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The Consumerization of the Automotive Environment: The ITS Data Bus

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ABSTRACT

Automotive development time precludes the timely integration of the latest developments in consumer items such as cellular phones, pagers, portable digital assistants, global positioning systems and other communication, computing and entertainment products into the automobile. Consumers, on the other hand, want access to the latest services and features provided by these devices when traveling. At the same time, consumers do not want to duplicate their expenses by dedicating this equipment to their cars.

This paper will outline a current industry effort to define a solution for meeting the networking needs of these consumer products in the automotive environment.

INTRODUCTION

A variety of products, working alone or as part of a larger system, can help to make traveling a safer, more productive and more enjoyable experience for today's busy consumer. Taking advantage of the newest components and software in the automotive environment will require a communication network in the vehicle which allows components to be easily installed, removed or upgraded, as the consumer's needs or location changes.

The standardization of a communication network protocol that would allow rapidly evolving consumer products to be used in the automotive environment would enable manufacturers of consumer products to design for their use in a vehicle, and would also allow vehicle manufacturers to provide customers an adaptable platform that could take advantage of these products. The consumer would benefit from the ease with which components and features could be added or removed, allowing them to easily "upgrade" the capability of their cars. This can increase the vehicle's effective lifetime, and help maintain the resale value by allowing future owners to perform vehicle upgrades as well.

THE VISION

Advanced electronic systems have been managing critical functions in cars for over 20 years. In fact, approximately a dozen embedded computers control powertrain, safety, and other systems in a typical production vehicle today. The automotive OEMs have spent a considerable amount of time, effort and money to ensure the quality and reliability of these automotive-specific systems is as high as possible.

However, there is a growing trend towards using an ever-increasing number of portable consumer electronic products in the vehicle which provides a unique environment for communications, computer and entertainment products. In addition, the U.S. Department of Transportation's Intelligent Transportation System (ITS) effort to improve the efficiency and safety of surface transportation will require new technology in several consumer-oriented products to achieve their objectives. Auto makers are concerned that the reliability and functionality of existing systems is not compromised by the addition of hardware and software that they did not develop or qualify for use in the vehicle.

Many interested parties are involved in this effort to speed up the integration of consumer products into the vehicle environment. Vehicle manufacturers would like to offer state-of-the-art electronics to customers without being restricted by long design cycles. Customers would like a simple, inexpensive way to install the latest products in their vehicles. Electronics manufacturers would like to design automotive and consumer electronics that can be used in multiple platforms by many different manufacturers. Of course, the semiconductor industry is anxious to supply the enabling technologies to make all of this possible. The biggest obstacle to achieving these goals is that no single communication standard exists today that will enable this ITS vision to be realized [1].

Experts are projecting that a consumer market will develop for ITS products and services that will reach \$29 billion by the 2015 [2]. Figure 1 shows the six different areas that make up the majority of this ITS market [2]. The most rapid growth in this market will come between 2000 and 2005 and will consist mainly of in-vehicle products. Consumers' need for safety, security

and comfort will drive the growth of private sector spending on ITS components. However, a market for commercial fleets with different requirements, such as electronic clearance and credentialing, freight mobility, and on-board safety monitoring is also developing.

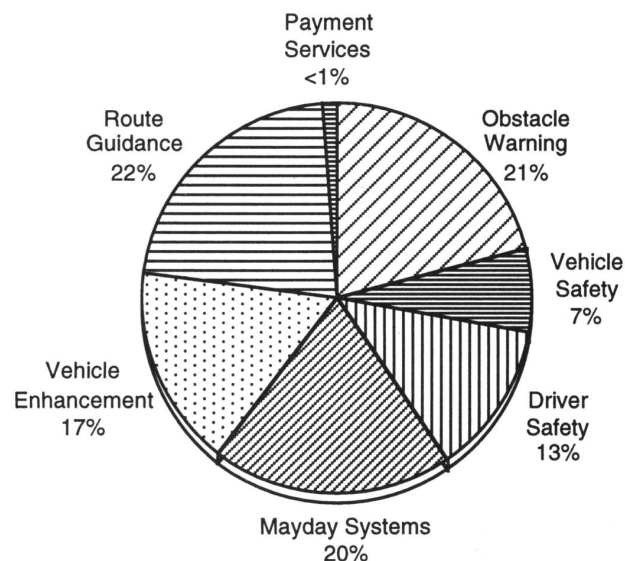


Figure 1 - ITS Consumer Projections for 2015 [2].

