Resistance Is Futile—Electronics Are on the Rise

Electronic Control Units and Communication Protocols

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Electronics content in cars has been steadily increasing since as far back as the early 1970s, starting with the introduction of the electronic voltage regulator and electronic ignition. By the early 1980s, advances in electronics made the widespread introduction of electronic spark control and engine control electronics possible. These applications made it common for sophisticated digital electronics to be standard equipment in vehicles. The trend for increased electronics content continued to accelerate in the 1990s with the introduction of Electronic Stability Programs (ESP), side-impact restraint systems, immobilization security, and other systems.

IHS Global Insight has developed extensive knowledge in the areas of electronic control units (ECUs) and in-vehicle network architectures tracking vehicle manufacturers' attitudes towards the use of communication protocols and related technical trends for in-vehicle network architectures. This is completed by a detailed analysis—on model level—of the market for selected ECUs in such vehicle domains as Body/Comfort, Chassis, Powertrain, Multimedia, and Safety. The following market observations have been made:

- Vehicle manufacturers are trying to limit, even reduce the number of ECUs through functional integration, to cope with increasing complexity due to growing demand for safety and convenience features.
- Although selected communication protocols have already reached maturity in terms of implementation, the increased amount of functions within a vehicle requires the addition of further bus systems.
- The drive for standardization is expected to result in one or two dedicated communication protocols per application area.
- The lack of visible consumer benefit makes it difficult to properly market communication protocols and electronic control units. Instead, the use of communication protocols is implied in the offering of advanced vehicle functions.

Electronic control units are an established part of today's vehicles and virtually every vehicle manufacturer implements communication protocols to some extent. In addition, virtually every supplier is implementing them in their product offerings in order for their products to be integrated into the vehicle's architecture. However, device production is done on a Tier-3 level with traditional semiconductor suppliers such as Freescale being active players in the automotive industry.

Historically, the use of ECUs has its roots in engine management and has since developed into a complex area for vehicle manufacturers. Today's vehicles feature between around 30 ECUs for small cars and 80 ECUs for high-end luxury cars, covering a wide range of applications. Although implementing buses for data transfer has significantly reduced the amount of complexity in a vehicle's wiring harness, the in-vehicle network architecture of a common medium-sized vehicle has again reached a state where managing its level of complexity is almost impossible.

Therefore, a number of vehicle manufacturers have tried to limit and even reduce the number of ECUs in their high-end luxury models to off-set increasing complexity. It is expected that more powerful ECUs will emerge in the future allowing bundling functions that are currently realized using two or more ECUs. In conjunction with application-specific bus protocols, fewer ECUs can be utilized more efficiently, thereby reducing the complexity of the in-vehicle network architecture.

The interior domain is one of the key areas of functional integration. With the implementation of a centralized body control module, common functions such as lights and windscreen wipers have been integrated into a single control unit. However, increased demand for functional integration led vehicle manufacturers to implement generally two central body control modules with one located in the front of the vehicle, the other one in the back.

TECHNOLOGY TRENDS

Although ECUs have been used for some time, the area of automotive communication protocols and in-vehicle network architectures is relatively young. Initially developed to organize data transmission more efficiently and thereby addressing problems such as increasing complexity in both weight and number of nodes, as well as EMC compliance, new features such as advanced driver assistance and increase comfort applications are bringing today's communication protocols to their performance limits. Bus systems in today's cars, especially at the top end of the segments, are already becoming somewhat overloaded.

IHS Global Insight believes that this is yet another focal point in the development of in-vehicle architectures that will increasingly become an issue for smaller vehicles as well. Four main application domains have been established where a growing demand for advanced functionality and therefore increased hardware complexity is expected.

Advanced Driver Assistance and Chassis Integration

Chassis systems have evolved from purely physical applications to systems that progressively incorporate advanced electronics, starting with advancements in braking technology. With the increasing electronics content in chassis systems, integrating the various chassis sub systems became possible, and desirable. The need for sophisticated systems-to-systems communication arose, as software became a vital backbone of the inner workings of today's chassis systems. Two communication protocols have the potential to fulfill this need: the high-speed CAN and Flexray.

With Flexray only recently being introduced in series application, the high-speed CAN bus remains the communication protocol of choice for chassis integration. Interestingly, the German/American volume manufacturer Opel was the first to present an integrated chassis solution, its IDS Plus Chassis System in March 2004. Opel opted for a high-speed CAN solution to realize the data exchange between the braking and suspension system.

