Multi-Display System for New Crown

– Audio System Using CD-ROM –

● Junichi Terahata

Mobile information systems are gaining popularity to reflect the rapid progress of the information age. The most advanced systems now in use are the so-called multi-display systems which use a CRT for highly flexible display of information and data as their core and provide various functions. These systems are aboard GM, ETAK, Fords and Toyota's Soarer.

In 1987, Toyota announced a multi-display system using CD-ROM, the first of its kind in the world, for its New Crown to succeed the highly reputed Soarer's multi-display system. Dubbed the AVC system, this multi-display system combines audio, visual and communication functions into an integrated unit. It has been developed jointly by Toyota Motor Corporation, Nippondenso Co., Ltd. and Fujitsu TEN. In the joint development project, Fujitsu TEN undertook the development of the audio unit, CD-ROM decoder and audio interface computer as detailed in this report.

1. Introduction

In 1985 the first Soarer equipped with a multi-display system rolled off a Toyota Plant amid great fanfare. Since then, this new mobile information system has been highly celebrated for its advanced features. The multi-display system developed recently by a joint project team of Toyota, Nippondenso and Fujitsu TEN for the Toyota New Crown is an improvement of its predecessor for Soarer, and can offer the world's first CD-ROM (compact disk read-only memory) audio-visual information service functions, including display of graphic data, such as maps and other information, in an instant.

In the tripartite project, Fujitsu TEN undertook the development of a CD-ROM audio system – one of the most vital subsystems to the multi-display system with improved operability, visibility and radio reception.

This paper introduces this new generation mobile multi-display system in summary and its CD-ROM audio system in detail, together with our product evaluation system which evaluated the CD-ROM audio system.

2. Introduction to multi-display system

2.1 Functions

The Toyota New Crown announced in September 1987 has on its instrument panel a display system (hereinafter simply referred to as AVC system) enhanced with CD-ROM functions jointly developed by Toyota Motor Corporation, Nippondenso Co., Ltd. and Fujitsu TEN.

Compared with the conventional system aboard Toyota Soarer, the AVC system has many improvements:

1) External information display function enhanced by CD-ROM

    – Increased volume of map and other information

    – Reduced latency time for data retrieval and display

2) Display of audio system status data on CRT

With functional blocks as illustrated in Figure 1, this new system can display information and data in the following six modes on its 6" CRT color display installed in the center of the instrument panel.
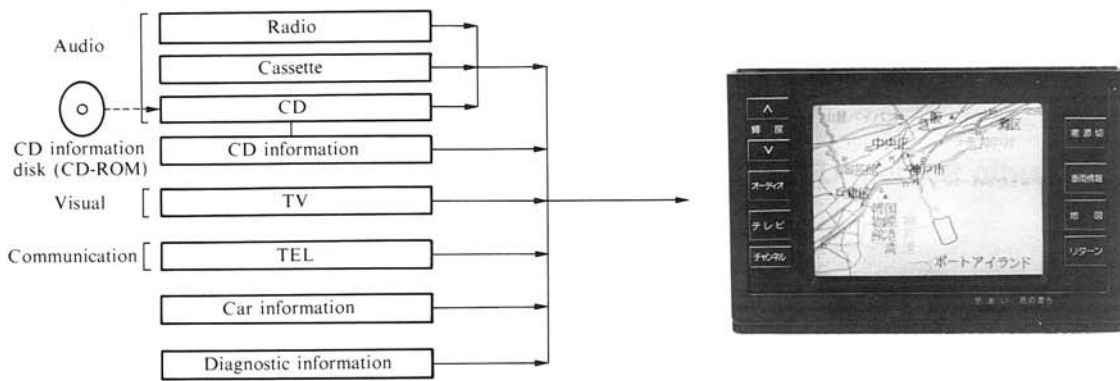
① CD information mode: Map information and car

Figure 1. Functional block diagram

location (Figure 2)

② Audio mode: Audio status (Figure 3)

③ Car information mode: Remaining mileage, maintenance requirements, etc.

