Approaches to the Development of the In-Vehicle LAN System

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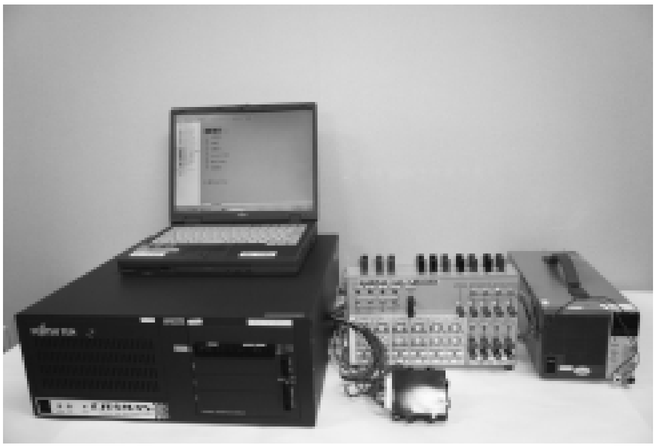

Abstract

Nowadays, the electronic control system has become more intelligent and advanced to make cars safer , more comfortable and environment-friendly. With this trend, it becomes more difficult for an electronic control unit to centrally control all the system in a vehicle, which leads to decentralized control by using the in-vehicle LAN or integrated control by multiple electronic control units. This paper introduces both our approaches to the development for the in-vehicle LAN system that is becoming crucial platform technology for the electronic control system, and our development of the gateway technology for networking that is one of our current development themes.

1 Introduction

Having entered the 21st century, the demand for environmental considerations, safety, and comfort of cars is growing further. The number of electronic control units (hereinafter referred to as ECUs), as a device to meet the demand, has increased year after year. Approximately 100 units of ECUs are equipped in a high-end vehicle where one or more types of LAN system are used for concerted or integrated control by sharing information from sensors and/or an actuator function among ECUs. Most of our developed ECUs (for engine control or other purposes) can be applied to the in-vehicle LAN system, and we, as an ECU supplier, have developed ECUs, positioning the in-vehicle LAN system as one of the important element technologies. This paper outlines the technology of the in-vehicle LAN system, which we have worked on, and the gateway technology that is currently under development.

2 Approaches to the development of the in-vehicle LAN system

2.1 History of the in-vehicle LAN system

In the 1980s, few ECUs were adopted in cars even in the North America and in Europe, although a communication protocol for the in-vehicle LAN system had already been developed. At that time, most of the ECUs were directly connected to others, and the universal asynchronous serial (UART) communication was used for them in many cases. In the mid-1990s, as the number of ECUs increased and the request for sharing information collected by one sensor among multiple ECUs arose, car manufacturers began to install in-vehicle LAN systems in full scale since the physically direct connection had problems of cost, reliability and installation. Around that time, FUJITSU TEN developed a gateway ECU that is applicable with the communication protocol for body control system, BEAN (Body Electronics Area Network), developed by TOYOTA. This is the ECU that had a gateway function to link information by connecting BEAN with ECUs, such as an anti-theft ECU that was available as a dealer optional when buying a car. In recent years, LIN (Local Interconnect Network) has been widely used as the local BUS for the body control system.

In the 2000s, the in-vehicle LAN system started to be installed as a standard feature of the car and its installation is rapidly growing to meet the need of exchanging a deal of information among ECUs for engine control, brake control, and other purposes, to improve performance of "driving, turning, and stopping" and better function of car diagnosis. CAN (Controller Area Network) is the common interface standard for power train control at present. In 2002, we conducted our first full-scale development of a CAN product called Translate ECU. The Translate ECU is a type of gateway ECUs, which converts protocols in order to connect to the CAN the ECU that only supports conventional serial communications by physically direct connection. Since the Translate ECU, most of our ECUs whose major function is engine control have been equipped with a communication function with CAN.