For further integration of the chassis subsystems, braking, steering, and suspension, a dedicated high-speed CAN bus solution will be required. Since such a solution appears to require a fourth, in some cases a fifth CAN bus, Flexray proves to be a viable alternative, especially for realizing advanced driver-assistance functions.

Driver-assistance systems are a group of technologies that aim to monitor and notify the driver of the vehicle's external environment. Although a vast array of driver-assistance systems are slowly gaining market exposure, only collision-avoidance systems interact directly with chassis systems and therefore benefit from chassis integration the most.

Active and Passive Safety Systems

In the last 20 or so years, a great development effort has been conducted to meet society's need for safer vehicles; for example occupant protection systems such as airbags are now installed in most vehicles, making significant contributions to safety.

Nonetheless, while major applications for in-vehicle network architectures and communication protocols have been infotainment, comfort and convenience, as well as drivetrain and chassis systems, vehicle manufacturers have only recently started to look at a dedicated network for safety systems. An example of such an application is the BMW 7-Series, in which 13 ECUs managing various passive safety systems spread across the vehicle are integrated using a network called Intelligent Safety Integration System (ISIS).

Using BMW's proprietary Byteflight protocol, ISIS is used for the intelligent triggering of airbags, belt tensioners, active headrests, and future passive safety systems. In contrast to present systems, which are controlled from a single unit, ISIS is an interconnected system of autonomous and thus individually optimal single systems. BMW developed the Byteflight protocol in conjunction with Motorola, Infineon, and Elmos.

While ISIS only acts after the collision, both Mercedes and Toyota have developed integrated safety systems that act in the pre-collision phase triggering passive safety systems prior to an accident. Networking various systems, both approaches provide a pre-crash functionality. PRE-SAFE, from Mercedes, networks classic passive safety systems, such as seat belt and airbags, with comfort features such as seats and sunroofs. Recent PRE SAFE versions include an emergency brake assist that applies maximum brake pressure prior to a collision in order to minimize impact. Moreover, the system moves the seat in an optimal position and closes the sun roof, as well as widows, to prevent occupants from being catapulted out of the car during an accident.

Toyota takes a somewhat different approach. Its systems are based on the evaluation of data gathered by various sensors actuating the brakes and seatbelts. Toyota uses a CAN network to integrate the two ECUs that the system is using.

Such development advances show that integrating passive safety systems is only the first step towards fully integrated safety systems. Integrating passive with active safety systems is expected to begin with vehicle stability control systems, such as ABS and ESP. Interestingly, it is expected that a master/slave architecture will be implemented for the various ECUs within the safety domain.

Infotainment

The growing demand for advanced in-car infotainment systems and their subsequent introduction has forced vehicle manufacturers to add hundreds of meters of wiring to vehicles. However, as infotainment systems have developed at a rapid rate, it has become apparent that higher bandwidth (that point-to-point wiring cannot provide) will be required for systems-to-systems communication.

As a result, a network bus architecture has been developed, which comprises of thick, two-wire cables. Until recently, the most popular solution has been the CAN-based IDB-C (Intelligent Transportation Systems Data Bus - CAN) protocol. Since IDB-C can only be used for lower speed automotive multimedia applications, a new data bus for infotainment was practically mandatory because of the heavy data flow associated with multimedia applications and two-way communications. IHS Global Insight believes that the use of a common high-speed bus would help vehicle manufacturers and their suppliers to simplify the process of selecting multimedia devices, as the data bus would eliminate the issue of differences between the automotive and electronic design cycles.

Vehicle manufacturers and suppliers have turned towards replacing data-carrying copper wire with optical fibre, for gaining bandwidth and reducing weight. Some of the advantages of plastic optical fibre (POF) are its high-transmission capacity, insensitivity to electromagnetic interference (EMI), lack of cross talk, lightweight and small form factor. The speeds at which POF delivers are particularly important in applications that use multiple video channels, which allow backseat occupants to watch separate video images. In these situations, the data streams are so large that bandwidth and speed become especially critical.

The fibre optical communication protocol that is favored by such vehicle manufacturers as Audi, BMW, and Mercedes-Benz among others is the MOST (Media Oriented Systems Transport) bus. Although challenged in the longer term by the automotive version of Firewire, it seems that MOST bus technology would be the preferred medium for vehicle manufacturers for some time, as it is being pushed strongly by the German premium vehicle manufacturers.

