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Telematics Digital Convergence – How to Cope with Emerging Standards and Protocols

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Digital convergence, in recent history, has been prevalent in the consumer equipment domain and the design engineers in this area have been struggling with a plethora of emerging standards and protocols. What lessons can we learn from their struggle? The same dilemmas now exist in in-vehicle telematics and infotainment systems but with the added issues of extremes of temperature, safety, security, and time in market.

This paper first describes and positions each emerging in-vehicle standard and their respective strengths and weaknesses. It then explores the designers dilemma: how to build flexible and scalable system architectures which will allow the time in market of telematics platforms match that of the host vehicle while still communicating internally and to other external systems. It then goes on to discuss enabling technologies and how to implement reconfigurable and upgradeable telematics platforms that can be designed for protocols today and in the future.

Introduction

In-car electronics content has seen tremendous growth in recent years, not only in the traditional body control and engine management areas but in the new areas of driver assistance systems and telematics type applications. Figures recently published by the IEEE we have seen annual rises in car electronics of up to 16% and they announced that by 2005 electronics will account for 25% of the cost of a mid-size car.

One of the high growth area is telematics systems (the convergence of mobile telecommunications and information processing in cars) which exhibit characteristics more like those of consumer products, i.e., short time to market, short time in market, and changing standards and protocols. These characteristics are the complete opposite to those of traditional in-car electronics, which could potentially cause issues from design right through to manufacture and servicing. These issues have an impact on the way engineers are approaching designs and also choosing in-car bussing systems.

The traditional in-car bussing systems based on a serial, event triggered protocol, such as CAN and J1850, have been used in the body control area successfully for many years. Bandwidth and speed restrictions will make it difficult for these to be used in the newer real time applications. A range of new bussing standards have been emerging such as time-triggered protocols and optical data busses to meet these new data throughput challenges.

In-car buss networks can be divided into four main categories:

- **Body Control –** covering data and control signals between car seat controls, dashboard / instrument panel clusters, mirrors, seat belts, door locks, and airbags (passive safety).
- **Entertainment and Driver Information Systems –** communication and control between radio, Web browser, CD / DVD player, telematics, and infotainment systems.
- **Under the Hood –** networking between ABS brakes, emission control, power train, and transmission.
- **Advanced Safety Systems –** data transfer between brake-by-wire, steer-by-wire, and driver assistance systems (active safety).

We will look at each area in turn and discuss the different vehicle emerging standards and protocols that apply to each area. Figure 1 and Figure 2 show the various in-car networks and their intended applications.