Fig.1 Gateway ECU (left) and Translate ECU (right) of FUJITSU TEN

2.2 Approaches to the development of evaluation technology for in-vehicle LAN system

As major communication protocols such as LIN and CAN are standardized by standards bodies including International Organization for Standardization (ISO), the efficiency of ECU design has been improved. However, the in-vehicle LAN structure (the number of EUCs to connect, wiring diagram, properties of electronic devices, etc.) is different depending on type of cars even at one car manufacturer, and thus LAN design requirements are different from one type of cars to another. Under these circumstances, advanced evaluation technologies for the in-vehicle LAN system are necessary to provide ECUs that have a reliable communication function. FUJITSU TEN has developed original evaluation technologies early on, focusing on that point. In addition to the evaluation tests designated by auto manufacturers, we have conducted our original tests to improve quality of our ECUs. When conducting an evaluation test simulating an actual in-vehicle LAN structure, normally, you have to check a huge number of combination patterns because disconnections and/or short circuits of communication wirings, and abnormal flames should be checked at each point. In 2003, FUJITSU TEN developed and introduced an automatic evaluation device (MCC: Multi Communication Checker) to improve efficiency and quality of the evaluation (Fig. 2).

FUJITSU TEN developed the HIL (Hardware In the Loop) simulator (product name CRAMAS) originally for in-house use to improve efficiency in our ECU development. Today, we provide it to many customers beyond our company. We customized CRAMAS for automatic evaluation of in-vehicle LAN ECU to create MCC, which realizes an efficient evaluation. The introduction of MCC slashes the evaluation process and enables evaluation without relying on workers to obtain stable results. Moreover, by using MCC, evaluation patterns can be easily added and evaluation technologies are effectively accumulated. Since it is compatible to the communication protocol of CAN and LIN, at present, auto manufacturers and ECU suppliers use MCC, too.

Fig.2 CRAMAS MCC

＜Features of CRAMAS MCC＞

①Efficient evaluation of functions

・In-House achievement) 55% reduction in evaluation process

②Improved reliability of evaluation result

・Stable results without relying on evaluation workers

③Easy accumulation of evaluation technologies

・Advanced GUI function allows easily creating evaluation patterns and registering them in database.

2.3 Technological trend of the in-vehicle LAN system

Since around 2005, new sensors including radars, cameras and others that can be equipped in car have been developed. The new ECUs that materialize advanced safety functions such as pre-crash safety have been installed along with these sensors. Because of the sharp increase in nodes connected to in-vehicle LAN system and quantity of information data coming in/out of the system, multi-channel networks have become popular, where the in-vehicle LAN system consists of multiple sub-networks. Today, in some high-end vehicles, the in-vehicle LAN system has 3- or 4-channel CAN sub-networks with multi-channel LIN local-networks. The information data transfer between these sub-networks is achieved by adopting an exclusive gateway ECU or giving gateway functions to an ECU connected to multiple sub-networks.

In the future, as for the drive control system and movement control system of in-vehicle LAN, CAN will be taken over by FlexRay, which is being standardized for X-by-Wire vehicles, and as for the information control system which handles a huge amount of information, such as surrounding monitor function, MOST or IDB1394 is expected to be widespread as the next generation communications (Fig.3). Thanks to these high-speed communication protocols, a vast quantity of information can flow. At the same time, unless the number of ECU decreases dramatically, the multi-channel sub-network system will continue to advance. It is expected that the near-future LAN structure will be the multi-channel network with layers of MOST (or IDB1394), FlexRay, CAN and LIN. (Fig. 4)