To accommodate the integration of this consumer technology in the vehicle, the SAE is developing an ITS Data Bus standard for networking ITS-related consumer products. The goal of the SAE effort is to develop a global solution for ITS system communication, and to help achieve this the membership of the SAE ITS committee includes representatives from all regions of the world. To understand the difficulties in achieving this type of standard, both the vehicle manufacturers' and consumer electronics industries' perspective must be understood.

THE VEHICLE & VEHICLE ELECTRONICS

A limited amount of consumer electronics is already present in today's vehicles, but much of it is not connected to existing vehicle electronics systems. Furthermore, over \$1000 of electronic content is already present on a typical production vehicle in automotive-specific systems such as engine control, various safety systems and body electronics. Vehicle manufacturers also use these electronics systems to meet legislated vehicle requirements for emissions and safety and provide creature comforts and differentiation.

Figure 2 shows the proposed interconnection of the existing automotive electronics systems with the consumer electronics and infrastructure networks which will make up ITS [3]. Just as the ITS products may make use of vehicle system information, many of the existing vehicle systems will be enhanced by the addition of the

ITS Data Bus and access to the consumer electronics systems.

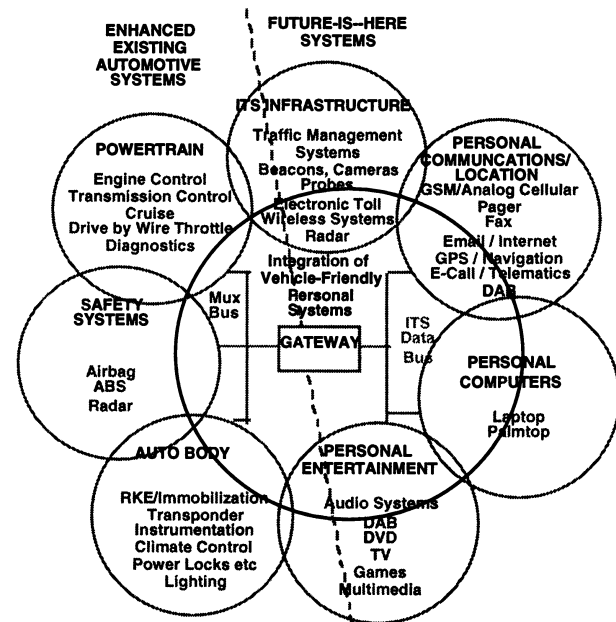


Figure 2 - ITS Data Bus integration with existing vehicle electronic systems.

However, the auto makers want to ensure that the reliability and functionality of existing systems is not compromised by the addition of hardware and software that they did not develop or qualify for use in the vehicle. The safety and security of the existing vehicle systems must be maintained if greater access to them is allowed. There must be a firewall to protect systems and proprietary software that vehicle manufacturers have invested significant time and money to develop and qualify. This is especially true in areas where the software is a major differentiating feature for electronics systems which have similar capabilities in most vehicles, such as memory seat or climate control systems.

Vehicle manufacturers are also concerned with growing cost. The addition of more electronics must be valued and accepted by customers. It will serve no purpose to develop a highly capable system of ITS components which is prohibitively expensive to install and use. This is especially true in the automotive environment, which has traditionally been very cost sensitive.

CONSUMER ELECTRONICS

From the consumer electronics perspective, the consumerization of the automobile is actually decades old. It started when the first radios were installed in vehicles. More recently, portable CD players have been interfaced with the existing vehicle tape player system through ingenious adaptations by entertainment equipment companies. Also, portable wireless products

are routinely brought into the vehicle environment and are expected to work there. However, at this time there is no interaction between these products. The more recent consumer items involve basic wireless communication to and from the vehicle, which is independent of the vehicle itself.

In the last few years, new systems have been made available by several automotive OEMs and other suppliers which combine consumer cellular and global positioning technologies to provide more advanced safety and navigation services. These systems, collectively known as telematics, provide vehicle owners with roadside assistance and emergency services via nationally-accessible customer assistance centers. Examples of these systems include the RESCU (Remote Emergency Satellite Cellular Unit) system from Ford Motor Company, the OnStar system from General Motors Corporation and the AutoLink® system from HighwayMaster, Corp.