Nevertheless, it is expected that IDB 1394, a high-speed version of Firewire that has been designed specifically for automotive applications, will replace MOST as an in-vehicle network communication protocol in the longer term. A key trend is establishing itself as car-to-environment communication becomes ever more important. The recent strong demand of connecting mobile devices, such as MP3 player, to the vehicle has forced vehicle manufacturers to implement USB connectivity and to provide an AUX-IN port. Also, the wireless protocol Bluetooth is being implemented in more and more vehicles since almost all mobile phones use this protocol for device-to-device communication.

Comfort and Convenience

Recent years have seen an increasing demand for comfort and convenience systems. Although typically being relatively price insensitive, these systems have now emerged in vehicle segments that are all *but* price insensitive. As a result the number of related electronic control units has been steadily increasing. Although the introduction of central body control units has somewhat reduced the number of dedicated control units, the reduction in complexity has been somewhat offset through the implementation of new comfort functions.

In order to integrate comfort and convenience features into the in-vehicle network architecture, the CAN-B protocol has historically been used. Nonetheless, increasing price pressure for the integration of comfort and convenience features has led to the development of the LIN protocol as a low-cost alternative. It is expected that LIN will further gain market share as comfort and convenience features have soundly established themselves as a key product differentiator, alongside infotainment offerings.

MARKET TRENDS

Market Drivers

The Growth in Complexity (Increasing Number of ECUs) Provides Impetus for In-vehicle Network Architecture Change.

In-vehicle network architectures have become ever more complex in recent years, as the integration of various electronics systems have became possible and desirable. The need for sophisticated systems-to-systems communication arose, as software became a vital backbone of the inner workings of today's automobiles.

The average number of ECUs in a modern car ranges between around 30 for a lower segment car to around 80 for a luxury vehicle. In order to provide sophisticated communication between the various control units, vehicle manufacturers as well as suppliers have long been developing communication protocols to cope with increasing dataloads that systems integration generally requires. First implementing proprietary network solutions, the Controller Area Network (CAN), developed by Mercedes-Benz AG in conjunction with Robert Bosch GmbH in the early 1990s, has been an industry-wide standard since 1994.

Ever since, the CAN protocol has been catering for a multitude of applications. The increasing number of ECUs has led to the emergence of different dedicated CAN solutions with today's vehicles featuring up to five dedicated CAN buses. Nonetheless, the increasing number of CAN bus solutions in today's cars does not diminish the complexity problem that has initially led to the development of in-vehicle network architectures.

New communication protocols such as the Media Oriented Systems Transport (MOST) have been developed to cater for the different application areas for communication protocols in today's vehicles. It is expected that future applications, and changing requirements in data load and transmission speed, will continue to spawn new communication protocols such as Flexray.

Dramatically Rising Efforts for System's Integration Requires Advanced In-vehicle Network Architectures

To an extent technical developments in the automotive industry have historically been limited to single systems. However, increasing demand for safety and comfort in cars has led to the uncontrolled addition of systems and features in cars. In order to cope with the increasing complexity of the wiring harness, vehicle manufacturers started to integrate various sub-systems in order to manage functions more effectively.

The traditional in-vehicle network architecture has split into power and signal. Whereas electrical power is still distributed using a copper-based wiring harness, signal transmission is realized by advanced bus systems. It is expected that developments in signal transmission technology will further be driven by increasing data loads, transmission speeds, and fault tolerance leading to more advanced communication protocols. It is also expected that the use of fibre optics will increase as a low-weight and non-EMC alternative for copper-based bus systems, thereby offsetting their cost disadvantages.

Need for Higher Data Rates Paves the Way for Advanced Communication Protocols

Integrating more sophisticated systems has resulted in the need to exchange more data. Information that is provided by a multitude of sensors from a number of different systems is collected and evaluated by an ECU that provided yet another function. Data transmission depends on bandwidth, the amount of data that can be transmitted in a given time frame. Initial developments have been limited to about 100 kbps of CAN. New in-vehicle applications such as multimedia or safety relevant functions, as well as smart sensor comfort features, have led to the increase of the usable bandwidth spectrum. Currently, it ranges from 20 kbps to 25 Mbps, depending on the application. It is expected that future automotive applications will result in more adapted solutions for communication protocols providing impetus for continuous development in this area.

Plug-And-Play Approach Increases Competition

The field of infotainment offers a wide choice of gadgets for the audiophile driver. Nevertheless, the availability of advanced products is somewhat limited to the Aftermarket. In order to take an increasing share of the Aftermarket, vehicle manufacturers have to strive for solutions that can merge the fast-moving world of consumer electronics and the slow-moving automotive world. Two possibilities are currently on the horizon, MOST and Firewire.

