Development of a Vehicle-Mounted GATEWAY ECU

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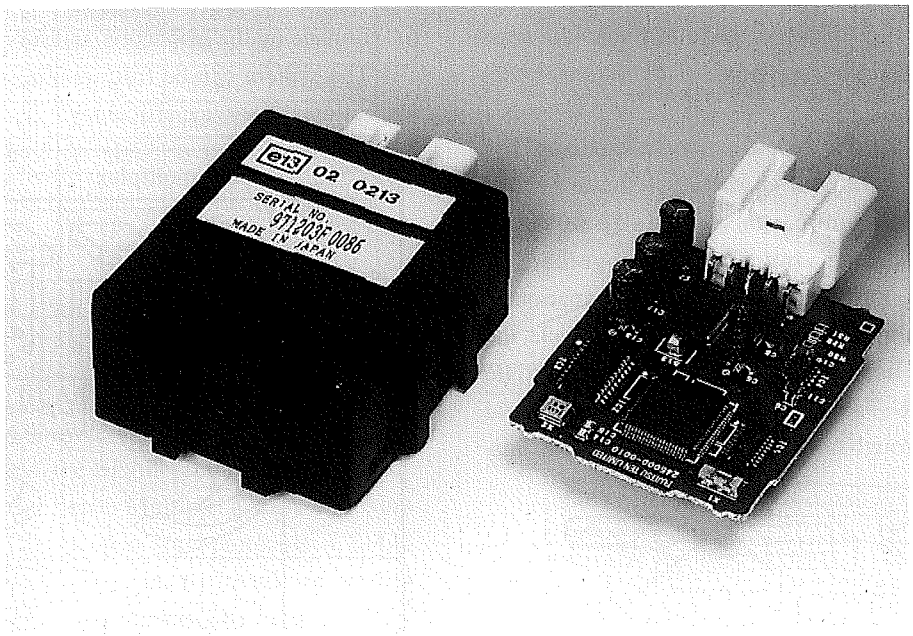

Abstract

Breakthroughs in multimedia and sensor technologies have made highly advanced information integral to vehicle operation. This, in turn, has paved the way for widespread use of multiplex communication technologies (such as the vehicle-mounted LAN), which offer more precise, sophisticated control. Dealer-optional products developed by Fujitsu Ten exemplify this incorporation of multiplex communication function in automobiles.

The dealer-optional products mounted on various vehicles and coordinated-control compatible with (line-) genuine systems require special care, so as not to adversely affect the (line-) genuine systems in terms of versatility, reliability and security of information.

This paper is a report on the successful development of a marketable GATEWAY ECU, following careful consideration of specification requirements for incorporating multiplex communication functions into dealer-optional products.

This technology is applicable to other products which use multiplex communication technology. We expect that the GATEWAY ECU technology will assist in the development of communication algorithms.

1. Introduction

In addition to security systems for mounting at production lines (OE systems), Fujitsu TEN is developing security systems as dealer options. Since multiplex communications technology is now frequently applied to OE systems, the dealer option products (optional ECUs) should be changed as well. To assist in attaching an optional ECU easily to a LAN-mounted vehicle, we developed a GATEWAY ECU (product name: optional bus buffer) supporting Toyota Motor's unique protocol Body Electronics Area Network (BEAN). An outline of the development is introduced here.

2. Outline of Multiplex Communications for Vehicle

Multiplex communications generally refers to transmitting and receiving signals altogether, or continuously transmitting and receiving information in segments. For multiplex communications on a vehicle, the number of signal lines is reduced and several electronic control units (ECUs) can exchange information on a real time basis only through one (or two) communications line.

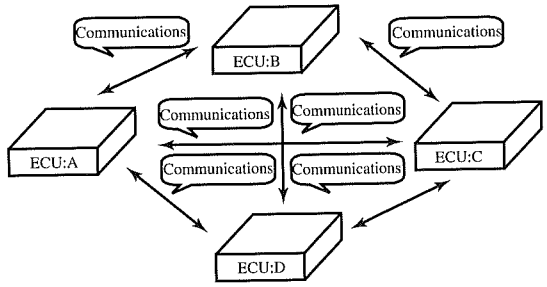

Figure 1 Concept of multiplex communications

2.1 Advantages of Multiplex Communications

This multiplex communications technology generally offers the following advantages:

1) Simplifying the system

The optimum function arrangement simplifies harness routing and allows functions to be integrated in each area (cabin, door, hood, or trunk).