④ TV mode

⑤ Telephone mode: Mobile telephone

⑥ Diagnostics mode: Fault diagnosis

2.2 Basic system configuration concepts

The AVC system was developed with simplicity and user-friendliness in mind, and its audio and video processors are separate from each other.
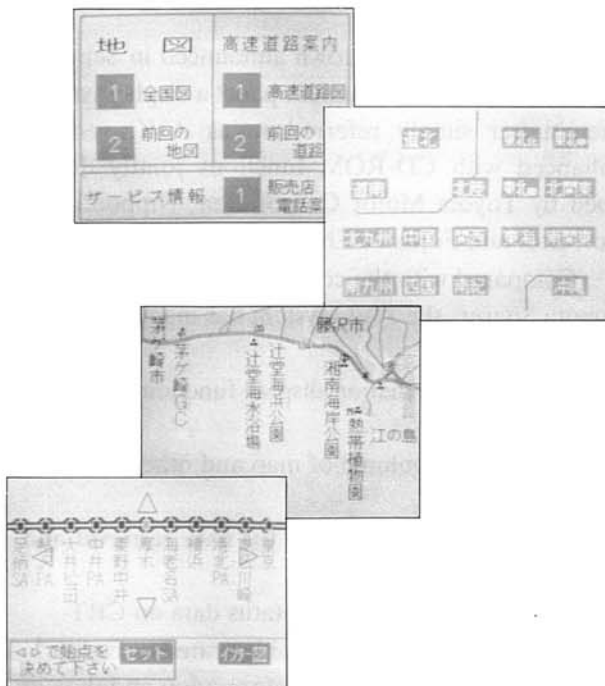
Video processing is carried out by the CRT-ECU (Electronics Control Unit), and audio processing by the audio assembly. The main control of the entire system is carried out using CRT panel switches and easy-to-operate satellite switches for improved operability and safety. (Figure 4)

2.3 System configuration

A block diagram of the AVC system is shown in Figure 5, and a mounting layout in Figure 6.

The ECUs used are: CRT ECU serving as a master controller of transmission and CRT display, slave ECUs − Touch Switch ECU for controlling CRT menu/video input changeover, Audio ECU interconnecting the audio assembly and AVC system, TV Tuner ECU, etc.

The audio ECU, which is one of the main features of the AVC system, is provided with an integrated 3-in-1 audio assembly, and controls all audio circuits for the radio, cassette player, CD and TV, and reproduces signals from CD-ROM. Further detail will be discussed later. The data stored in
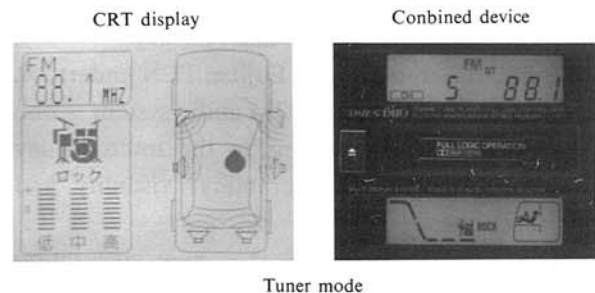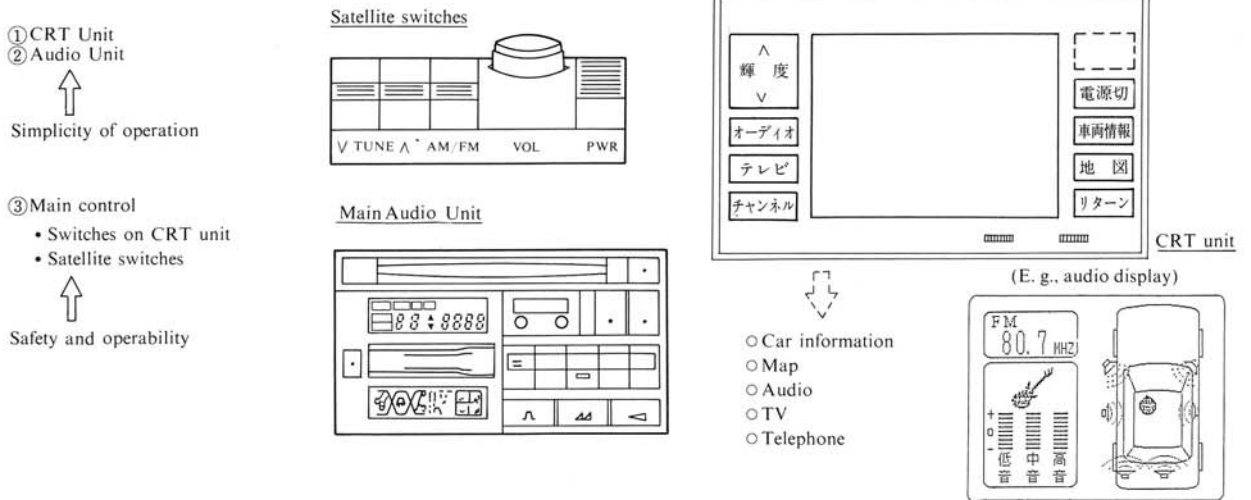

