MONET-Compatible Car-mounted Information Terminal

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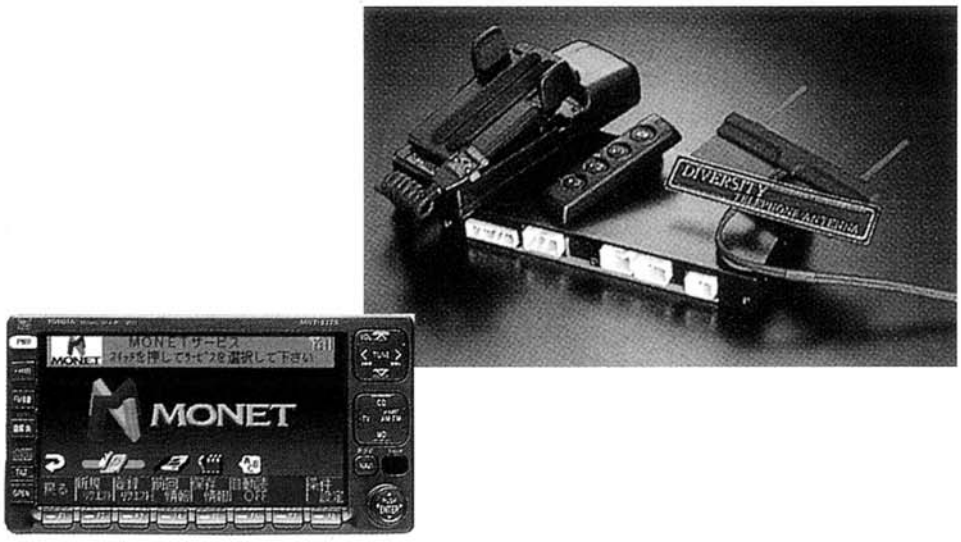

Recently, such representative car computer systems as car navigation systems have been improving at a very rapid pace. As a result, by as early as the beginning of the 21st century, we will likely see the arrival of automatic payment systems and automatic driving systems, otherwise referred to as "Intelligent Transport Systems" (ITSs). One of the main purposes of ITS is to make vehicles high information-oriented forms of transportation. An example of this is the appearance of built-in systems providing on a real-time basis traffic information that is useful to the driver, a system realized by linking the vehicle's car navigation system with its communications equipment. The ATIS which was introduced in 1995 and the VICS which made its appearance in 1996 provide mainly traffic information. Automobile manufacturers, however, have started working on building systems that provide drivers with other categories of useful information such as weather forecasts and news reports.

This paper introduces MONET, a new information service system that has been jointly provided by Toyota Motor Corporation, Fujitsu Limited, and Fujitsu TEN Limited since November 1977.

1. Introduction

The recent rapid spread of car navigation systems is giving rise to new information services, such as Automatic Transit Information Systems (ATIS) and Vehicle Information and Communications Systems (VICS), systems that offer drivers information about accidents and traffic jam on a real-time basis. Coincidentally, at about the same time, the number of users of cellular telephones (especially digital versions) grew rapidly. (Currently, cellular telephone service subscribers number 25 million.)

Under these circumstances, the Intelligent Traffic Guidance Service (ITGS), a new service for Mercedes Benz automobiles became available in 1997. This service uses the car's cellular telephone system to provide (via the car navigation equipment) drivers with not only traffic information, but also news, weather forecasts, and other information.

Other Japanese automobile manufacturers, led by Toyota Motor Corporation became actively involved in building systems offering similar information services. Since 1994, Fujitsu TEN Limited, with the cooperation of Fujitsu Limited and Toyota Motor Corporation, has been working on realizing a practical information service system.

This joint effort led to the establishment of Toyota Media Station Inc. in July, 1997. In November of that year, the new company began offering a new service called MONET (an acronym for MObile NETwork that has the same pronunciation and spelling of the well-known painter).

Fujitsu TEN has developed a hands-free Electronic Control Unit (ECU). This paper outlines the equipment and discusses its future aspects.

2. Characteristics of the MONET-compatible hands-free ECU

2.1 Overall system

Information that can be handled by the MONET-compatible hands-free ECU includes traffic-related information on such as that on accidents, traffic jams; information on facilities such as parking facilities and restaurants; entertainment-related information such as upcoming events; and general information such as news and weather forecasts; and personal-use information including electronic mail.

These pieces of information are collected by Toyota Media Station Inc. from information providers or via the Internet, then transmitted to users on request (See Figure 1).

2.2 Function overview

The MONET ECU, a sophisticated information terminal, works with cellular telephones and navigation equipment to collect information in types, forms, and quantities required by the driver and passengers when necessary (See Figure 2).