2) Reducing the number of harnesses used

ECUs do not require individual harness wiring because they can share general-purpose I/O signals through a communications line.

3) Making ECU compact

ECUs do not require individual I/O interfaces because they can share general-purpose I/O signals through a communications line.

4) Enhancing and extending system functions

Unifying information makes it easy to realize cooperative control over systems under independent control and to extend functions by using software.

5) Enhancing mounting efficiency

Simplifying the entire system enhances the efficiency with which vehicles are mounted on vehicles.

6) Enhancing the inspection and service efficiency

The system can be fully diagnosed to enhance the inspection and service efficiency.

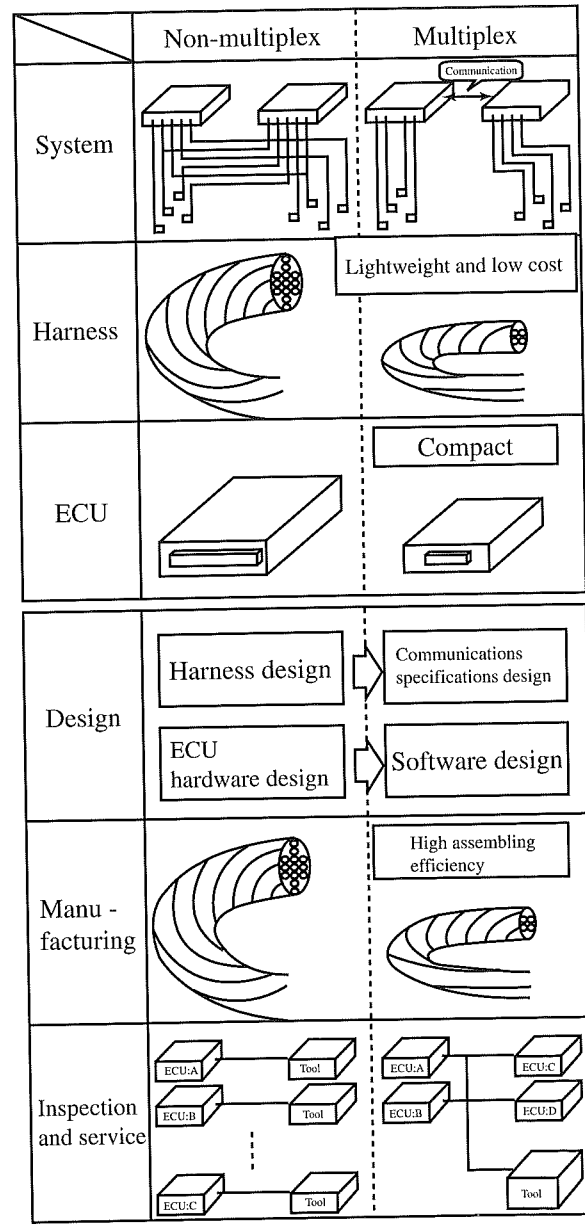

Figure 2 Advantages of multiplex communications

2.2 Communications Protocols

Several kinds of protocols are used for multiplex communications. Toyota Motor's unique communications protocol BEAN exhibits the superiority of a general-purpose protocol developed for automotive use.

Table 1 compares the BEAN protocol with other general-purpose protocols.

Table 1 Comparison of main protocol specifications

	BEAN	ISO9141	J1850	CAN
Access method	CSMA/CD	Master-slave	CSMA/CD	CSMA/CD
Communications line	Single	Single	Single	Twisted pair
Transmit-receive circuit	Discrete	Discrete	Dedicated IC	Dedicated IC
Data length	1~11Byte	1~7Byte	0~8Byte	0~8Byte
Extensibility	◎	○	◎	◎
Communications capacity and responsiveness	◎	○	◎	◎
Radiated noise	◎	◎	○	○
Cost	○	◎	△	×

2.3 Outline of the BEAN Protocol

To satisfy the OE system requirement for real-time switching information, the BEAN protocol uses the same access system Carrier Sense Multiple Access/Collision Detection (CSMA/CD) as other main protocols. CSMA/CD transmits information sequentially in order of priority while monitoring the communications line vacancy. Since the load on the communications software is comparatively small, CSMA/CD is good for an ECU with an 8-bit or 16-bit CPU. CSMA/CD also facilitates system extension by connecting additional ECUs. In addition, an optimum communications speed that depends on the radiated noises was adopted to realize a communications line from a single wire. The hardware was realized at low cost by making the transmit-receive circuit discrete.