For example, AutoLink is a safety, security, information and convenience service for motorists in the United States and Canada that provides a communication link from the car to an information services complex [4]. The vehicle-mounted control unit has a GPS receiver, processor, modem and a wireless transceiver. Future plans for AutoLink include interfacing to existing vehicle systems. This includes the ability to: (1) unlock the doors when the keys are locked inside, (2) link a service center to the vehicle to diagnose on-road engine problems and (3) report diagnostics from other vehicle systems. "Telematics," as they are being called, represent a new class of wireless services for drivers. A single system may integrate several features [5].

These new systems utilize information from existing vehicle systems, but are typically hardwired into those systems. In order to provide the widest range of services possible to the consumer, electronics manufacturers want easy access to a variety of information already available to the vehicle systems, without having to continually meet the more extensive quality and reliability testing requirements of the vehicle manufacturers, which would increase their cost and development cycle time.

A NEW CONSUMER IN-VEHICLE NETWORK

To develop a solution which will meet the in-vehicle networking needs of the ITS market, the Society of Automotive Engineers ITS Division has established an ITS Data Bus committee, which has been tasked with developing the appropriate recommended practices and standards for networking consumer products in the vehicle. The ITS Data Bus, or IDB, is intended to be based on an open, non-proprietary serial communication protocol. To add system functionality, the IDB can be interfaced to the existing vehicle multiplex bus via a gateway, which can allow a selective exchange of data between components on the IDB and components on the vehicle bus. However, an interface to the vehicle bus is not a requirement, since the IDB can operate independent of all vehicle systems. This independence will allow consumer manufacturers the freedom to integrate IDB interfaces into their popular consumer products without the need for performing a full automotive level network qualification. This

independence is important, since, in reality, the ITS Data Bus is a consumer electronics network operating in a vehicle, not simply another automotive network. It is targeted for networking consumer components that are independent from automotive control systems.

While the IDB can function as a truly independent network in the vehicle, the gateway is the key to achieving the full potential of the IDB. This gateway, which should be implemented under the full control of the vehicle manufacturers, will provide the means for vehicle data which can be valuable to IDB applications, such as vehicle speed or fuel economy, to be passed from the vehicle to the IDB. This gateway can also allow, under tightly controlled conditions, information originating on the IDB to be transmitted onto the vehicle bus. This gateway should only allow information transfers between the IDB and the existing vehicle network that have been shown by formal validation to have no detrimental effects on the safe operation of the existing vehicle systems. It really acts as a firewall, controlling and limiting the flow of information between the two networks to only that information which is valuable to both. The ITS Data Bus approach to interfacing a network of consumer electronics components and systems with existing vehicles systems is demonstrated in Figure 3 [6].

To achieve the goal of developing an independent, non-proprietary bus for consumer manufacturers to utilize, the ITS Data Bus committee is working, as a whole and through several dedicated task forces, to develop the appropriate IDB documents. The first document produced by the ITS Data Bus committee is SAE J2355 - ITS DATA BUS ARCHITECTURE REFERENCE MODEL. This document, which was initially approved by committee ballot in April, 1997, is an information report which outlines the goals and requirements of the ITS Data Bus. It describes the ITS Data Bus network architecture, indicating the roles the ITS Data Bus, the vehicle network and the gateway would play in the system.

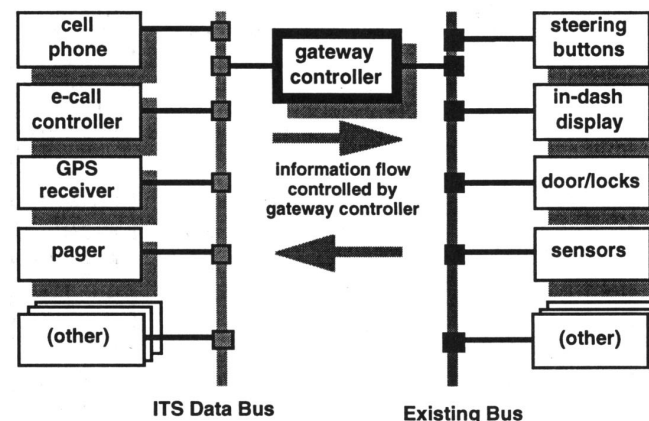


Figure 3 - Dual Bus Architecture.

An architecture reference model shown in Figure 4 shows the interrelation of software, hardware and communications on the proposed ITS Data Bus [6].

