revolutionized the mean time before failure (MTBF) of modern vehicles. Today, new cars have earned the enviable reputation of rarely failing and being easily repairable in the event of a breakdown. Quality and reliability have become the automotive industry's new trademark.

Ensuring this value proposition requires more than just a good car. The user experience starts at purchase and continues through the vehicle's life as customers return to their service centers for occasional maintenance and repairs. The manufacturers that figured this out were the ones that ultimately succeeded, and today, every car manufacturer has a network of dedicated, efficient, and well-supported service centers. The modern notion of "pre-owned" cars, where the service centers sell second-hand as well as new vehicles, and continue to service them, has more to do with preserving the reliability reputation of the manufacturer rather than extending their business model.

In the last few decades, there was a change in automotive systems, where electronics took over as the key technology in the car. This transition has expanded service centers into electronic diagnosis experts, who must execute electronic servicing faster than ever.

Cars Beyond 2020

The modern vehicle, regardless of cost, contains a plethora of electronic systems, as shown in Figure 1. Some of these are obvious, radar, entertainment, navigation, etc. Most of these critical electronic systems are hidden from the driver but are integral to the vehicle's operation.

A vehicle in 2020 can contain 100-300 micro-controllers or processors, 50+ complex electronic control units, between 5 and 20 million lines of software code, and several miles of wire harness

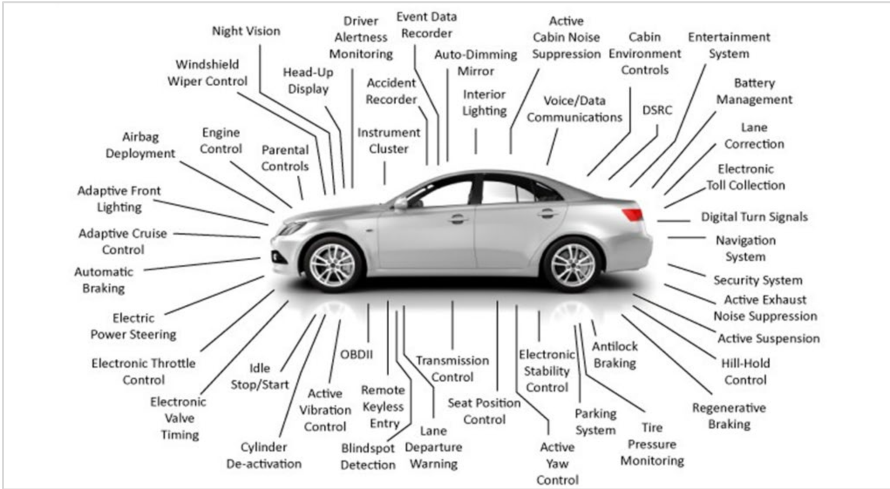

Figure 1 – Electronic Components in a Modern Vehicle
Image Courtesy: Vehicular Electronics Laboratory, Clemson University

Moreover, these systems interact. For example, the steering system might interface with the suspension to provide a smooth ride, or the cruise control operates the accelerator and brakes for a complete driving function.

As such, a fault in one car component might be caused by a separate system. Diagnosing a fault in one area might involve uncovering a problem in a separate component. These problems may manifest as intermittent, hard-to-track electronic signals rather than a more obvious worn-out mechanical part. Solving these issues is a complex task.

On top of this, next-generation cars contain autonomous driving modes and other even more powerful systems representing the latest state-of-the-art in computer science. These systems must adhere to rigorous safety standards, such as ISO 26262. Automotive electronics are set to become ever more sophisticated.

Servicing a Complex, Interconnected Computer Network on Wheels

Enabling mechanics to reliably identify and repair problems quickly is a key component of the automotive value proposition. However, the vision of the oil-soaked mechanic working under the hood of a car is gone. Today's service centers need highly skilled mechanics, and a group of electronic technicians with computer expertise to run diagnostic routines.

The modern car has diagnostic systems that interface with service computers to provide codes that indicate potential or existing problems. Although these aid in a first-pass diagnostic operation, more detection work is often required. For this technicians must refer to service manuals in the form of pages of online material or immense paper manuals.