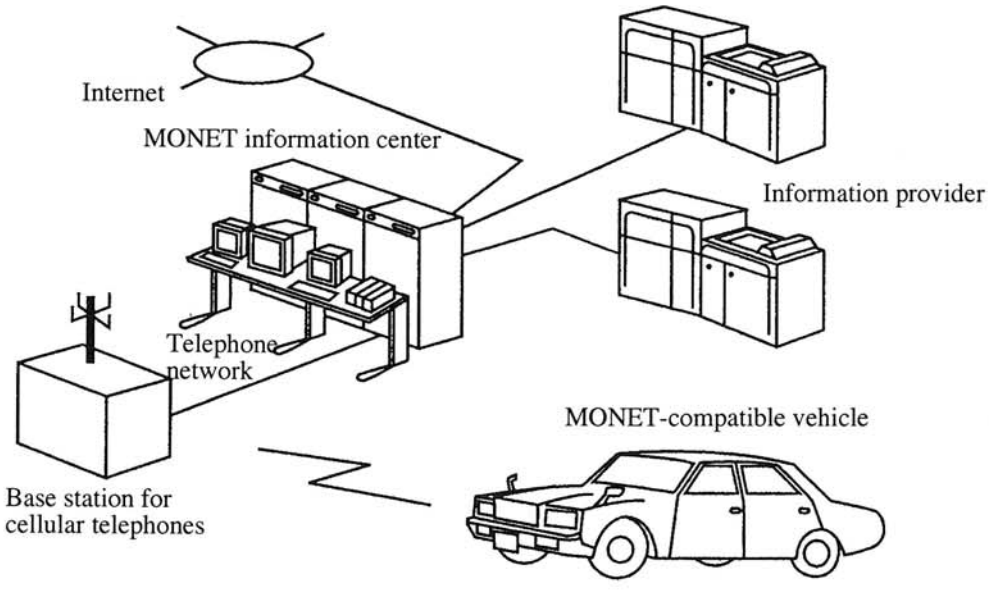

Figure 1 Configuration of a MONET system

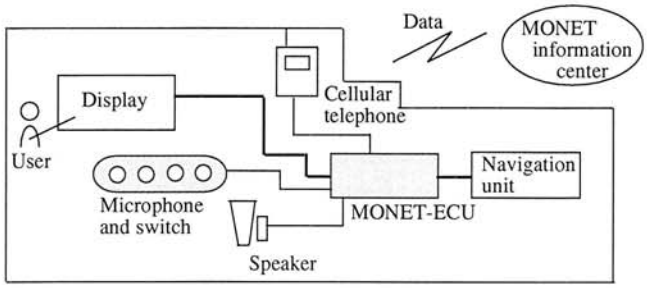

Figure 2 Components of the MONET car-mounted equipment

The MONET ECU has the following two major functions:

- Obtaining MONET information
- Serving as a hands-free telephone

2.2.1 Obtaining MONET information

The user can retrieve MONET information by originating a call after selecting the type of information desired, from the menu displayed on the terminal. Types of frequently used information or services can be registered in advance so that a request for the desired information/ service can be issued with a few actions (See Figure 3, 4).

Information obtained may be text or image data. It is presented on the display installed in the passenger compartment.

Figure 3 MONET initial screen

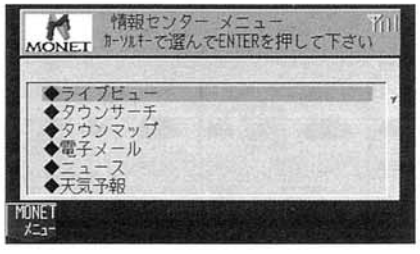

Figure 4 Menu for making a request

① Communications

For communications, the MONET ECU uses a digital cellular telephone (9600 bps) which is a reliable cellular telecommunications media. The MONET ECU is designed for compatibility with any manufacturer's cellular telephone. It contains software that allows it to work as an adapter controlling data communications to and from the cellular telephone.

The protocol for communications between the center and the car-mounted product is the Mobile Network Communications Protocol (MNCP) developed jointly between Toyota Motor Corp. and Fujitsu Limited. Innovations have been made to the protocol to shorten line connection times.

② Linkup with navigation equipment

When obtaining information, the MONET ECU uses as key data the vehicle's destination and current location set on the navigation equipment. For example, if a restaurant close to the destination is selected, position information (latitude and longitude) on the destination is obtained from the navigation system. This information is then transmitted to the information center as key data for information retrieval.

If the information received contains position information, the position information is passed to the navigation equipment. For example, position information (latitude and longitude) about a restaurant is passed to the navigation equipment so that the position of the restaurant can be displayed on the navigation map (See Figure 5).

Figure 5 Display of specific location on MONET map

③ Data retrieval via voice synthesis

To ensure safe driving when the vehicle is traveling, the MONET ECU has a function that uses voice synthesis to read the text data out loud.

Since the data to be read out loud is transmitted from the center separately from the data to be displayed, there is no reading error (See Figure 6).

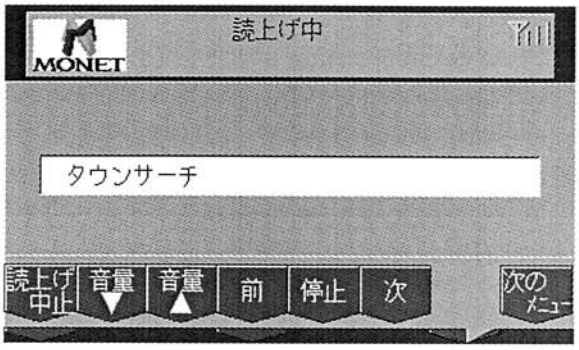

Figure 6 Screen displayed when text is being read aloud

④ Information storage

Information once retrieved can be stored in a nonvolatile memory so that it can be viewed at a later time. This means that the user need not down-load information from the information center each time such information is required. Instead, the user can view the information by retrieving it from the memory in the terminal.