Figure 2. Map mode

CRT display   Conbined device

Tuner mode

Figure 3. Audio mode

① CRT Unit
② Audio Unit

⬆

Simplicity of operation

③ Main control
• Switches on CRT unit
• Satellite switches

⬆

Safety and operability

Satellite switches

∨ TUNE ∧ ˙ AM/FM   VOL   PWR

Main Audio Unit

輝 度

オーディオ
テレビ
チャンネル

電源切
車両情報
地　図
リターン

CRT unit

(E. g., audio display)

○ Car information
○ Map
○ Audio
○ TV
○ Telephone

FM
80.7 MHZ
低中高
音音音

Figure 4.   Switches and controls

Video display

Wireless remote
controller (infrared)

6″ CRT → Touch switch ECU

TV tuner ECU

Video signal

CRT · ECU
(Master ECU)

Optical fiber cable   Common bus (digital communication)

TV audio

Mute (TEL)

Optical fiber cable

Car ECU   Car ECU

Main audio unit → Audio ECU/ CD-ROM → Audio power unit

TEL ECU

Mobile radio telephone transceiver

Satellite switch station

Rear CS

Front SP   Speakers

Front SP

Booster amplifier

ANT

Booster amplfier

Remote

Rear SP

Woofer SP

CD audio system

Rear SP

Woofer SP

Rear window ANT   TV · ANT

Figure 5.   System block diagram

Front SP
CD-ROM
CRT display
Main audio unit
(3 in 1)
Audio ECU

TV remote controller

ANT amp.
Rear SP
Woofer SP
TV tuner
Audio power amp.