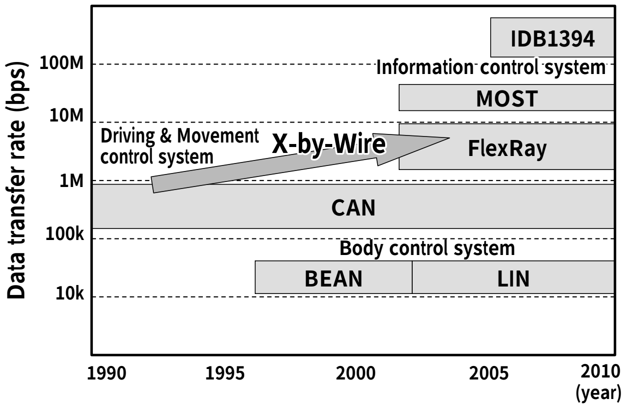

Fig.3 Technological Trend of In-Vehicle LAN

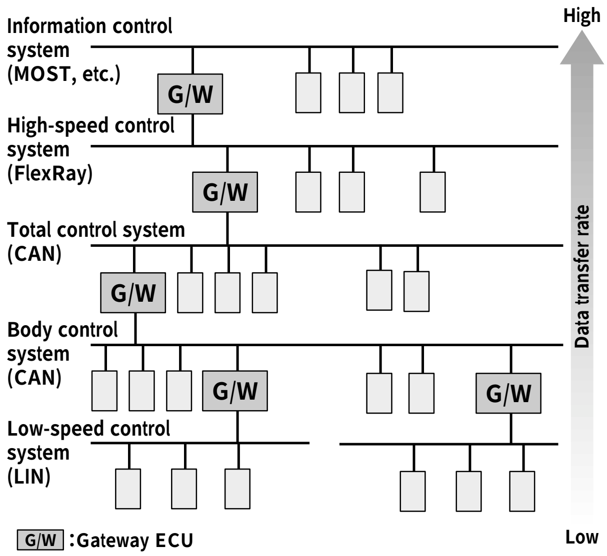

Fig.4 Future LAN Structure

2.4 Endeavor for future technology of the in-vehicle LAN system

As the in-vehicle LAN system is notably advancing, auto manufacturers face challenges of efficient development and ensured reliability. In order to deal with these challenges, the movement of standardizing the in-vehicle LAN structure is emerging, and a flexible LAN structure in car is pursued to apply to various classes of cars raging from the compact car equipped with little electronic devices to the high-end car heavily equipped with them. We, as an ECU supplier, started discussion on standardization of the in-vehicle LAN structure with car manufacturers from 2003. At the discussion on the basis that we would standardize the multi-channel in-vehicle LAN system comprised of multiple CAN sub-networks, the mainstream at present, we found it inevitable to improve performance of the gateway that deliver information between sub-networks. If a faster communication protocol like FlexRay or other current protocols is adopted for a part of sub-networks, the improved gateway function will help enhance the standardization of the in-vehicle LAN structure. With the results from the discussion, we launched in earnest anew technology development aiming at improving the gateway function. We have already finished the base development and we are now in the stage of product development. The following is the outline of it.

3 Outline of Gateway technology development

3.1 Requirements for improved performance

Given the development trend of the advanced safety functions from now on, it is highly likely that the ECU control will become more sophisticated and integrated than today by exchanging detailed information between ECUs. The information relayed to ECUs must not delay beyond expectation nor be disconnected because each ECU needs to control feedback at a certain period. A gateway function for routing the data at minimum time is required. Conventionally, gateway function is loaded in a gateway ECU or an engine control ECU and processes data with a 16- or 32-bit microprocessor. Delay time of data routing mainly depends on processing ability of the microprocessor and/or the amount of data routed. Given an increased amount of data to be routed in the future, when using a gateway with the conventional performance, routing time will be longer. Thus, integrated control will not be realized.

In parallel with an increasing number of electronic devices in car, ways/patterns of equipping them have been diversified. In some cases, the same ECU and/or sensor in one vehicle are connected to a different sub-network depending on type of vehicle. For example, in a vehicle, sensor A is connected to sub-network A to transfer data to ECU (B) that is connected to sub-network B. But in another vehicle whose type is different from the above, the same sensor A is connected to sub-network B to transfer data to ECU (B) that is connected to sub-network A. The gateway is required to easily deal with these differences in data routing specifications. The aforementioned conventional technology needs engineering change in software to handle such differences, and software requires a good deal of verification whenever it is modified. That poses challenges to streamlined engineering process and quality control when the types of car continue to increase.

The following two points are the main requirements of the gateway performance and need to be improved.

＜Requirements＞

①Improved performance of data routing to keep it within the certain time guaranteed.

②Easy engineering change and verification responding to changes of data routing specifications.

3.2 Study for technical solution

In order to seek a technical solution to enhance performance of data routing, we first clarified the limit of the current technology. Fig. 5 shows the results from software simulations including microprocessor model, where delays in data routing of conventional gateway were measured.

＜Conditions of simulation＞

①Used a 32-bit microprocessor that is widely used for vehicles (at up to 100MHz clock frequency)

②Used conventional gateway software (but modified the software to add channels)

③Assumed it to be integrated in an in-vehicle LAN structure that is expected to be common in 2008 to 2010.