⑤ Types of information

The types of information currently available are given below. The information menu is managed by the center and updated automatically when appropriate.

- Road traffic information (See Figure 7)
- Facility information (parking facilities, gas stations, restaurants, ski resorts, interesting town spots and others) (See Figure 8)
- Town map
- Japan Automobile Federation (JAF) guide
- Hospitals
- Police stations
- Live images
- Electronic mail (See Figure 9)
- News (See Figure 10)
- Weather forecast (See Figure 11)

Typical information screens are shown below.

<Road traffic information>

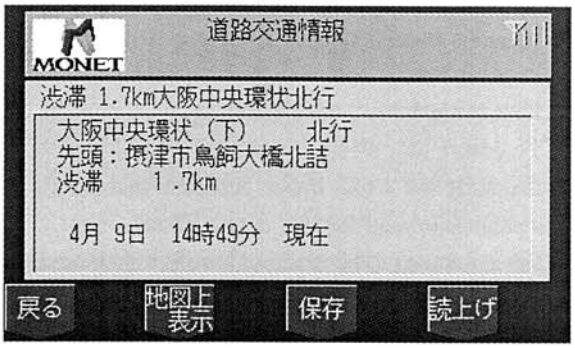

Figure 7 Traffic information screen

<Facility information>

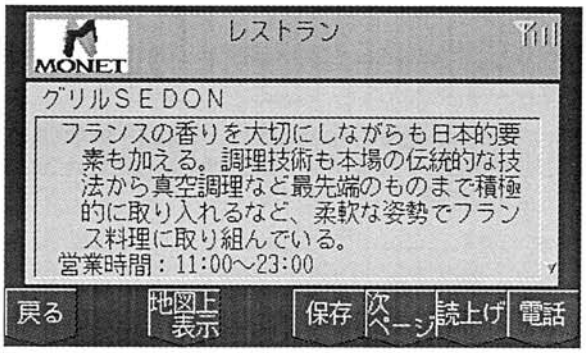

Figure 8 Restaurant information screen

<Electronic mail>

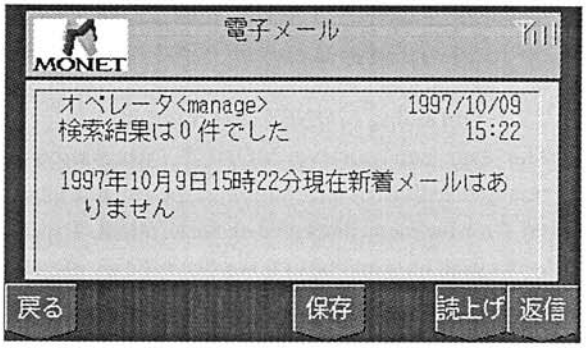

Figure 9 E-mail screen

<News>

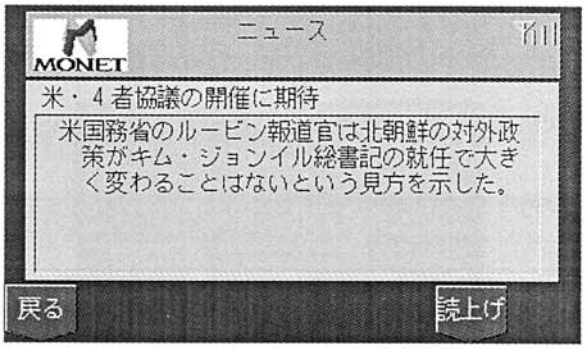

Figure 10 News screen

<Weather forecast>

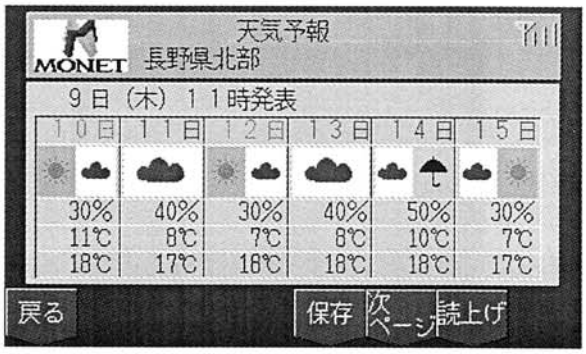

Figure 11 Weather forecast screen

2.2.2 Serving as a hands-free telephone

Using a cellular phone while driving is not recommended. Sometimes, however, their use is unavoidable. Hands-free telephone systems are intended to minimize the driver's operation loads when using telephone.

The driver does not need to operate the cellular phone directly. The driver only needs to use certain screen buttons, an attached microphone, and a switch for either making a call or responding to an incoming call. Using a microphone and loudspeaker installed in the vehicle interior allows the driver to operate the cellular phone in a hands-free manner.

The MONET ECU is also equipped with standard functions a typical cellular telephone would have plus a function for transferring data to or from the cellular telephone.