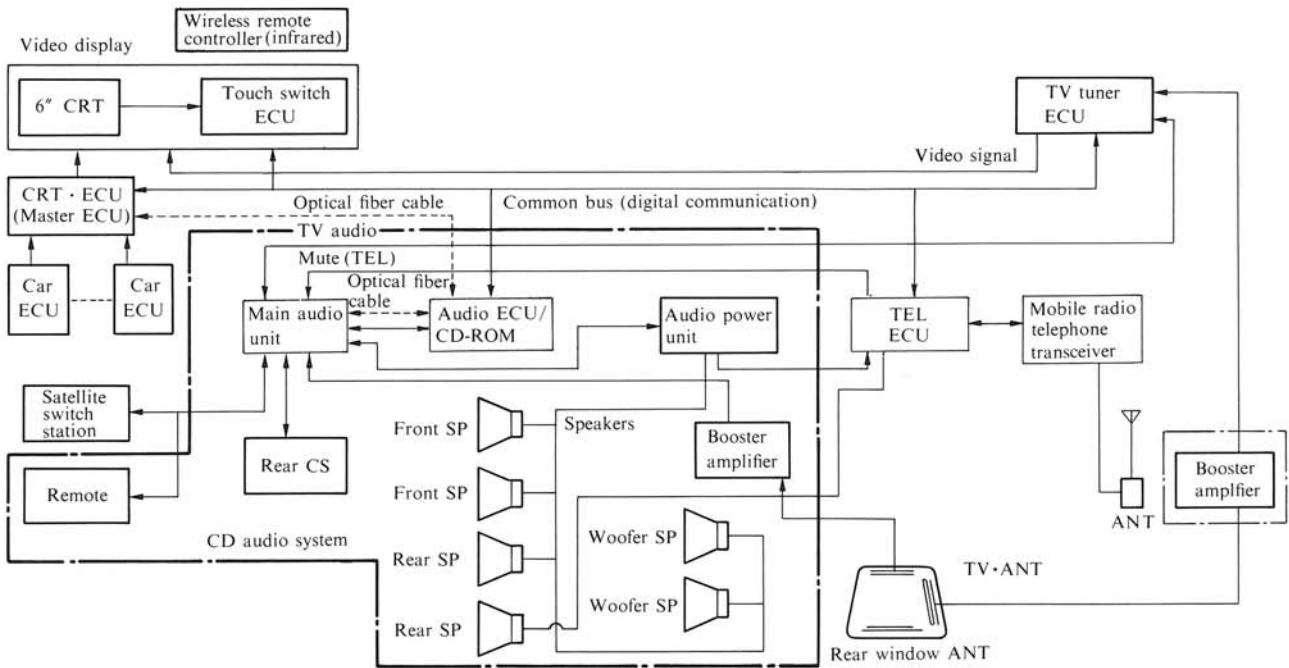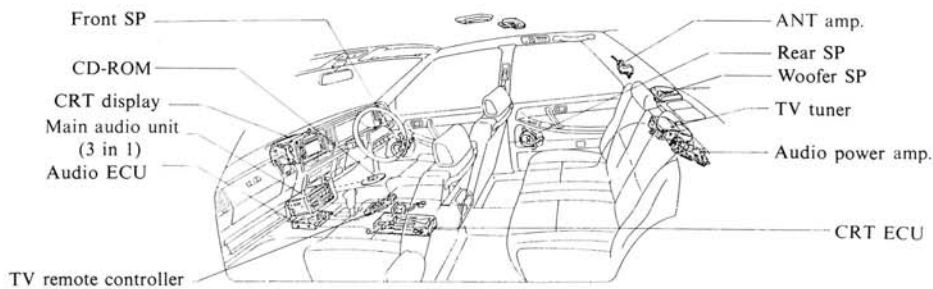CRT ECU

Figure 6.   Mounting layout of AVC system components

CD-ROM is channeled to the CRT display via an optical fiber cable.

The operational flow of the AVC system is as follows:

First, the desired display mode is selected by operating the CRT touch switch. The selected mode is transferred to CRT ECU, which then polls a relevant slave ECU for display data. If the audio mode is selected, the audio assembly is polled for data via the audio ECU. At the direction of the CRT ECU, the audio assembly delivers audio status or data such as map information stored in CD-ROM to CRT ECU via audio ECU for display on the CRT. What has been developed by Fujitsu TEN for the AVC system relates to the audio system enclosed by a dot-and-dash line in Figure 5.

Now let us describe in more detail the audio assembly and audio ECU composing the audio system.

3. Audio assembly, audio ECU, and their features
3.1 Audio assembly

Of all the AVC system components, the audio assembly holds the most important position in terms of car entertainment. This section describes the features of the audio assembly and the technical problems that had to be overcome for its development.

3.1.1 Features
1) The audio assembly consists of an audio processor and CD player for CD information service. It has not only the conventional audio functions, but also a function to transmit CD-ROM map data to the audio ECU.
2) World's first 3-in-1