The increased adoption of ring topology based multimedia communication protocols such as MOST allows vehicle manufacturers to implement a plug and play architecture similar to that which can be found in the computer industry. This is believed to increase competition in the automotive field as plug and play allows electronic devices to be developed on many different levels.

The recent trend in connecting vehicles to the multimedia environment through USB or Bluetooth has enabled third-party hardware and software suppliers to build products tailored to the automotive industry. It is, therefore, expected that the increasing gap between automotive and consumer electronics development cycles can be significantly narrowed to a point where it virtually disappears, as new devices can easily be integrated in an automobile. This trend leads IHS Global Insight to expect that traditional automotive suppliers will become increasingly threatened in their efforts to maintain and gain market share.

MARKET RESTRAINTS

Lack of Standardization Hinders the Wider Implementation of Communication Protocols.

Standardization is believed to be key for inexpensively implementing bus architectures. Vehicle manufacturers typically spend months re-engineering because supplier products rarely comply with the vehicle manufacturers' proprietary vehicle architectures. Standardization would allow vehicle manufacturers to plug new electronics systems into vehicles at the last moment before the start of production, offering a higher degree of flexibility.

No Visible End-Customer Benefit Hinders the Quick Implementation of Advanced Communication Protocols.

Communication protocols have proven invaluable for the integration of existing systems and the development of new functionalities. The use of communication protocols is somewhat invisible to the end customer. It makes it very difficult for market players to develop a viable business case for the implementation of communication protocols; for example, vehicle manufacturers are unable to directly charge a surplus for the usage of the CAN protocol. The benefits of implementing CAN are only indirectly related to the driver. It is recommended that vehicle manufacturers market the implementation of communication protocols with emphasis on the new functionalities that this implementation will generate.

Limited Bandwidth and Functionality of Buses Increase Complexity of In-Vehicle Network Architectures.

Since the development of the CAN protocol in the early 1990s, a host of communication protocols have emerged in order to cater for various in-car applications. Targeted at a specific application, communication protocols have become somewhat specified. However, linking various communication protocols—their main differences are transmission speed and bandwidth—is challenging, and has led to the development of gateways. Although gateway technology has significantly improved recently, the increasing number of gateways in a car poses additional challenges for overall systems reliability.

OUTLOOK

Ever since the first in-car electronics were introduced, engineers simply added new electronics systems as they became available. Initially, electronic control units, sensors, and related actuators were wired directly from point to point. After the car body and its engine, the wiring harness is the third-heaviest, and the most expensive, component in a modern vehicle, and consequently there arose a requirement for an alternative solution for systems communication.

At the same time, vehicle manufacturers started to define architectures that would bundle common functions into single ECUs. Therefore, in-car network architectures remain among the very few areas where vehicle manufacturers have retained a high level of research and development authority, as they define the communication protocols and standards.

It is expected that the definition of an in-vehicle network architecture will shift to an earlier slot in the product development cycle, as often one or two scalable architectures are developed for the entire product range. Also, defining key components before generating the package of new development projects enables vehicle manufacturers to have the latest technology and to take advantage of any opportunities to differentiate themselves from their competitors.

Driven by the advent of innovative vehicle applications, contemporary in-vehicle network architectures have again reached a level of complexity that requires a technological breakthrough in order to manage their level of complexity and to fulfill the heightened customer and legal requirements. IHS Global Insight believes that further functional integration into fewer ECUs would be such a breakthrough. The resulting optimized use of computing power would allow the implementation of new and advanced functions without significantly increasing hardware complexity. Shifting complexity from hardware to software does not solve the complexity problem entirely.

Solving the complexity problem opened opportunities for suppliers formerly unknown to the automotive industry, namely traditional semiconductor suppliers as well as software developers. It is expected that semiconductor supplier and software developers will be integrated even more in the definition and specification of future electronic control units, communication protocols, and subsequently, entire in-car network architectures.

A detailed analysis of the approach to in-vehicle networking, by model, is offered By IHS Global Insight as a 2D ECU Location Diagram Database covering 85 models of European vehicle manufacturers. A matching database covering the major North American vehicle manufacturers is being developed and should be available during the latter half of 2009.

Additionally, IHS Global Insight maintains detailed model-level analysis of the market for selected electronic control units covering such vehicle domains as Body/Comfort, Powertrain, Chassis, Safety, and Infotainment.