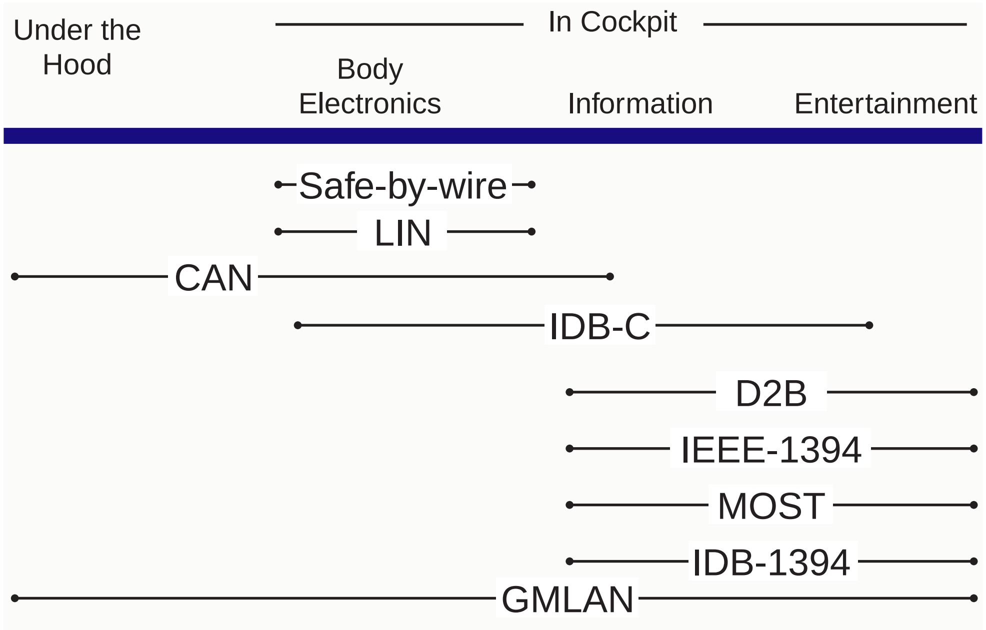

Figure 1: **Applications for In-Vehicle Networking**

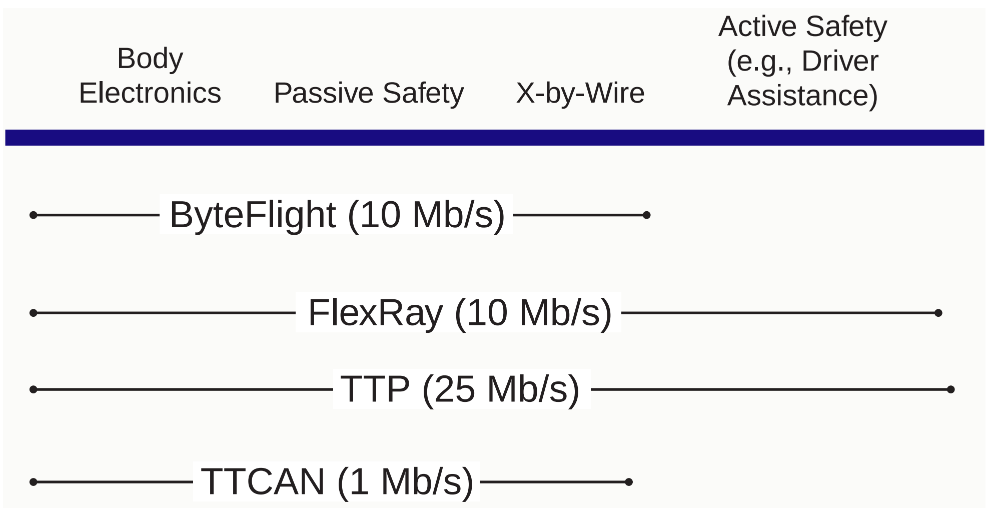

Figure 2: **Safety Critical Busses**

Body Control and "Under-the-Hood" Busses

Controller Area Network (CAN)

In the mid-1980s, Bosch developed the Controller Area Network (CAN), one of the first and most enduring automotive control networks. CAN is currently the most widely used vehicle network with more than 100 million CAN nodes installed. A typical vehicle can contain two or three separate CANs operating at different transmission rates. A low speed CAN running at less than 125 Kb/s for managing the body control electronics such as seat and window movement controls and other simple user interfaces. Low speed CANs have an energy saving sleep mode in which nodes stop their oscillators until a CAN message wakes them. Sleep mode prevents the battery from running down when the ignition is turned off.

A higher speed (up to 1 Mb/s) CAN runs more real-time critical functions such as engine management, antilock brakes, and cruise control. Controller Area Network protocols are becoming standard for under-the-hood connectivity in cars, trucks, and off-road vehicles. One of the outstanding features of the CAN protocol is its high transmission reliability, which makes it well suited for this type of application. The CAN physical layer is required for connections to under-the-hood devices and in-car devices.

CAN has found its way into general industrial control applications such as building management systems and lift controllers but more surprisingly, it is now being considered for use in telecommunication type applications such as Base Transceiver Stations (BTS) and Mobile Switching Centers (MSC) equipment. This is due to CANs protocol error management, fault isolation, and fault tolerance capabilities.