The audio assembly has realized, for the first time in the world, three functions for radio listening
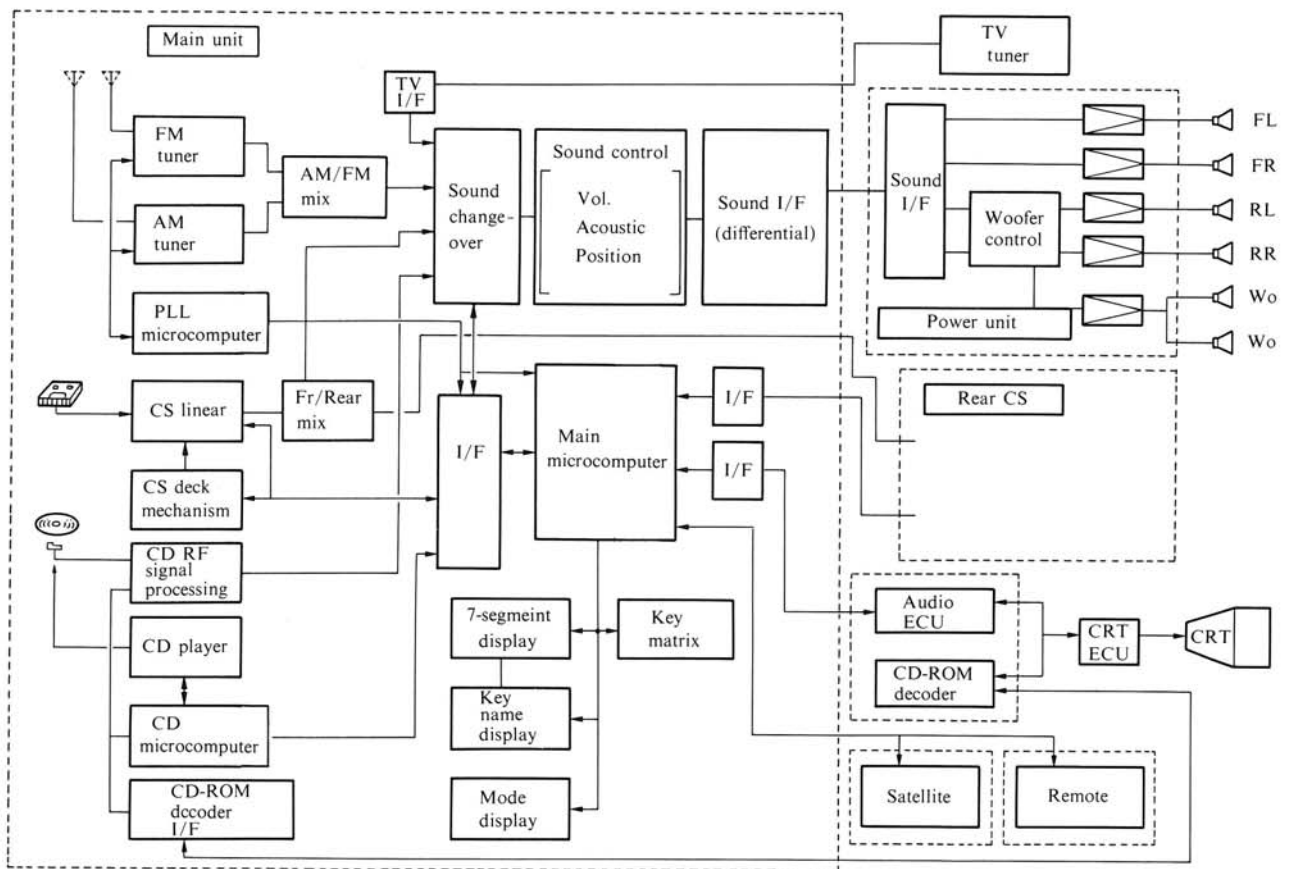

Figure 7. Block diagram of audio main unit

(FM/AM), playback of packaged media (tape, CD) in a compact 2 DIN size.

3) Ergonomic operation and display function

Operating system: Each of the buttons is assigned to electronically control three functions (radio/tape/CD) and display the status of the currently selected function.

Satellite switches: The most frequently used functions are installed at the most accessible location, independent of the audio assembly. They are controlled by a microcomputer interlocked with the audio assembly.

Display: A large-sized LCD is employed. It has a menu area for display of the selected function and an audio status display area to provide a clear picture of what the audio system is doing.

4) Microcomputer control

The audio assembly is controlled by three microcomputers (operation control, display control and general control) which are connected by a serial transmission system for simplicity and high-density integration of circuitry. User-friendliness is improved greatly as the microcomputer software is programmed in a way that will allow immediate callup of any function in whatever status according to the last-bid-first principle.

3.1.2 Design problems and new technologies

The development of the world's first AVC system brought a number of problems that had to be solved before putting the audio assembly in shape. To solve these problems for the completion of the AVC system, we have introduced new technologies.

Figure 7 is a block diagram of the audio assembly.

Our explanation here is limited to 1) the integration of three functions, 2) operation and display, and 3) improvement of radio reception.