① Dialing

The user enters a telephone number to make a phone call (Figure 12).

Figure 12 Dialing screen

② Automatic dialing

For automatic dialing, you simply select a telephone number registered in advance in the memory. The selected number is then automatically dialed (Figure 13).

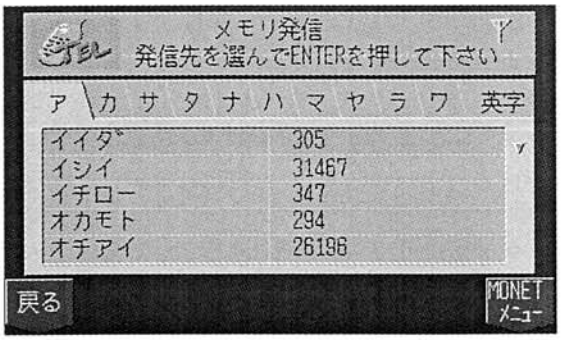

Figure 13 Screen for calling from memory

③ One-touch dialing

You can select one of the telephone numbers registered in advance in the memory by touching one switch. The selected number is then automatically dialed (See Figure 14).

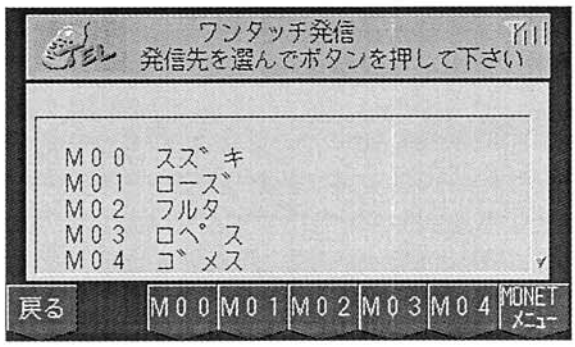

Figure 14 Screen for one-touch dialing

④ Answering incoming calls

You simply touch a switch to answer an incoming call.

⑤ Registering telephone numbers in the memory

You can register telephone numbers and names in the memory.

⑥ Transferring phone numbers from the cellular telephone to the terminal

You can transfer to the terminal those telephone numbers already registered in the cellular telephone.

3.1 Hardware characteristics

The MONET ECU uses Fujitsu's 32-bit CPU (SPARClite) and a newly developed MM-ASIC (MB87F116). A recent trend in implementing a function in a product is to design software specifically for that function. When developing the MONET ECU, we also designed software for a number of functions, including a digital data adapter (soft modem), voice synthesis, and image drawing control.

In the conceptual design stage, when we selected the components for the MONET ECU, we took into consideration the memory and CPU power required to run the software implementing these functions.

Figure 15 is a block diagram showing the internal components of the MONET ECU. The memory (flash memory, SDRAM, and SRAM) is arranged around the CPU and ASIC. The peripherals consist only of the required interfaces.

The cellular telephone (including the modem) and hands-free features incorporated in the MONET ECU are compatible with a good number of cellular telephone models.

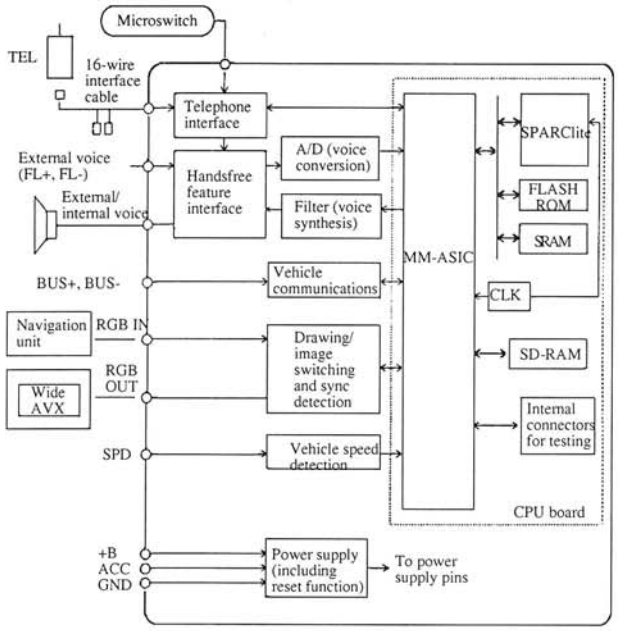

Figure 15 Block diagram of the MONET ECU

Connections between the MONET ECU and AV equipment conform to Toyota's communications specification for car-mounted equipment (AVC-LAN). This means that the MONET ECU is compatible with our and other manufacturers' display devices (including AVNs, AVXs, and TVs).

For compatibility with vehicles, two types of MONET ECU nits have been designed: One type comes with an antenna and a cradle (two models for 800 MHz and 1.5 GHz) and the other type is antennaless. The MONET ECU is therefore compatible with all Toyota models. We anticipate high growth potential for this unit in the future.

A noteworthy engineering feature is its high-density packaging which relies on BGA packages and type-1005 chip components (See Figure 16).

The CPU board is designed so that mounting of components is fully automated (double-sided reflow soldering) and that defects caused by human error are eliminated when the board is processed.