Today, documentation teams – ideally working simultaneously with the development engineers – generate service data and manuals. Writers create large circuit diagrams particular to each car type and variant, often manually translating details from design documents. This slow and error-prone process creates unwieldy service manuals that service technicians must search to track down possible issues. More recently, the manuals have been provided online with better indexing, although they are still static and cannot keep up with ever-advancing automotive technology. This is further complicated by vehicle variants that multiply vehicle schematic versions with a range of additional details. Each variant must be tracked, which means new documentation must be created, and this ultimately creates an unwieldly mass of data.

The Needs of Next Generation Servicing

Service centers need a new approach to informing their technicians of the necessary detail to repair and maintain vehicles. This new approach needs to allow the following:

1. An online, easy-to-understand, graphical indication of problem areas.
2. A flexible, dynamic representation that scales and adjusts itself to display problem areas directly, eliminating the need to wade through pages of data.
3. A graphical display that includes the variant and version of the specific car under inspection, handling each update to the vehicles with ease.

4. A direct connection between original computer-aided design (CAD) design data and automated diagnostics system to avoid translation errors.

It is possible to meet these requirements using technology created for the semiconductor design and verification industry, where it is common to view and process many millions of connections and components.

A Next-Generation Online Information Source

Altair® EEvision™ reduces electrical system complexity by creating a digital twin for the automobile's complete electrical system. Using the digital twin database, EEvision can instantly render the schematic focused on a problem area or for a specific Diagnostic Trouble Code (DTC).

Meeting the requirements above, the derived schematic is crisp and clear, as it has been designed for the exacting needs of the automotive industry. Their technology is based on over 25 years of pioneering system debugging and visualization for the semiconductor industry. Extending this experience to automotive services platforms means EEvision is an entirely new customizable platform for maintenance and service applications.

The design information from various CAD tools in use by automotive design engineers is automatically converted into the digital twin database format used by the rendering system, thus eliminating translation errors and providing a faster path for documentation creation that requires little manual authoring. Any updates to the designs, or special vehicle variants may also be loaded into the database easily for a complete documentation set.

The full rendering system may be accessed online using a web browser, which makes it easy to keep the documentation updated and include new diagnostic features (software). The browser may be accessed over a PC or even a tablet for on-the-spot examination of service schematics and component attributes while looking at the vehicle.

The resulting automated, reactive, online service documentation provides the following benefits:

- Easy to understand interactive, clear service display of specific repair scenario
- Quick to use: Fast, efficient problem detection and repair
- Accurate to produce: Variation aware schematics from original CAD files

Easy to Understand

The demands of the semiconductor industry required a clear, easy-to-understand schematic view. Modern System-on-Chip (SoC) semiconductors contain hundreds of millions of transistors and displaying these complex circuits in a meaningful fashion for circuit debugging and analysis requires a high degree of ergonomic and graphical user interface (GUI) skill. It is this same technology and expertise that Altair is applying to minimize automotive schematic complexity using digital twin model data.

The information contained in the schematic must be able to include a variety of detail on each component, on the wiring harness between them, and other key facts. This information should be graphical in nature (as shown in Figure 2) to make it fast and easy to identify in the car.

The graphics are also configurable in a variety of ways, to allow them to be set up for a company standard, or a preferred rendering style by the service centers. This customization ability makes the software adaptable to a broad range of different company needs

Figure 2 – Easy to Understand Schematic with Additional Component Information

Quick to Use

The skilled service center technician must not find it difficult to manipulate the schematic to quickly get the answer they want. Usability is a key aspect of this type of solution. A degree of automation is included to allow for this, for example Google-like searching through the complete vehicle electronic system.

For modern car diagnosis, it is not enough to simply provide a fixed-scale schematic page from a manual, and hope that it captures the problem scenario. EEvision actually redraws, based on automotive industry drawing standards, a schematic fragment linked to the problem description, either from a diagnostic code or manually entered information. As shown in Figure 3, a critical signal with an issue is highlighted in red. The schematic is drawn around this signal path to show the components most likely affected by it. In a normal document, this signal might cross multiple pages and wind its way around various blocks; in this case, it is front and center in the diagram so the entire signal path can be examined quickly.