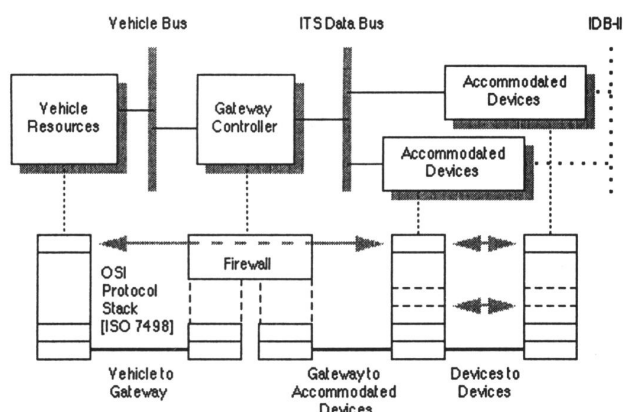


Figure 4 - ITS Data Bus Architecture Reference Model

To address the development of the ITS Data Bus protocol itself, the ITS Data Bus committee has formed several task forces, each charged with developing a particular section of the IDB protocol. The resulting ITS Data Bus documents will be published under the umbrella SAE document SAE J2366 - ITS DATA BUS. In order to streamline the IDB development process, the J2366 document has been divided into sections based upon the International Standards Organization (ISO) Open Systems Interconnect (OSI) reference model for network protocols (Figure 5).

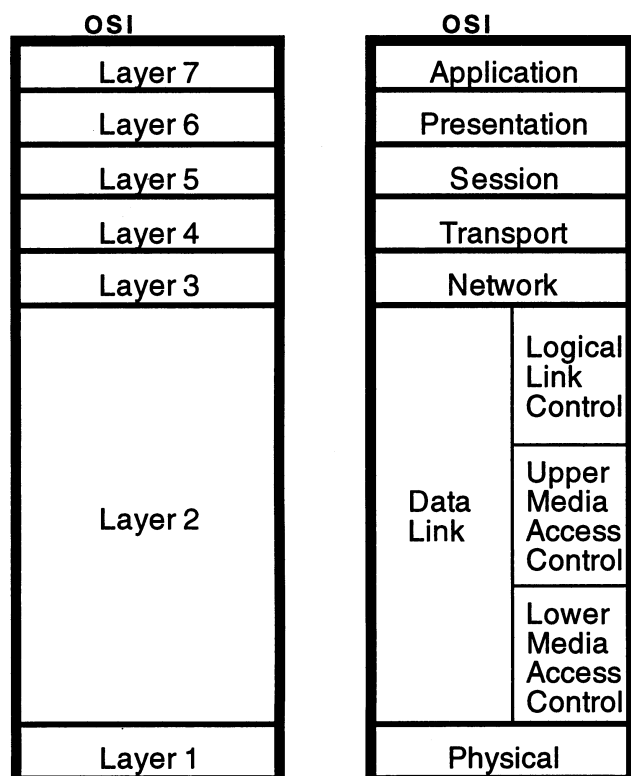


Figure 5 - ISO OSI Reference Model for Network Communication Protocols

SAE J2366 is currently divided into three parts, J2366/1, J2366/2 and J2366/7, with a different ITS Data Bus task force working on each. Each of these documents will address the corresponding OSI reference model layer. J2366/1 will define the physical layer targeted for initial implementations, including allowable media, electrical parameters and data signaling. J2366/2 will define the Data Link layer of the protocol, including the message structure and the low-level communication protocol itself, and J2366/7 will define the application layer, including the messaging and data encapsulation to be used. It is expected that J2366/7 will be a living document, with editions and modifications made as additional applications/uses of the ITS bus are identified. As the IDB protocol is defined, the additional protocol layers (presentation, session, transport and network) will be addressed by corresponding J2366/x documents as needed.

Another document being developed by a committee task force is a gateway reference model for implementing the gateway/firewall between the ITS bus and the existing vehicle data bus. This document, SAE J2367 - ITS DATA BUS GATEWAY, is being developed with significant inputs from the automotive OEMs, particularly from members of the SAE Committee on Vehicle Networks for Multiplexing & Data Communications.

The gateway reference model is intended to define not only the physical connections to the vehicle network and the IDB, but also provide a detailed list of the services to be shared between the two networks, and the bandwidth impact any messages passing from the IDB through the gateway can have on the vehicle network. Because of the potential impact on the vehicle network, it is imperative that the automotive OEMs agree up front to the services passed through the firewall. Without their cooperation, the potential network interface problems could prevent the IDB from taking full advantage of the gateway interface.