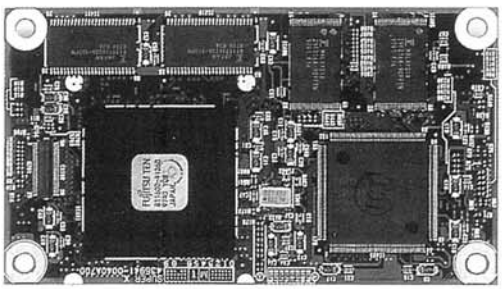

Figure 16 CPU board

For testing, we developed separately from the operating software testing software designed to run in the manufacturing stage. This testing software is stored in a flash ROM. Therefore, even if the operating software specification is changed, it will not affect the testing method. Since the operating software is installed after the completion of the test, there is no need to provide extra memory for testing software. In the course of product development, we also developed an automatic tester that can automatically test all of the functions of the MONET ECU in about seven minutes (See Figure 17).

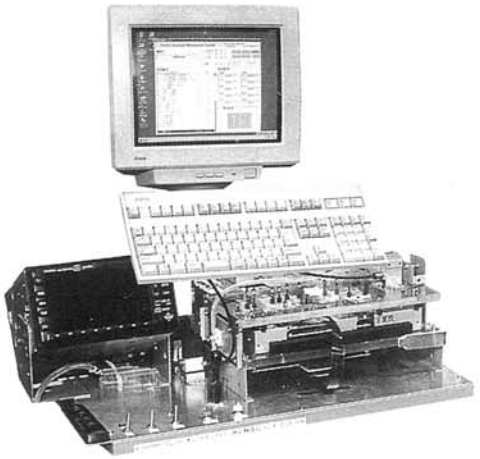

Figure 17 Automatic tester

3.2 Software characteristics

The MONET ECU contains a high-performance CPU and an advanced ASIC so that its principal functions are implemented by software. The software structure and the principal functions are discussed below.

3.2.1 Software structure

The software for the MONET ECU is structured hierarchically, with consideration given to development efficiency and horizontal expansion/evolution of software components (See Figure 18). Each hierarchical layer is briefly explained below.

- Device driver layer: This layer is designed for direct access to hardware. When the hardware is changed, smooth conversion can be accomplished by modifying this layer while maintaining interfacing (application program interface, or API) with the higher layer (server layer).
- Server layer: This layer is positioned between the device driver and application layers. It serves to

provide individual functions to the application layer. Since it is designed on the basis of predetermined APIs with the lower and higher layers, it can generally be used with other products having a similar structure.

- Application layer: This layer is designed in accordance with unique user specifications so as to implement functions (specifications) specific to the product.

The OS for the MONET ECU software is Vx WORKS for a number of reasons, including the good development environment offered by Vx WORKS. The authoring tool is VAPS because it can be expected to provide improved efficiency in screen control program development.

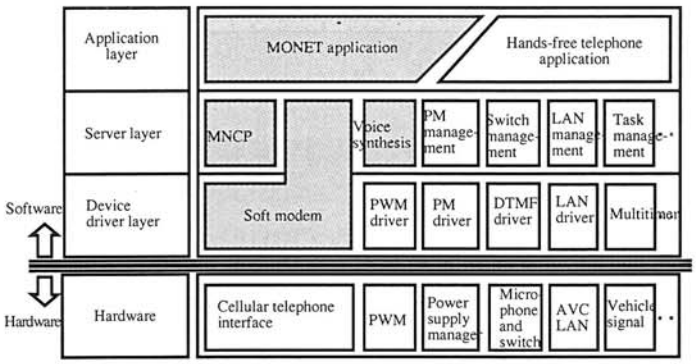

Figure 18 Software structure

3.2.2 Software modem

The MONET system requires a data adapter function because a digital cellular telephone is used between the center and the car-mounted terminal. The MONET ECU uses software for protocol conversion (software modem). Figure 19 shows the functional components of the software modem.

Considering requirements for a data adapter function built in the terminal and hands-free talk and listen function, we newly developed an API processing unit and a hands-free function control unit (for answer- on-hold and transfer-by-pre-assignment).

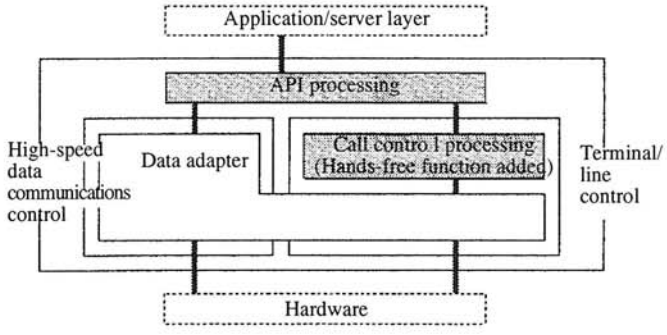

Figure 19 Structure of the software modem

3.2.3 MNCP

MNCP stands for the MONET communications protocol which was originally developed for communications between an information center and a terminal. By complying with MNCP, the MONET ECU assures high reliability, low communications cost, and expandability. The features of MNCP are as follows:

- To reduce communications overhead, MNCP uses long frames of up to 12K bytes in comparison with other communications protocols (See Figure 20).
- The connection between the center and the terminal is established only during the period from the time an information request is issued by the terminal to the time the information transmission from the center ends. If an extended period of time is required before information transmission can begin, the line will be disconnected temporarily after a certain period of time has transpired. The line will then be reconnected after the number of hours specified at the center (asynchronous communications) has transpired. This helps to reduce the communications costs to be borne by the user.
- The menu structure and the automatic update function make it possible to automatically update the services offered by the center. The data format used also assures flexible expansion of services offered by the center.