A useful analogy to this reactive schematic approach is to consider modern map drawing programs. In the past, when trying to choose a route to a specific location, one made use of paper maps, searching through them to first find the location itself, and then the ideal route to get there. I think we would all agree that the modern “Google Maps” approach where start and end locations are entered and a map is created and scaled around the area of interest, providing additional data on the locations as well as road changes, together with ideal routes to get there quickly accounting for traffic conditions, is faster and more accurate. EEvision applies a similar process to schematic scaling and electrical path representation

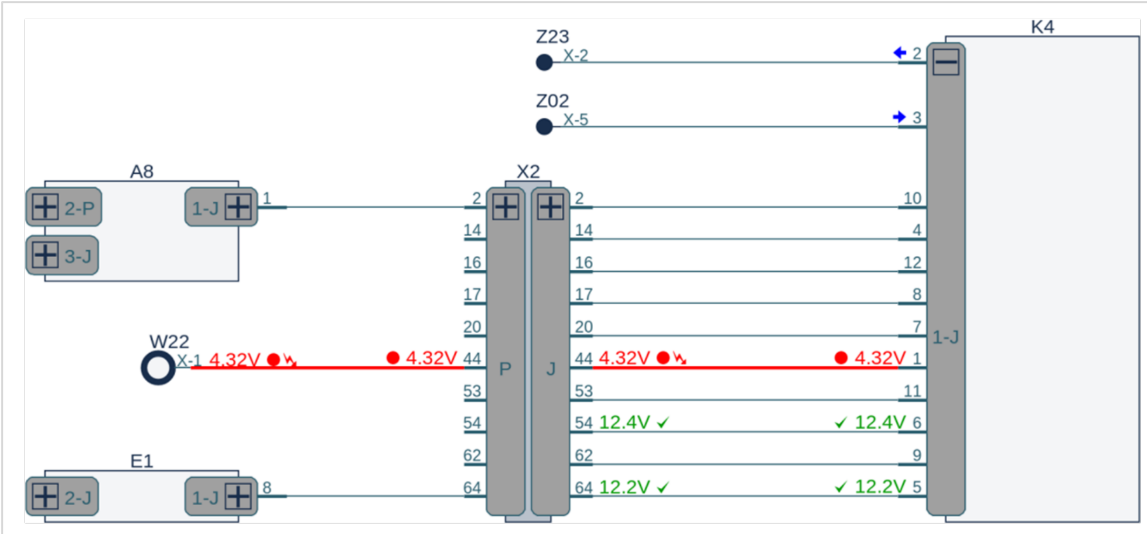

Figure 3 – Dynamically Rendered Schematic Around a Specific Signal

The schematic must also handle variants in the product, a common practice in the automotive industry. Vehicles will be modified as software or hardware changes or issues are discovered in the original design. In addition, custom features of some cars need to be included. This rendering system can take the internationally recognized Vehicle Identification Number (VIN) and use this to provide specific service schematics for the vehicle in question. To accomplish this with regular manuals would require dozens of thick paper books. With this online system, a simple database modification results in a new schematic on the fly, simplifying this process and increasing its accuracy.

Accurate to Produce

The production of the service documentation is a critical factor for modern vehicles. Today, documentation experts often create service documents with little automated tool support. This is a time-consuming and error-prone process, which can lead to bad diagnosis and wasted service center time.

In addition, updates to the manuals are frequently required, and this involves redrawing graphics and sending out these manuals to the service center network.

Producing the schematic database directly from the designer’s CAD systems significantly streamlines the production process while reducing errors. The development process, shown in Figure 4, operates as follows: A direct automated translation of the original CAD system data to the EEvision Data Base (EDB) digital twin model is executed, ensuring the fast production of accurate, error-free documents that can be updated immediately when any change is necessary. The EDB database has been created to store vehicle connectivity very efficiently so that service applications have easy and fast access to the entire vehicle connectivity, to component attributes or to additional service pictures and service instructions. EDB supports industry standard formats such as KBL, but also allows company specific customization (plugin mechanisms) to access customer specific CAD data. The EDB database and data structures are open and fully accessible via API interfaces to allow a high level of customization.

As the entire system is online, any updates or error fixes to the database can be provided immediately without having to reissue documentation.