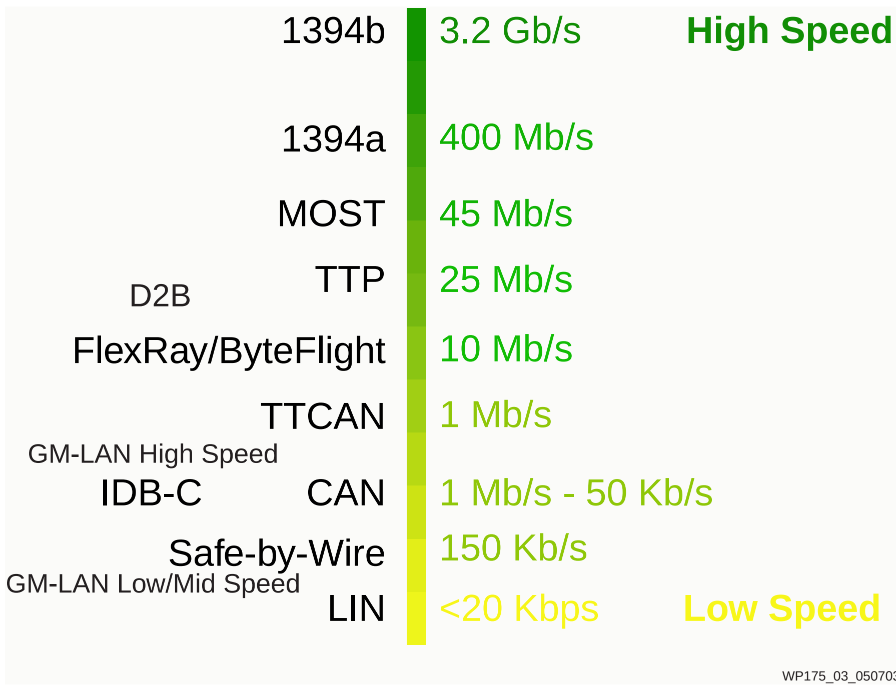

Figure 3: **In-Car Network Speeds**

Local Interconnect Network (LIN)

The Local Interconnect Network (LIN) has been developed to supplement CAN in applications where cost is critical and data transfer requirements are low. Developed in 1998, the LIN consortium comprises car manufacturers Audi, BMW, DaimlerChrysler, Volvo, and VW. LIN is an inexpensive serial bus used for distributed body control electronic systems in vehicles. It enables effective communication for smart sensors and actuators where the bandwidth and versatility of CAN is not required. Typical applications are door control (window lift, lock, and mirror control), seats, climate regulation, lighting, and rain sensors. Outside the automotive sector LIN is used for machine control as a sub-bus for CAN.

Local interconnect network (LIN) is a UART-based, single-master, multiple-slave networking architecture originally developed for automotive sensor and actuator networking applications. The LIN master node connects the LIN network with higher-level networks, like controller area network (CAN), extending the benefits of networking all the way to the individual sensors and actuators.

Entertainment and Driver Information Systems

Car infotainment and telematics devices, especially car navigation systems, require highly functional operating systems and connectivity. Until now the existence of both open-standard and proprietary stand-alone buses has worked quite well. But because of their integrated nature, future systems will require electronic subsystems to work together.

By relying on open industry standards, all key players from manufacturers to service centers and retailers, can focus on delivering core expertise to the end user, rather than expending the time and effort it would take to develop separate, incompatible designs for specific vehicles or proprietary computing platforms. Future systems will be highly integrated, open and configurable.

Several organizations and consortia are leading the standardization efforts, including the MOST Cooperation, the IDB Forum, and the Bluetooth™ Special Interest Group (SIG).

Media Oriented System Transport (MOST)

MOST networks, managed by the MOST Cooperation, are used for connecting multiple devices in the car including car navigation, digital radios, displays, cellular phones, and DVDs. MOST technology is optimized for use with plastic optical fiber, supports data rates of up to 24.8 Mb/s, is highly reliable and scalable at the device level, and offers full support for real-time audio and compressed video. MOST technologies are strongly supported by German automakers and suppliers. The MOST bus is endorsed by BMW, Daimler Chrysler, Harman/Becker, and OASIS Silicon Systems. A recent notable example of MOST implementation was its use by Harman Becker in the latest BMW 7 series.

Intelligent Transport System Data Bus (IDB)

The IDB Forum manages the IDB-C and IDB-1394 buses and standard IDB interfaces for OEMs for the development of after-market and portable devices. Based on the CAN bus, IDB-C is geared toward devices with data rates of 250 Kb/s. Applications for IDB-C include connectivity through consumer devices such as digital phones, PDAs, and audio systems.

IDB-1394 (based on IEEE-1394 Firewire) is designed for high-speed multimedia applications that require large amounts of information to be moved quickly on a vehicle. IDB-1394 is a 400 Mbaud network using fibre optic technology. Such applications include DVD and CD changers, displays, and audio and video systems. IDB-1394 also allows 1394 portable consumer electronic devices to connect and interoperate with an in-vehicle network. Zayante is one supplier who currently has 194 physical layer devices for the consumer market and demonstrated IEEE-1394 with Ford Motor Company. The demonstration included plug and play connections of a digital video camera, Sony Playstation II as well as two video displays and a DVD player.