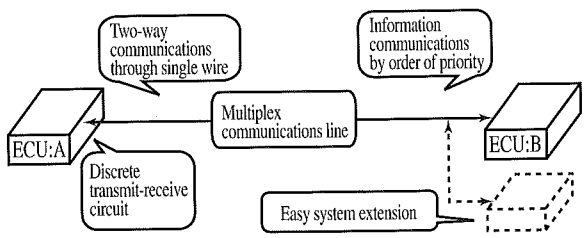

Figure 3 Features of BEAN

2.4 Relationship between Vehicle with a built-in LAN and Optional ECU

A vehicle without a built-in LAN used to require necessary wiring between ECUs and between ECUs and sensors and actuators. On this kind of vehicle, an optional ECU is used to fetch necessary signals from the vehicle wiring in parallel to establish a system. However, because vehicle-mounted LANs are common among OE systems for the purpose of satisfying high extensibility and added value requirements, it is becoming difficult for an optional ECU which cannot be connected to a vehicle-mounted LAN to acquire signals. An optional ECU is also expected to lead to enhanced extensibility and more added value, which will also lead to an increased number of input signals. Therefore, an optional ECU should also adopt a vehicle-mounted LAN for information transmission. (Figure 4)

By considering the information exchange speed, we decided to adopt BEAN as the protocol for a vehicle-mounted LAN.

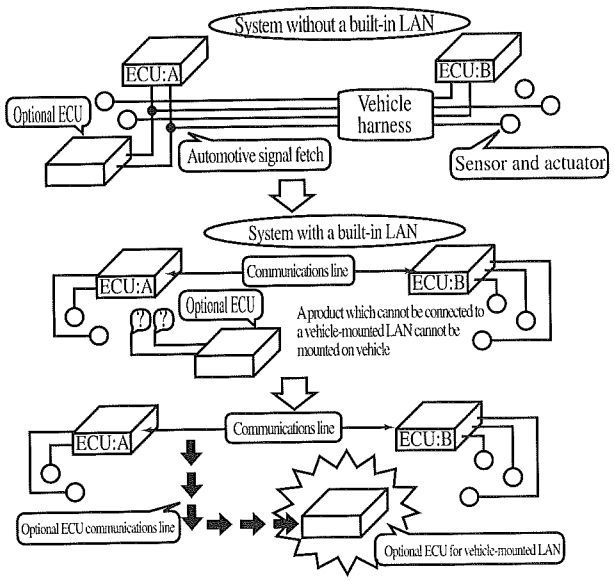

Figure 4 Change to vehicle-mounted LAN

3. Problems and Resolutions Taken in Connecting Optional ECU to Vehicle-mounted LAN

An optional ECU should be connected to a vehicle-mounted LAN by considering the following:

Problem 1: Avoiding communication faults

Problem 2: Ensuring information security (secrecy)

Problem 3: Reducing OE system bus load

Problem 4: Ensuring extensibility

The GATEWAY ECU solved the subjects as explained below.

3.1 Avoiding Communications Faults

Since various key control (safety and drive) systems are connected to the communications line of a vehicle-mounted LAN, a communications fault on the optional ECU communications line (referred to as the option bus in this document) must not affect the OE system. A communications fault is mainly attributable to a physical factor, such as grounding, short-circuit, or the physical disconnection of the communications line or an ECU fault. In the interest of developing the market, in the future, it is likely that the optional ECU communications line will be released to general users and nonspecific optional manufacturers, thereby increasing the chances that the above problems will occur more frequently. This problem cannot be permitted on a communications line where the key control systems are connected (referred to as OE system bus in this document). To resolve this, the GATEWAY ECU should satisfy the following specifications.