1) Realization of 3-in-1 functions

The first problem encountered was how to assemble radio, cassette and CD functions efficiently and effectively into a 2 DIN space (D: 160, H: 100, W: 180).

To solve this problem, we decided to realize these functions by modules. An example of modular structure is shown in Figure 8. The modular struc-

CD player unit

Power line filter unit

Audio assembly (3-in-1) complete
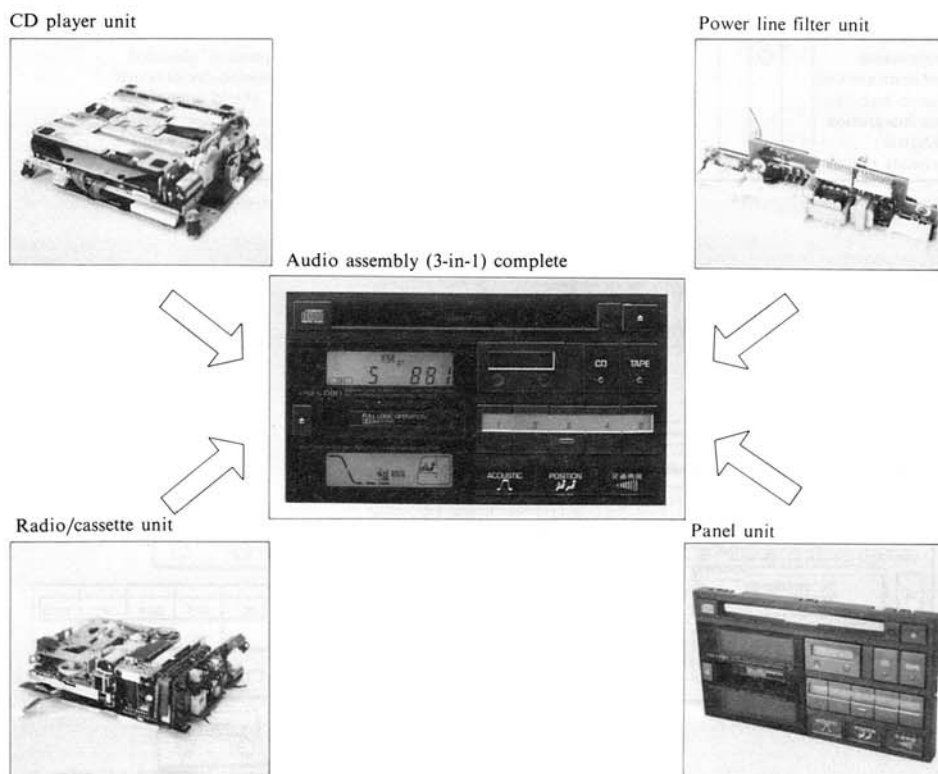
Radio/cassette unit

Panel unit

Figure 8. Modular structure

ture called for the introduction of various new technologies as summarized in Table 1, which lists the requirements and measures taken.

2) Operation and display

Operation: The operating system was designed with large, easy-to-read displays and keys of minimum number in mind. A large-sized LCD and microcomputers were used to make pushbuttons multifunctional and to display the functions selected by the pushbuttons. (Figure 9)

A system in which the selection and display of functions is carried out cyclically was adopted.

Direct change system: To improve the operation of the conventional audio system, the direct