The Digital Data Bus (D2B) Communications Network

The Digital Data Bus (D2B) is a networking protocol for multimedia data communication integrating digital audio, video and other high data rate synchronous or asynchronous signals and can run up to 11.2 Mb/s. The data bus can be built around either unshielded twisted pair (UTP), named "SMARTwire" or a single optical fibre. This communication network is being driven by C&C Electronics in the UK and has seen industry acceptance from Jaguar and Mercedes Benz. For example, the Integrated Multimedia Communication System that has been deployed in the Jaguar X-Type, S-Type, and new XJ saloon.

D2B optical is self configuring on start up, adapting to what ever devices are present on the network at the time. This means that new devices can easily be fitted to the network at any time during its life. Car makers that use the D2B optical multimedia system will find the standard evolves in line with new technologies as they are introduced. The standard will be backwards compatible ensuring that new products can be added to a cars system during its life time. D2B optical is based on an open architecture which simplifies expansion as no changes to the cable harness are required when adding a new device or function to the optical ring. The buss uses just one cable, either a polymer optical fibre or copper to handle the in-car multimedia data and control information. This gives better reliability, fewer external components and connectors and a significant reduction in overall system weight.

Bluetooth

Bluetooth wireless technology is a low-cost, low-power, short-range radio technology for mobile devices and for WAN/LAN access points. It is a computing and telecommunications industry specification that describes how mobile phones, computers and PDAs can easily interconnect with each other, and with home and business phones, and computers using a short-range wireless connection.

A driver will be able to use a Bluetooth cordless headset to communicate with a cellular phone in his or her pocket, for example. As a result, driver distraction can be reduced and safety increased. The automotive industry has created a special-interest group (SIG) for the definition of Bluetooth car profiles. The SIG includes such members as AMIC, BMW, DaimlerChrysler, Ford, GM, Toyota, and VW. One example of Bluetooth deployment in cars is Johnson Controls BlueConnect™ which is a hands-free system that allows drivers to keep their hands on the wheel while staying connected through a Bluetooth-enabled cellular phone.

There has however been some concern voiced over the long term support of Bluetooth devices and how noisy in-car environment will effect its operation. The lifecycle of cars and other vehicles is very much longer than that for consumer products or mobile phones so this mismatch between support and service timescales must be addressed by silicon manufacturers. However the Chrysler Group showed the use of Bluetooth connectivity in its vehicles at Convergence 2002 recently.

Advanced Safety Systems

FlexRay

FlexRay is a new network communication system targeted specifically at the next generation of automotive applications or "by-wire" applications. The by-wire applications demand high-speed bus systems that are deterministic, fault-tolerant, and capable of supporting distributed control systems. BMW, Daimler Chrysler, Philips Semiconductors, Motorola, and the newest member, Bosch, are working together to develop and establish FlexRay as the standard for next generation applications.

The FlexRay Communication System is more than a communications protocol. It also encompasses a specifically designed high-speed transceiver, and the definition of hardware and software interfaces between various components of a FlexRay "node". The FlexRay protocol defines the format and function of the communication process within a networked automotive system.

The technology is designed to meet key automotive requirements like dependability, availability, flexibility, and a high data rate to complement the major in-vehicle networking standards - CAN, LIN, and MOST.

With the increasing amount of data communication between the vehicle's electronic control units (ECUs), it is important that a high data rate can be achieved. FlexRay is initially targeted for a data rate of approximately 10Mbit/sec; however, the design of the protocol allows much higher data rates to be achieved.

FlexRay, as a scalable communication system, allows synchronous and asynchronous data transmission. Depending on the application needs, the communication cycle can be purely synchronous, purely asynchronous, or a mixture of both. The synchronous data transmission enables time triggered communication to meet the requirement of dependable systems. The asynchronous transmission, based on the fundamentals of the byteflight™ protocol, allows each node to use the full bandwidth for event driven communications.

FlexRay's synchronous data transmission is deterministic with a minimum message latency and message jitter guaranteed. FlexRay supports redundancy and fault-tolerant distributed clock synchronization for a global time base, thus keeping the schedule of all network nodes within a tight, predefined precision window.

Time Triggered Protocol (TTP)

Designed for real-time distributed systems that are hard and fault tolerant, the time triggered protocol (TTP) ensures that there is no single point of failure.

TTP is the mature network solution that is low cost and can handle safety-critical applications. TTP silicon support has been available since 1998. Second generation silicon, supporting communication speeds of up to 25 Mb/s, is available today. TTP has been adopted by aerospace companies due to its rigorous and plain safety approach. TTA Group, which is a governing body for time triggered protocol, has a membership including Audi, PSA, Renault, NEC, TTChip, Delphi, and Visteon.