A conformance document, SAE - J2368 CONFORMANCE TESTING PROCEDURE is also being developed by an ITS Data Bus committee task force. This document will outline the conformance testing procedures which will be necessary to ensure that products developed with an ITS Data Bus interface meet the electrical and data link layer requirements defined in SAE J2366.

The end goal of this committee is to produce a series of protocol documents which will be jointly balloted by both the SAE and the Electronics Industry Association (EIA). This is necessary to ensure that the protocol is accepted by both the automotive OEMs/suppliers and by the consumer product manufacturers. To meet this goal, the SAE ITS Data Bus committee has representatives of EIA-CEMA (Consumer Electronics Manufacturing Association) as current members, and a constant communication channel between the two organization has been established. In addition, the SAE has received government funds from the United States Department of Transportation to help defray the cost of developing the protocol specification. Part of the requirements for this funding is to have protocol specifications ready for ballot by the end of 1997. While this is a very aggressive goal, it is one that can be met.

ITS DATA BUS NETWORK REQUIREMENTS

As detailed in the SAE J2355 Reference Architecture document [8], several overall goals have already been established for the ITS data bus. These goals include:

- The development of a completely open protocol, not owned by any one entity, to ensure wide acceptance and use with "no strings attached."
- Keeping the connect cost per node as low as possible, with a target of <\$1.00.
- Requiring no network reconfiguration, either in the physical layer or at the component level, to add a new component to the system.
- Ensuring that the communication network does not interfere with the operation of the vehicle, particularly in regards to the gateway/firewall interface with the existing vehicle bus.
- Providing the ability for the protocol at the application layer to allow security and authentication services, when necessary, especially when transactions between the vehicle and some external service provider take place.

Fundamental requirements which the network must meet in order to maximize the application capabilities include: (1) no user configuration - hot switching, (2) plug & play and (3) self identification of nodes added to the network. Furthermore there should be no specific component requirements - no one piece required for the system to work. The components the user can have in a system should only be determined by what services/capabilities they want - desired applications can run on any platform that supports the capability: PDA, in vehicle PC, navigation device with user interface/display, etc.

The network must support low power operation, so that operation in the vehicle with the key off will not drain the battery. However, the system must allow any node to have the capability of waking up the network, if a particular application requires it.

The protocol should be physical layer independent. No particular network topology is required - but a bus is preferred. However, passive or active star, subnets, or other topologies are not excluded. In addition, gateways to other protocols should be viable, depending upon the desired capability of the components in the system. There could, in fact, be multiple gateways, i.e., USB or IrDA gateway to PCs or a wireless port for a wireless network, etc. The vehicle network could also interface to multiple networks. However, the gateway into the vehicle network must pass all of the rigorous qualification tests performed for existing vehicle electronics.

The network Data Link layer should support peer-to-peer communication and broadcast communication to fully support the possible range of distributed applications which can be implemented on this system.

A two-tiered bus structure for the ITS Data Bus has been proposed which will allow a wide variety of applications to be supported, without requiring the cost of a high bandwidth network. In the future, as components supporting services such as full motion video and Dolby AC-3 audio become available which will

require a high-bandwidth bus, a second tier network can be implemented to support these functions. Overall, this prevents all applications from incurring increased cost to support network bandwidth that they do not need.

ITS DATA BUS PROTOCOL - Several proposals have been presented to the ITS Data Bus committee for consideration as potential solutions for the IDB, including some existing protocols such as D2B Optical, Universal Serial Bus (USB), and ANSI 878.1 (ARCNET). There would certainly be obvious advantages in selecting an already proven protocol. However, each protocol discussed has had some limiting functionality which has prevented it from supporting all of the identified requirements. For example, D2B Optical, while it has more than enough available bandwidth to meet the network needs, currently has a node connect cost which exceeds the cost target by 4 to 5 times. Likewise, USB, which also has more than adequate bandwidth and in some instances meets the IDB cost target, has been implemented as a true master-slave network, preventing it from meeting the peer-to-peer communication requirement.

The desire of the ITS Data Bus committee is to first try to adopt a solution for the IDB which meets all of the established requirements. If this proves to be unfeasible, the committee will have to revisit the requirements document, and determine what compromises might be made to allow an existing protocol to be adopted for the IDB. Because of this goal to meet the requirements as currently defined, the three SAE J2366 task forces are currently developing a protocol proposal based upon the widely available Universal Asynchronous Receiver / Transmitter (UART), and the industry-standard RS-485 physical layer.