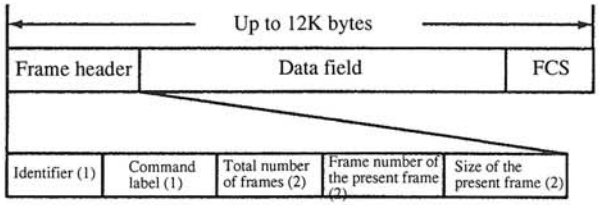

Figure 20 MNCP frame layout

3.2.4 High-quality voice synthesis

Voice synthesis is a means of providing information to drivers in a safe manner. The MONET system provides a high-quality read-out loud (voice synthesis) function. With voice synthesis, the driver does not have to worry about misreading any incoming data. This is achieved by assigning a language processor (which determines how each piece of text is pronounced, or is represented by phonetic characters) to the center and a waveform generator (which converts phonetic

characters to voice) to the car-mounted terminal (See Figure 21). The MONET ECU uses a waveform dictionary (2 megabytes, male voice), the best available to date, to synthesize natural-sounding, high-quality voices for the user.

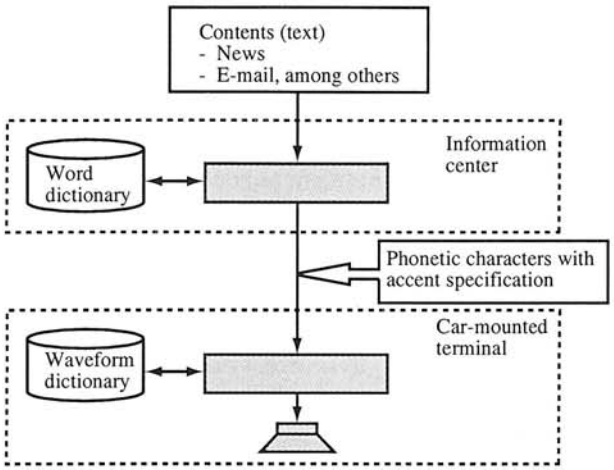

Figure 21 Structure of the voice synthesizer

3.2.5 MONET application

When the user obtains information from the center, the MONET ECU presents the information in one of the following ways:

① Display
- Text display: Obtained information is displayed as character information.
- Image display: Obtained GIF data (photographs and street maps) is displayed in 256 colors.
- Display of specific location on map: If position data (latitude and longitude) is attached to obtained information (including facility information and e-mail), a mark can be displayed on the navigation map. This location can also be designated as the destination by the navigation equipment.

② Read-out loud function
- If the user enables the read- out loud function, it automatically reads out loud information obtained from the center when the automobile is traveling.
- A read-out loud switch is available. It begins reading obtained information out loud.

③ Others
- Simple responses to mail messages (See Figure 22): When a mail message arrives, the user can respond to it by selecting one of simple messages stored at the center. It is also possible to attach information about the location of the automobile to the response to the mail message.
- Dialing: If a telephone number is attached to obtained information, a "Telephone" switch is displayed on the information screen. The user can make a phone call simply by touching the switch.
- Information storage: Up to 96 kilobytes of information can be stored — for example, about 30 e-mail messages, about 200 news items, 3 to 4 images, or 5 to 6 maps. (These figures vary from case to case.)

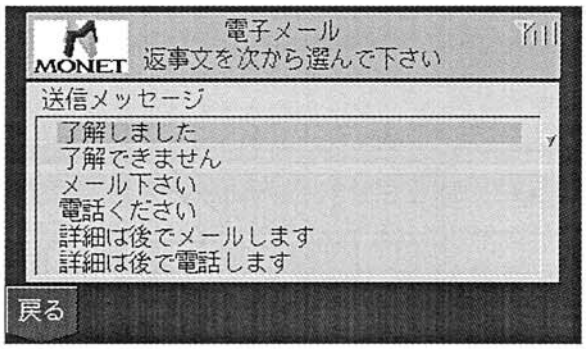

Figure 22 Screen displaying a list of selectable reply messages

3.3 Structure characteristics

Since the MONET ECU comprises optional car-mounted equipment, there is restriction on its installation position — for example, under either the driver's seat or the front passenger's seat. Considering such limitations in terms of installation locations, we took note of the importance of its external dimensions early in its design stage. We realized the importance of coming up with external dimensions that would be suitable for installation on any vehicle model. In the end, we concluded that the width would have to be a maximum of 240 millimeters (equal to the width of navigation equipment already in use) to enable installation of the ECU under the front seat.