Time Triggered Can (TTCAN)

The communication in the classic CAN network is event triggered; peak loads may occur when the transmission of several messages is requested at the same time. CAN's non-destructive arbitration mechanism guarantees the sequential transmission of all messages according to their identifier priority. For real-time systems, a scheduling analysis of the whole system has to be done to ensure that all transmission deadlines are met even at peak bus loads. To overcome this potential issue TTCAN was conceived.

TTCAN is an extension of the CAN protocol and has a session layer on top of the existing data link layer and physical layers. The protocol implements a hybrid, time triggered, TDMA schedule, which also accommodates event-triggered communications. TTCANs intended uses include engine management systems and transmission and chassis controls with scope for x-by-wire applications.

FPGAs Alleviate the Design Dilemma

The next few years will be a proverbial mine field for automotive electronics designers and choosing the correct data bus will be crucial to the success of integrating and testing units in production and long after the car has rolled off the assembly line. For Tier 1 suppliers and aftermarket unit design companies the problem is amplified as they will potentially supply units to many OEMs who will invariably all opt for different data busses and protocols. The industry has seen a huge shift of design philosophy away from designing a different unit for every OEM and indeed every car model to reconfigurable platforms. Reconfigurable platforms cleverly partitioned between software and reprogrammable hardware will allow the designer to change the choice of system bus or interface late in the design process and even in production. The reconfigurable system concept also enables different standards and protocols to be tried, tested and put on road trials and if you they are not found to be suitable another bus interface can be loaded into the system and tried out until the best configuration is found.

While this may seem like a designers nirvana and unobtainable it can be realized today by utilizing programmable logic devices (PLDs) in the form of Field Programmable Gate Arrays (FPGAs) and Complex Programmable Logic Devices (CPLDs). PLDs can hand back to the designer the control over all phases of design from prototype, through pre-production and all phases of production. This flexibility and control can be lost when developing systems based on ASICs and ASSP devices. PLDs can also alleviate over stocking and inventory issues as these generic devices can be used across many projects and are not application specific like ASICs. Once the programmable logic based unit is on the road it can even be reconfigured remotely via a wireless communication link to allow for system upgrades or extra functions.

The reconfigurable hardware platform can be brought to market quickly by utilizing drop in IP Core blocks. For example, Memec Design recently announced the availability of a cost optimised CAN core interface. The Memec CAN core contains the complete data link layer, including the framer, transmit and receive control, error core design, and flexible interface enables access to each internal status and frame reference. Bit rate and sub-bit segments can be configured to meet the required timing specification of the connected CAN bus. Error counters and error interrupt events report errors. The core is designed to provide a bus bit rate of up to 1 Mb/s, with a minimum core clock frequency of 8 MHz. The CAN Core can provide an interface between the message filter, the message priority mechanism and various system functions such as sensor/activator control. Alternatively, it can be embedded into a system application interfacing with the microprocessor and various peripheral functions. Another example is the LIN core available from Intelliga. The LIN core, iLIN, is supplied as a reference design that uses a synchronous 8-bit general purpose micro-controller interface with minimal buffering for the transportation of message data. In addition, the reference design includes a single slave message response filter and a software interface that allows the connected micro-controller to perform address filtration.

IP Cores can be used as part of a more complex design to provide the interface to the CAN or LIN bus instead of using a discrete device. Reducing component count has many benefits including lowering overall system cost, reducing inventory, increasing system reliability and also can help reduce PCB complexity and layers. Figure 4 shows a generic in-car multimedia design showing the use of the CAN core coupled with PCMCIA interface, PCI bridging, IDE interface plus other functions. These functions can be modified, changed or enhanced during the design phase or modified depending on the end customer requirements. In this way one PCB can be used for many customers with customisation taking place within the FPGA instead of at the board level. This model can be extended to include modification or upgrades in the field utilising a wireless connection to reconfigure the FPGA in system.