・CAN sub-network channels: up to 6

・The number of nodes and amount of routed data: estimates for 2008

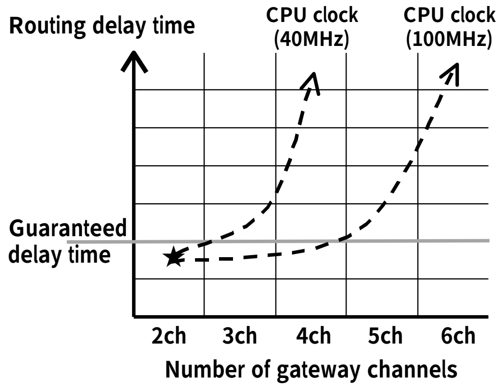

Fig.5 Results from Performance Simulation

Even when CPU clock frequency increases up to 100MHz using the conventional software, 4 is the limit of gateway channels. If you try to push the limit up to 5 channels, delay in data routing goes beyond the time guaranteed. When analyzing processing time in detail per functional block of the conventional software, we found that the time to search a destination channel (to which channel data should be delivered) increases dramatically as the number of gateway channels increases.

With these results, we started technology development of hardware to find the destination channel at high speed. In the beginning, to create hardware with all gateway functions was discussed as one of solutions. However, we decided to seek other solutions where the software processing function remains flexible because the hardware with all gateway functions must be big and expensive, and that means we will have to overcome cost issues. Other reasons are because it must meet all failsafe requirements as a gateway that routes important data, and must fulfill its unique function of coping with individual conditions per car type.

＜Development goals＞

①To develop compact hardware for searching destination channels, which can be equipped on a microprocessor in car.

②To guarantee the delay time of data routing, including software processing, by using a microprocessor equipped with the developed hardware (up to 6 gateway channels).

③To have a function for easy modification and verification of the software after changing data routing specifications.

3.3 Outline of hardware development

Fig. 6 shows the outline of our newly developed gateway hardware.

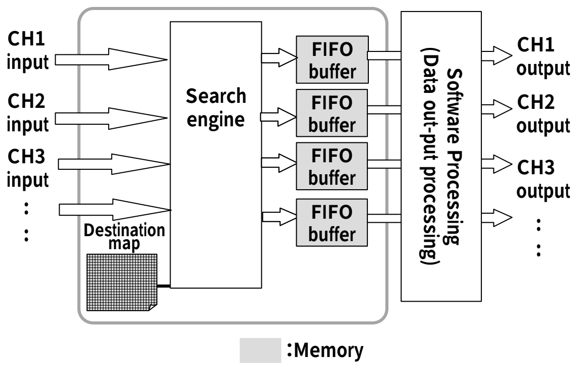

Fig.6 Rough Image of Gateway Hardware

When routed data is received by the gateway hardware, the hardware searches the destination of the data based on a destination map that is set beforehand, and transfers the data to the FIFO forwarding buffers. The software is required only to start up the function of sending the data so that the software processing speed has little impact on the delay in data routing. Even when the gateway hardware receives multiple data simultaneously, there is no problem with its processing speed because the searching engine can process at almost the same speed as the software that is positioned later in the process flow does.

As Fig. 7 demonstrates, we gave it another function for handling differences without design change even when ECUs are connected to sub-networks at different points and/or even when the gateway has to route the data to an opposite direction.

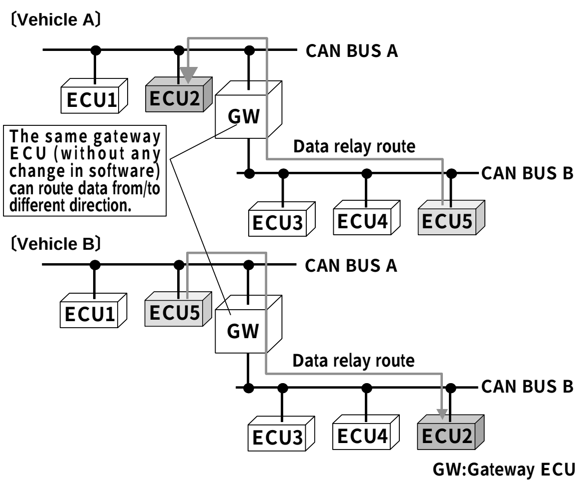

Fig.7 Image of Gateway Feature Routing Data in Undefined Directions

3.4 Approaches to the production

We have already finished the base development of the aforementioned hardware, and are developing it for a next gateway ECU that supports CAN sub-network with multiple channels up to 6.