The customer presented us specifications stating that the external dimensions be the same as those of existing equipment incorporating lower level functions compared to those of the MONET ECU. To satisfy the customer's specifications, we concluded that the external dimensions for regular production would have to be 240 mm (width) × 117 mm (depth) × 30 mm (height). Figure 23 shows the exterior of the main unit of the MONET ECU.

To package all of the necessary functions within a MONET ECU having these external dimensions, we had to reduce the area of the PC boards with components mounted on them. We solved this problem by using the components given below:

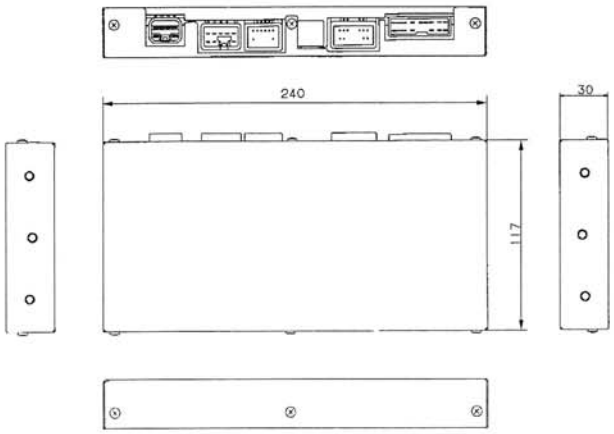

Figure 23 Exterior of the MONET ECU

① High-density packaging provided by Fujitsu's 32-bit CPU (SPARClite), a newly developed MM-ASIC (MB87F116), and type-1005 chips.

② Two-board configuration — a CPU board (65 × 115) structured so that reflow soldering can be done on both sides and a main board (219 × 111) mixing ordinary and discrete components, with shortened processes realized with stable quality of mounted components and fully automatic testing.

③ New 9-millimeter high, 70-pin reflow-soldered connector for linkage between the CPU and main boards.

Using the components described above allowed us incorporate all of the necessary functions within the desired external dimensions. In particular, the ASIC was the result of our first attempt to use high-density BGA packaging. It is structured so that any heat it generates must be dissipated.

When designing the heat radiation structure, we considered the close contact between the IC and the radiator, focusing on the quality of the contact, the ease of assembling the two, and the ease of after-sales service activities. For this purpose, we chose a material that we believed assures good contact. For this selection, we considered that the material should:

① have a high degree of thermal conductivity,

② facilitate the assembly process, and

③ not have any adverse effect on the environment.

Table 1 lists the evaluated materials and their properties.

We designed the heat radiation structure with emphasis on ease of assembly, by using two PC boards and inserting silicone rubber between the ASIC and the radiator.

Figure 24 shows the structure of the MONET ECU.

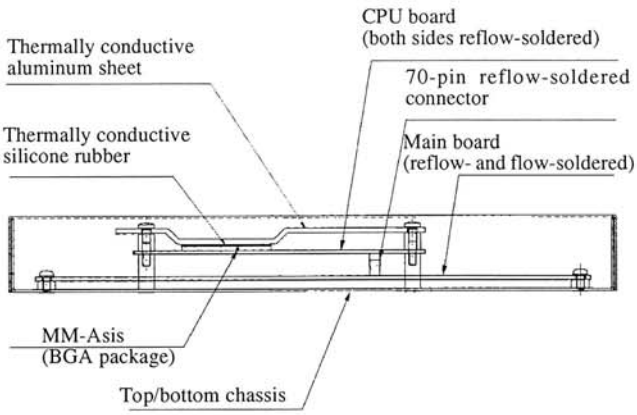

Figure 24 Structure of the MONET ECU

Table 1 Evaluated materials for heat radiation and their properties

Category	Bonding material				Sheet	
Manufacturer	Company A		Company B	Company C	Company D	Company E
Type	One-pack silicone		Two-pack silicone	One-pack silicone	Silicone rubber sheet	Silicone rubber sheet
Hardening condition	25°C, 72 hours	150°C, 30 minutes	150°C, 60 minutes 120°C, 90 minutes	25°C, 72 hours	–	–
Viscosity	250p	500p	400p	Data not available	–	–
Pot life	10 hours (25°C) 3 months (25°C)	2500 hours (°C)	8 hours (25°C) 6 months after delivery	Data not available 6 months (25°C)	– Unlimited	– Unlimited
Thermal conductivity	3.8×10^{-3}	4.5×10^{-3}	4.0×10^{-3}	4.0×10^{-3}	3.2×10^{-3}	3.2×10^{-3}
Measures against electric contact failure	Implemented	Not implemented	Not implemented	30. Implemented	Implemented	Implemented
Overall evaluation	△	△	△	○	⊙	⊙

⇧

Selected by us

4. Future perspectives

The question that has been most often asked since November, 1997 when the MONET ECU was introduced to the market is "Will a voice recognition feature be available?" In response to this request, we are studying voice recognition features which can be used by the user to make phone calls and to begin the operation required to obtain information when the vehicle is traveling.

At present, for safety reasons, restrictions are in place covering complex button operation. Owing to its ease of operation, a MONET ECU using voice recognition technology is likely to enjoy more frequently use during drives.