Base Technology

EEvision’s algorithms generate easy-to-read automotive style documentation for harness and logical schematics. By recognizing common circuit patterns, and detecting and analyzing critical circuit paths, EEvision will automatically render key schematic fragments on the fly, showing only the part of the circuit that is important for the service job at hand. It can also perform current and signal flow analysis to create compact and easy-to-read schematics. Place- and-route techniques produce clean, easily readable automotive-style drawings of complex vehicles.

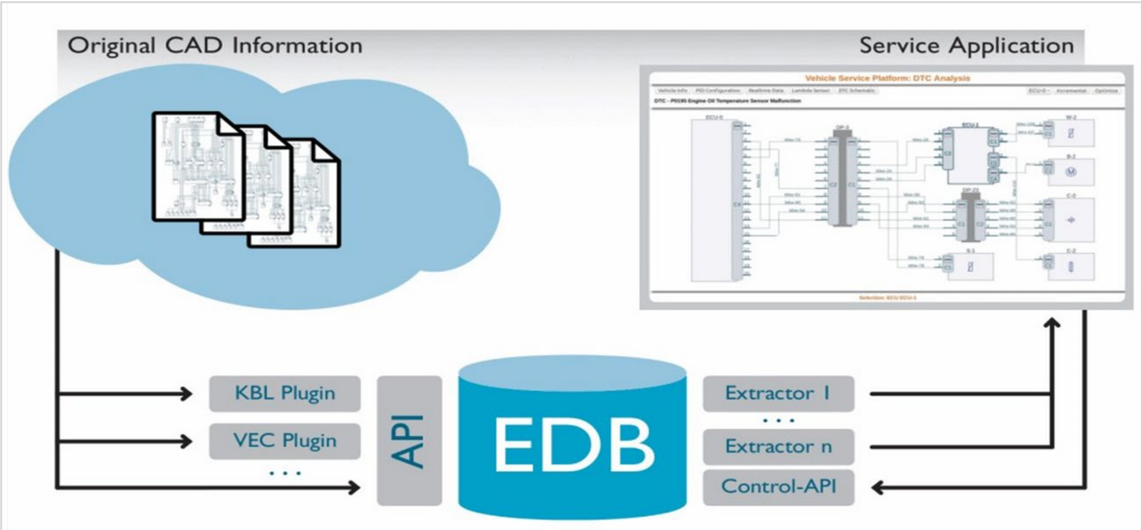

Figure 4 – Automated Database Production Process Flowl

Many features that originated from extensive prior experience within the semiconductor debug domain are incorporated in EEvision. For example, the automatic reduction of circuit complexity reduces the number of components and wires that are shown for a certain diagnosis task. The incremental schematic navigation, where a service engineer can start circuit exploration from any given start component or connector of a vehicle and interactively 'dive/browse' through the entire vehicle connectivity with instant access to component attributes and part numbers

Applying EEvision in Various Industries

The functionality of EEvision has clear benefits that may be applied to applications well beyond automotive service.

Aeronautical companies have many of the same issues as automotive suppliers when it comes to service, and the complexity, as well as efficiency, requirements are even more extreme. Indeed, one aeronautical company focused on satellites has made use of EEvision technology.

Of course, any manufacturer of transportation vehicles beyond the automotive industry alone will benefit from EEvision technology. Construction machines, agricultural vehicles, and fire engines, for example, must be returned to service as quickly as possible to avoid expensive downtime. A well-known European truck manufacturing company has embedded EEvision technology in its repair and diagnostic tools to accelerate vehicle service.

Looking beyond automotive requirements, railways, shipping, and other transportation industries will benefit from these tools. They may also be applied to improve services for industrial machinery, power generation and other electrical plant that makes use of complex interconnect.

Availability of Technology

EEvision and the related EDB database are both in production use today. The technology is available as visualization engine software libraries for the integration into Windows- or Linux-based diagnostic and repair tools, and also for cloud-based service solutions in combination with JavaScript and HTML5 technologies (client– server architectures

Summary

The EEvision digital twin platform introduced here can be customized for specific service solutions to help to significantly improve service center efficiency and cost. At the same time the efforts to create documentation for service centers (especially service schematics) is reduced. Also, on-the-fly distribution of data and software applications will reduce distribution costs and maintenance efforts, while allowing flexible access to always up-to-date vehicle service data.