<Specifications for avoiding communications faults>

1) The OE system bus shall be protected even if the option bus is short-circuited with a battery voltage (+B) or grounded.
   (Electrical isolation)
2) An abnormal signal (information) on the option bus shall not be transmitted to the OE system bus.
   (Software isolation)

To satisfy these specifications, the GATEWAY ECU's communications elements for the option bus and those for the OE system bus are kept separate for electrical isolation, with the ECU filtering information for software isolation. This isolation function protects the OE system from faults. (Figure 5)

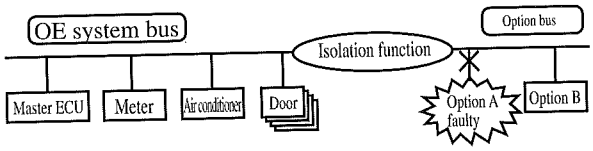

Figure 5 Avoiding a communications fault

3.2 Ensuring Information Security (Secrecy)

Since the security and other anti-theft systems are connected to the communications line, it must not be possible to decipher communications information easily from the option bus. In addition, signals must not be altered easily from the option bus or the OEM system must not malfunction. For example, if a forged signal is given from the option bus to the communications line when the security system connected to the OEM system bus is on alert, a function must detect and eliminate this pseudo signal. To resolve this, the GATEWAY ECU should satisfy the following specifications:

<Specifications for ensuring security>

1) Information from the OE system bus to the option bus shall be limited to broadcast (general-purpose information) or optional ECU frames.
2) Information from the option bus to the OE system bus shall be limited only to dedicated frames for cooperative control with the OE system.
3) Information from the option bus to the OE system bus shall be enciphered to prevent alteration.

To satisfy these specifications, the GATEWAY ECU filters frames from the OE system bus and option bus and limits information transmission in both directions. Information (especially, control requests) from the option bus is enciphered to ensure its validity and information transmission to the OE system bus is limited. The contents of enciphering are changed periodically to make deciphering even more difficult. This ensures information security. (Figure 6)

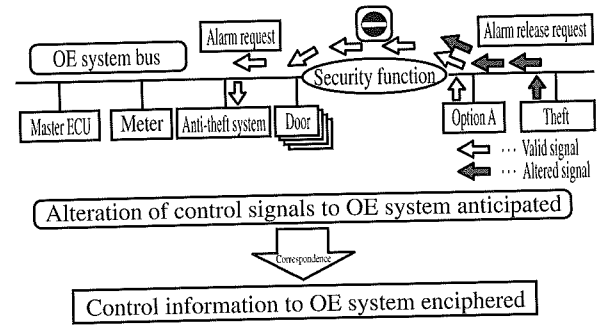

Figure 6 Necessity of information security (secrecy)

3.3 Reducing OE System Bus Load

In the future, products will be connected to a vehicle-mounted LAN as optional ECUs. Accordingly, the response efficiency and control performance of the OE system must not suffer any deterioration as a result of any significant increase in the amount of information on the communications line.

In multiplex communications, the communication speed limits the volume of information. The volume of information increases simply in proportion to the communication speed. However, you cannot simply

increase the communication speed because radiated noises from the communications line, radio noises, and loads on the communications processing CPU begin to pose problems. To resolve this, the GATEWAY ECU should satisfy the following specifications:

<Specifications for reducing OE system bus load>

1) Information from the option bus to the OE system bus shall be minimized.
2) In multiplex communications, information to the option bus shall be transmitted completely with no loss. (Data hold function)

To satisfy these specifications, the GATEWAY ECU has a data reorganization function that transmits not all information from the option bus but only necessary data to the OE system. (Information from the option bus is reorganized to reduce the data volume to 1/5.) A six-stage buffer was prepared for communications data so that information could be transmitted to the option bus even if the shortest frame continues after the longest one. This reduced the load on the OE system bus. (Figure 7)