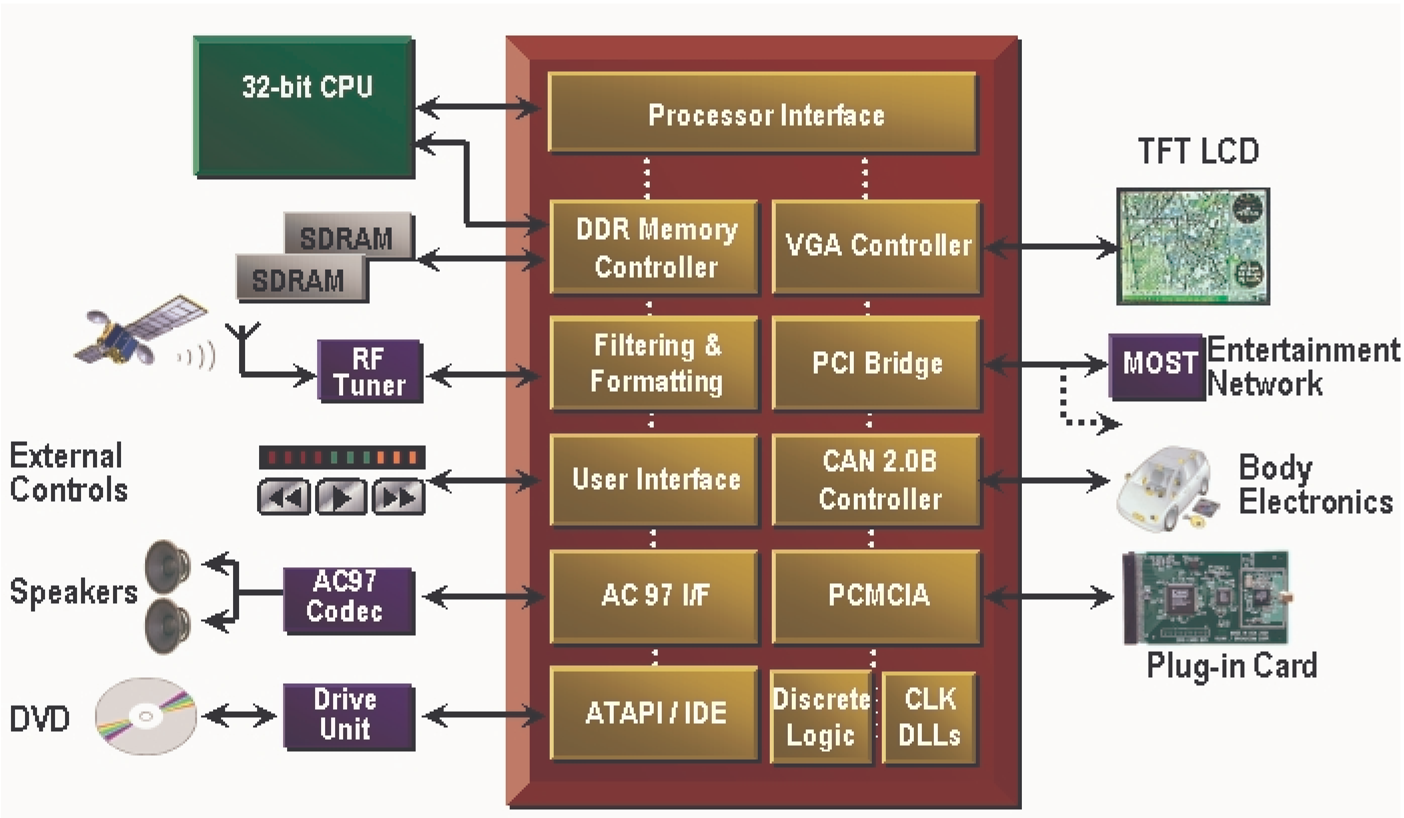

Figure 4: **In-Car Multimedia Design Showing Functions Embedded in an FPGA**

Conclusion

It is clear that there are numerous emerging in-car bussing systems providing data and control signals to and from nodes as diverse as door locks to highly sophisticated multimedia terminals. The needs of each bus are different, at the low end we need low cost relatively low speed busses and at the high end we require high speed, real time data transfer over optical media. Many automotive OEMs are backing more than one standard due to uncertainties over which one will eventually prevail. As a designer these uncertainties can delay development and ultimately lead to lost revenue. A solution designers are turning to are reconfigurable systems based on FPGAs that can be reprogrammed to accommodate changing standards and protocols late in the design process and even in production. The bus interface can take the form of pre-verified drop in IP Cores that can safe time and effort and thus increase time to market.

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Revision History

The following table shows the revision history for this document.

Date	Version	Revision
05/27/03	1.0	Initial Xilinx release.