As part of recent ITS trends, development efforts will be focused on building vehicle emergency reporting systems (for transmitting mayday messages) in Japan. In Europe, Daimler Benz has already begun developing such a system, dubbed TeleAid. In October 1997, Daimler Benz began operating TeleAid on a trial basis, by having a limited number of users try out the system. It can be briefly described as an emergency reporting system using a cellular telephone. When an accident occurs, manual operation using an emergency switch or the generation of a signal caused by the expansion of the air bag triggers the origination of a call to the service operation center to notify it of the accident.

When a report with a request for rescue is transmitted from the operation center to a police station in the vicinity, it contains information about the vehicle model, vehicle identification number, vehicle body color, the driver's cellular telephone number, and hospitals in the vicinity. In addition, the location, time, and other information about the accident are automatically reported through data communications. Therefore, the request for rescue contains accurate information that is promptly sent to the destination (See Figure 25).

In Japan, the relevant companies and government offices have also begun working on building a similar system for use in the near future. Compatibility with such a system will be indispensable for next-generation car-mounted information terminals.

It is possible at present to browse WWW sites on the Internet providing a wealth of information on this topic.

The key to success with car-mounted products will lie with the ability to develop a good user interface.

We believe that it will be necessary to build a system that allows drivers to obtain the desired information and see it in images form or listen to it in voice format, via simple operation.

5. Conclusion

Since November, 1997 when the MONET ECU was introduced, we have been receiving over 100 inquiries about MONET per day. This trend suggests that numerous users are interested in MONET.

For further spreading, it is necessary to realize the following:

- Lower system price
- Diversified services
- Improved communications infrastructure

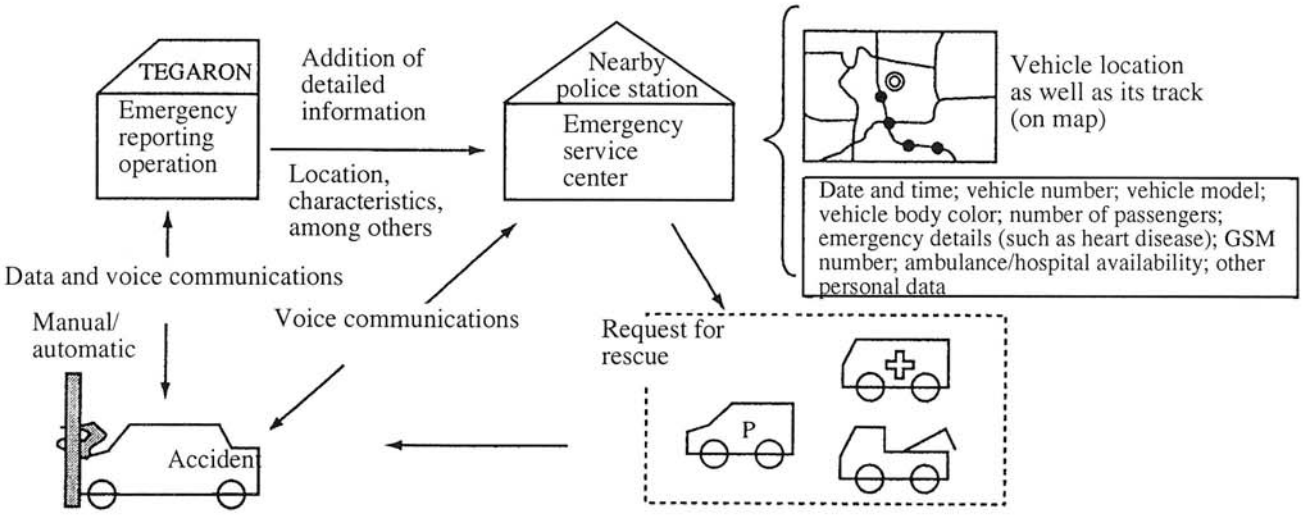

Figure 25 How teleAid works

At present, the terminal costs about 45,000 yen and the service charges are 6,000 yen a year (the registration fee is 2,500 yen). For most users, this price level seems to be generally reasonable although whether a particular user will be willing to accept the price level will depend on the services available to the user. However, it will be necessary to respond to the market's demand for lower prices as soon as possible. What is needed for this purpose is to increase the integration of ICs and combine a greater number of components, including CPUs, into a single chip. We have made MNCP available to all manufacturers concerned so as to expand the MONET concept beyond Toyota, for the reason that a greater number of people recognize what the attractive features of MONET are, and because they understand the potential for more enjoyable and fulfilling driving with MONET.

The transmission speed of the cellular telephone is the key to the improvement of service and the real-time availability of information. In 1996, DoCoMo began a packet communications service of which the transmission speed is 28.8 kbps, or three times the conventional speed. DDI, IDO's CDMA One service has a transmission speed of 64 kbps, and DoCoMo's W-CDMA service has a transmission speed of 384 kbps. Transmission speed are constantly improving.

New MONET systems will be developed to take advantage of such high-speed communications infrastructures.

We would like to conclude this paper by remarking that MONET is a system which may ever evolve and will be included in standard car-mounted equipment. We will keep working on developing new MONET products, taking the development of this MONET ECU as our starting point.

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