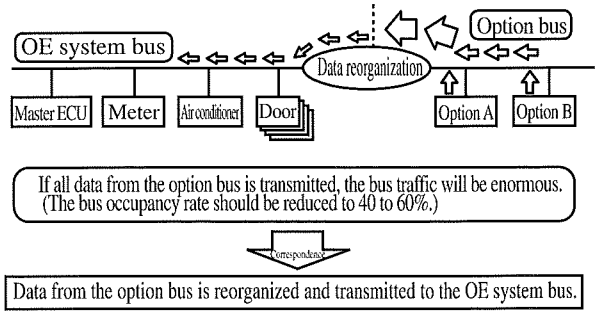

Figure 7 Bus load reduction

3.4 Ensuring Extensibility

Since Fujitsu TEN is not the sole manufacturer of optional ECUs, a vehicle-mounted LAN should also accept the products of other manufacturers. In addition, an optional ECU should be mountable on any vehicle. To solve this subject, the GATEWAY ECU should satisfy the following specifications:

<Specifications for ensuring extensibility>

Information transmission to the OE system bus shall be permitted if only the enciphering rules are satisfied regarding information from a new optional ECU. (However, data is not organized.)

The GATEWAY ECU enables even a new ECU of no data reorganization to be connected to the option bus if only the new ECU satisfies the communications rules about security. This ensures extensibility.

4. Achievement

By solving the above four subjects, we developed a GATEWAY ECU satisfying the requested specifications. (Figure 8)

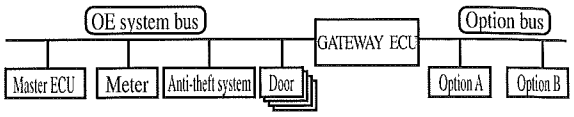

Figure 8 GATEWAY ECU

Figure 9 shows the functional concept of the GATEWAY ECU that always deciphers information and reorganizes data. This GATEWAY ECU transmits information from the OEM system bus to the option bus with cipher data. If information from the option bus is identified as formal data after deciphering, the data is reorganized and transmitted to the OE system bus. The data is rejected if it is not formal.

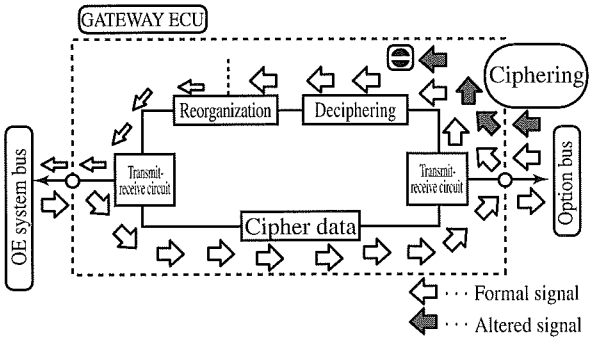

Figure 9 Functional concept of the GATEWAY ECU

This product was marketed with an anti-theft security system for the 1998 model of a European vehicle.

Figure 10 shows the block diagram of the GATEWAY ECU and Table 2 lists the main product specifications.

A GATEWAY ECU, this product has the following additional functions:

1) Power management function

When the vehicle is left unused or no communication is requested, this function automatically changes the GATEWAY ECU to sleep mode to reduce the amount of electricity consumed.

2) Option frame transmission suppression function

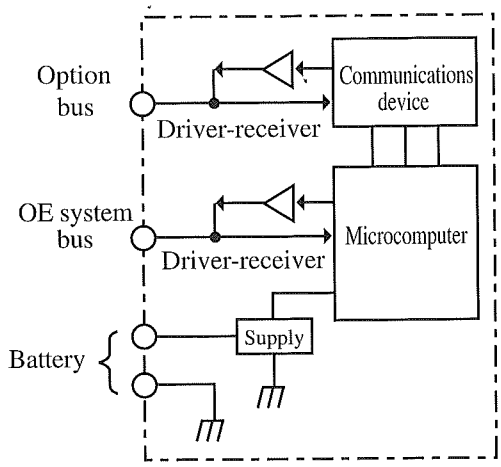

Figure 10 Block diagram of the GATEWAY ECU

Table 2 Main specifications

Operating voltage	10～16V
Operating temperature	-30 ～ +80℃
Current consumption (dark current)	1.5 mA max.
Product size	65×55×30mm
OE system bus protocol	B E A N
Option bus protocol	B E A N