Utilizing the UART for the LMAC sub-layer of the Data Link layer will easily allow the network cost target to be met, while at the same time providing IDB implementers a wide array of microcontrollers, from many semiconductor suppliers, to choose from. Adopting the UART also allows a great deal of flexibility in the development of the remainder of the Data Link layer. Currently, several options for a UART-based Data Link layer are being considered, including token-passing and Carrier Sense, Multiple Access with Collision Detection (CSMA / CD) network implementations. The final determination will be made based on what meets the network requirements most efficiently.

Targeting RS-485 as the initial physical layer provides a cost-effective, twisted pair solution which allows multiple physical topologies, while meeting the requirement of supporting a multidrop bus logical topology. Also, because the UART and RS-485 have been used for years by the Truck and Bus industry for the SAE J1708 protocol, there is already a considerable pool of experience within the automotive industry for this type of network solution.

SEMICONDUCTOR TECHNOLOGY FOR THE GATEWAY - As described above, the gateway shown in Figure 2 is a key technology to the success of the ITS data bus. Since several other communication protocols may exist in a vehicle, translation between protocols, rather than simply bus-to-bus routing, will frequently be required. Examples of other protocols which are

currently being used for in-vehicle networks include SAE J1850, CAN and SAE J1708. Because of the functionality the gateway between these networks will be required to perform, a microcontroller (MCU) will be necessary to provide the intelligence that this network-to-network translation requires. Ideally this MCU will have the integrated capability to communicate using one or even both protocols, to allow an easy gateway implementation. In the worst case, the MCU will need to utilize a separate communication peripheral for each protocol.

As previously mentioned, a UART-based protocol is currently being considered for the ITS Data Bus. Since hundreds of MCUs already exist with a UART interface, software development will be all that is required, once protocol development is complete, to facilitate the IDB network interface.

One example of an MCU optimized for acting as the gateway between an existing vehicle bus and a UART-based IDB network is the MCU illustrated in Figure 6, the MC68HC912B32. This device has UART (SCI) and SAE J1850 interface modules integrated with a 68HC12 CPU. With the simple addition of the appropriate physical layer drivers, this type of device would be well suited to act as the gateway between an SAE J1850 data bus in a vehicle and the ITS Data Bus.

Once the protocol standard is complete, semiconductor manufacturers will begin to define new products optimized for IDB communication. Products with expanded-functionality UARTS that allow better utilization of CPU bandwidth are among the future products that can be expected. Until then, existing UART components are available from a number of suppliers.

OTHER SEMICONDUCTOR TECHNOLOGIES - Implementing the various aspects of consumerization will require several semiconductor technologies in addition to microcontrollers and ASICs that address the gateway and the communication protocol. For example, RFID tags require RF semiconductors and obviously any RF communication to-from the vehicle will use RF technology. As mentioned earlier, excessive cost is a major concern for vehicle manufacturers when consumer electronics are added. Combining these technologies in a full system-level approach can avoid unnecessary cost and complexity.

Global Positioning System (GPS) components are a good example where multiple semiconductor technologies are required in a new consumer/vehicle application. GPS technology, which was originally design with typical military system sophistication and cost, is among the consumer products that are finding growing acceptance in vehicles. GPS is being used to cost-effectively implement vehicle positioning, which is an important part of ITS-related applications such as navigation, safety and security systems. Figure 7 demonstrates three of the semiconductor technologies which are combined to form a GPS system. While the cost of this technology has dropped dramatically in recent years, a roadmap to further system cost reduction is essential to the success of this and other new consumer systems intended for ITS-related applications.