In order to equip the hardware for a specific microprocessor for cars, we developed and created a prototype combining a target microprocessor and FPGA with a semiconductor maker. Fig. 8 is the appearance of the prototype.

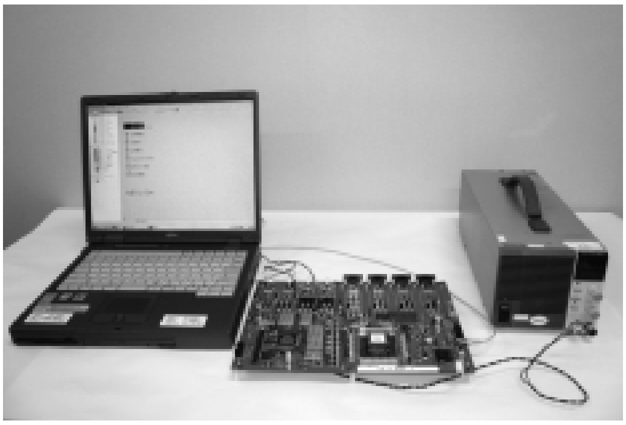

Fig.8 Appearance of Prototype

We tried to make the hardware compact in the design stage of the base development; however, we found that the memory used for it had to be downsized considerably after studying a specific chip size (cost) of microprocessor. After many discussions with a car manufacture and the semiconductor maker, including hearing their request specifications, we succeeded in downsizing the destination map and the FIFO buffers for sending data without compromising the performance of data routing process. We already finished verification of the prototype actually mounted on a microprocessor, and decided the specifications of the microprocessor. Now, we are in the process of designing.

The development of an ECU that functions as a gateway with up to 6 channels brings more importance onto the evaluation technology than before. Especially, in order to quantitatively evaluate processing ability of routing data between 6 channels, we have to sample the routed data with resolution less than 1ms using the same reference time. Moreover, it is very difficult for a conventional measurement instrument for general purpose to give a gateway ECU simulated LAN data of all ECUs connected to the 6 channels. At present, we are trying to expand the aforementioned MCC function to apply to the development of the next ECU. Fig. 9 shows the appearance of the evaluation device under development for the next gateway ECU.

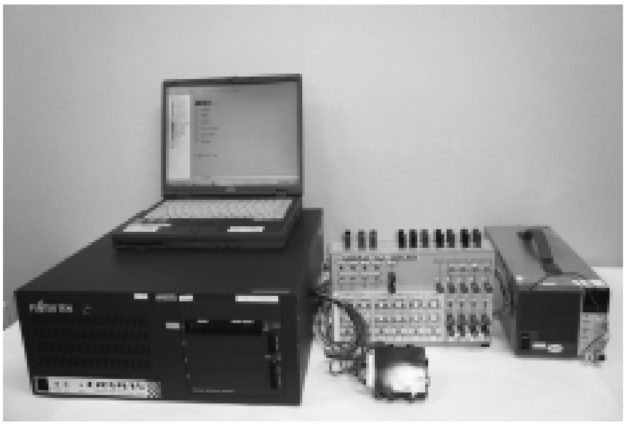

Fig.9 Appearance of Evaluation Device under Development for Next Gateway ECU

4 Conclusion

We have introduced so far FUJITSU TEN approaches to the development for control LAN system technology as well as the history of the in-vehicle LAN system and its future trend. Based on the newly developed gateway technology, we will continue keeping our development up to the future trend of the control LAN system. Concretely, we have been in discussion of applying the technology to FlexRay. The development of car functions is expected to expand its area from the current integrated control to cooperative control of infrastructure. And it is likely to promote further interaction and integration between controller ECUs such as engine controllers and multimedia ECUs such as AVCs. The development of the in-vehicle LAN system has to stay ahead of it. We continue working hard to be a reliable partner for car manufactures with regard to in-vehicle LAN technology development as a supplier that provides the radio communication technology in addition to the technologies of controllers and multimedia.

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