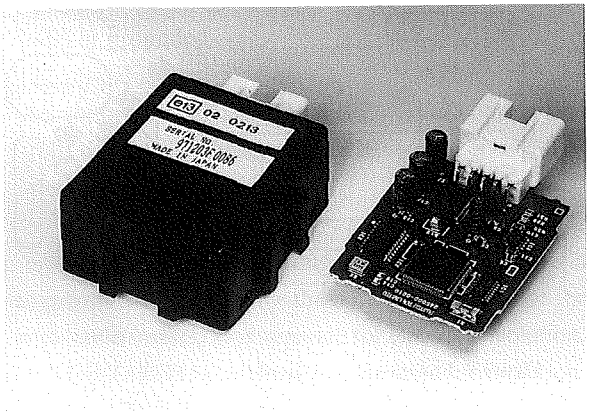

Figure 11 GATEWAY ECU (Photo)

This function judges a congestion on the OE system bus and suppresses information transfer from the option bus.

3) European radio certificate (95/54/EC)

The GATEWAY ECU passed the certification tests of European countries, attesting to the fact that they are sufficiently reliable for use in vehicles throughout the world.

5. Future Development

The GATEWAY ECU developed this time exchanges information between the same protocols (BEAN) but the algorithm is applicable to other protocols. Figure 12 shows protocols of fields that may be connected to vehicle mounted equipment in the future. Optional ECUs of other manufacturers should be adopted only when they conform to CAN, J1850, ISO9141, or other world standards. (Technologies can be shared among automobile manufacturers.) For human-machine interfacing or external information exchange, the RS-232C widely used in personal computers, and the networking ITS data bus should also be considered as means of transmitting information.

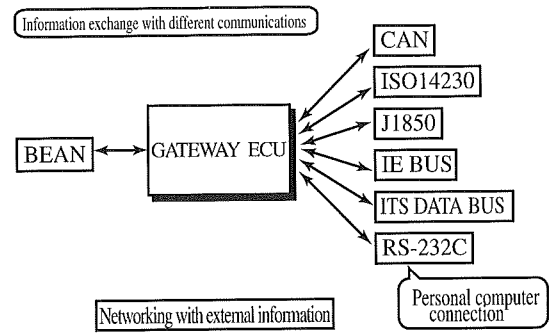

Figure 12 Future development of the GATEWAY ECU

6. Conclusion

For the GATEWAY ECU, we developed basic technologies necessary for linking on-vehicle equipment to various external systems to extend the functions.

There is no doubt that mobile computer and multimedia equipment will be mounted on vehicles in the near future. To extend the functions of on-vehicle equipment through computer and multimedia equipment, we need to ensure that the information used therein remains reliable. The GATEWAY ECU will likely play a very important role in situations where there are exchanges of information on the products having different developing environments and reliability levels. By the time on-vehicle equipment is able to execute application software with relative ease (Plug & Play) as is the case with personal computers, the GATEWAY ECU itself may become the equivalent of an operating system (OS) that will at the same time serve as a mobile computer integrating all systems linked to the LAN. To be prepared for the day that this becomes a reality, we will develop products that can be combined with the technologies used in multimedia equipment and personal computers.

Lastly, we'd like to express our gratitude to Mr. Uehara who works at Body Design Department I of Toyota Motor, for his useful advice and guidance on communications in developing the GATEWAY ECU.

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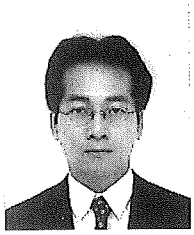

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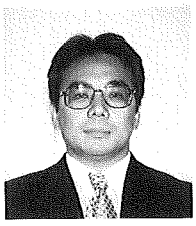

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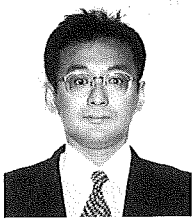

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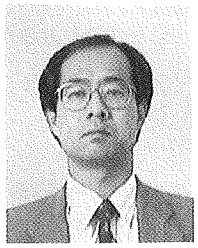

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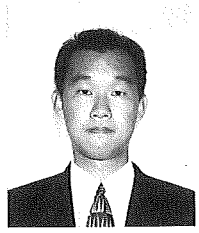

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