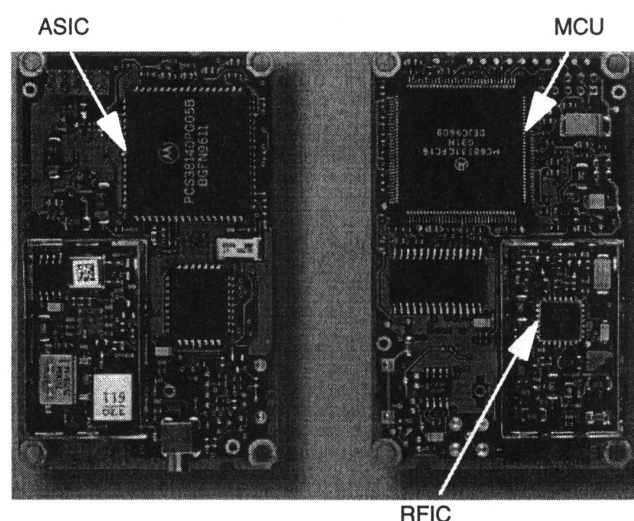


Figure 7 - Front and back of GPS board with semiconductor chipset. RFIC, ASIC and microcontroller technologies provide the basics for the system.

SUMMARY

The ITS Data Bus being developed by the SAE promises to meet the demands of vehicle and electronics manufacturers, as well as consumers. To accomplish this the standard must be open, easily implemented, and cost effective, both for the consumer electronics manufacturers and the automotive OEMs. If the IDB meets these goals, and the functional goals which have been outlined in the various reference architecture documents, it will enable an entirely new generation of consumer devices to be used in the automotive environment, making travel safer, more efficient and more pleasurable. It will allow current year electronics to be installed in new vehicles, and it will alleviate the need for the consumer to duplicate new gadgets and technology in order to achieve the maximum benefit during the hours spent driving.

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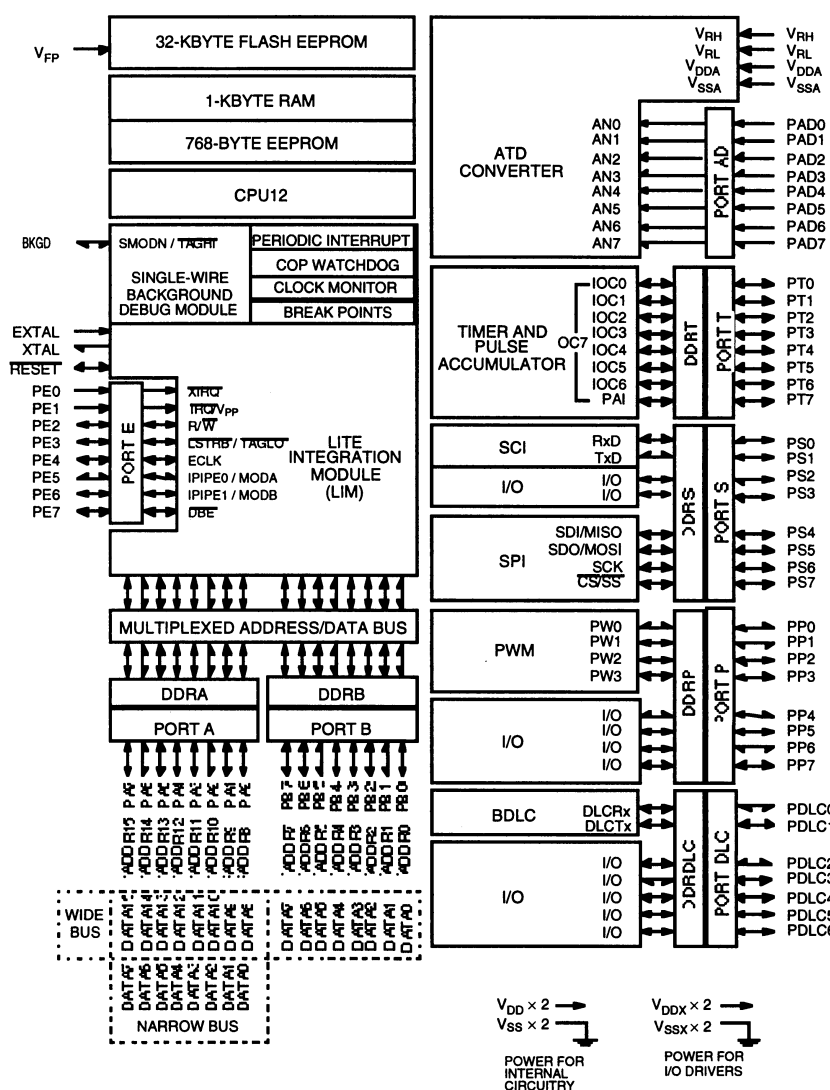


Figure 6 - Example of existing microcontroller, the MC68HC912B32, which can support both the SAE J1850 and UART-based protocols at the Data Link layer.

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