Table 1. Requirements and measures

| Requirements					Elemental technologies	Principal measures
Modular structure					1) High-density integration	
					2) Establishment of interface between units	
Miniaturization and high-density integration	AR	CD	CS	Front		
	○	○	○		1) Integration of circuits	Microcomputer power supply/reset/watchdog circuits Diversity circuit, EQ/APS circuit
	○		○	○	2) Use of fine patterns	0.3 mm-wide pattern
	○				3) Unification of component circuits	FMIF unit, diversity unit, OPF unit
	○		○	○	4) Use of multilayered printed circuit boards	3-layer printed circuit board
	○	○	○	○	5) Use of small chips	2.1 × 2.5 mm chip
	○		○	○	6) Development of miniaturized parts	Plunger, HF coil
		○	○		7) High-density integration	Differential I/O circuit, Dolby circuit, Rotation detector, CD-ROM data transmission
Interaction between circuits due to high-density integration (Digital crossalk noise)	○	○			8) Shielding of microcomputers and peripheral circuits	CD microcomputer IC shielded with flexible printed circuit board LCD driver IC shield in an enclosure Total shielding of diversity unit
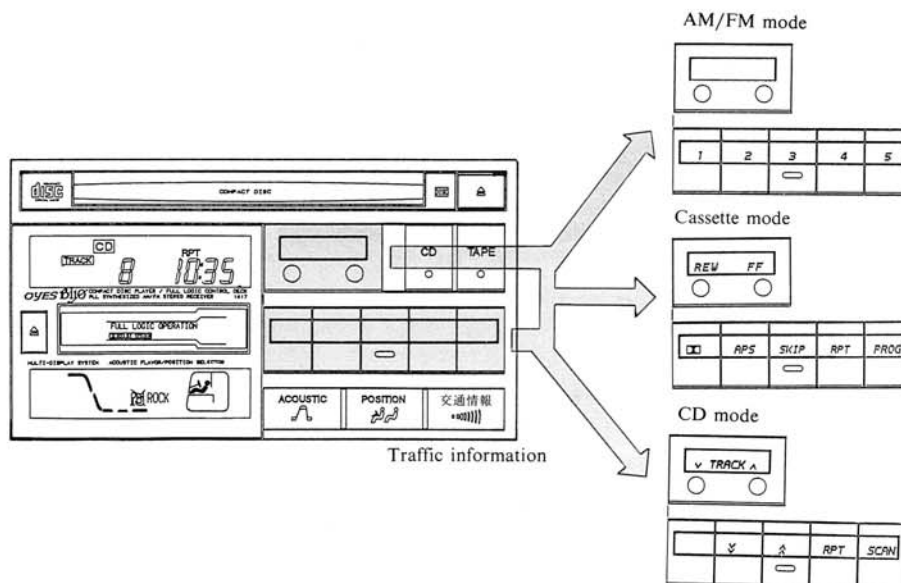
Figure 9. Illuminated pushbuttons
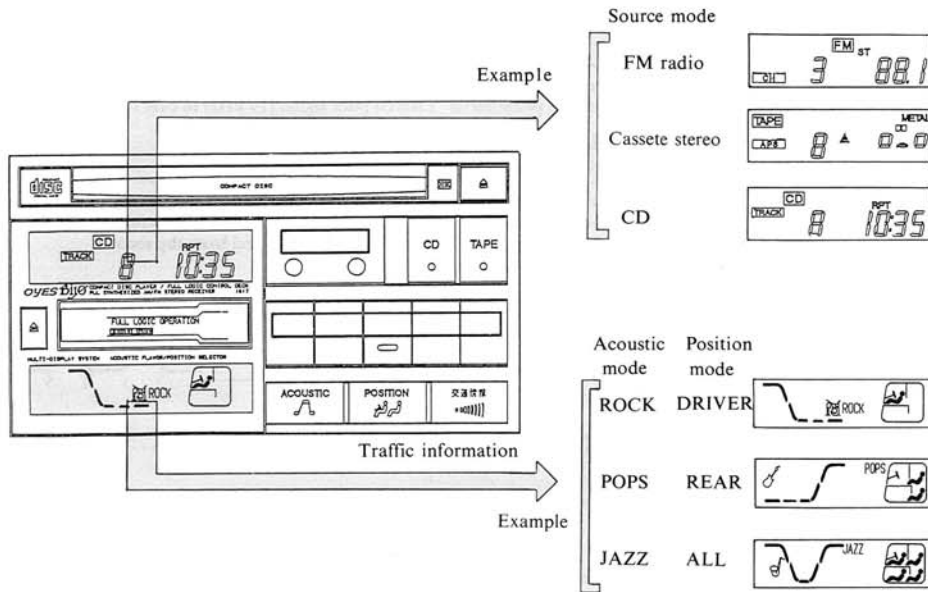
Figure 10. Display of fundction and audio output status

change system was employed. It allows the user to select a desired source directly whenever he or she wants to listen to it. By using a microcomputer, all the packaged media can be put in a standby mode for ready selection and listening.

Display: The function and audio output status are displayed simultaneously in respective display areas so that the user can quickly understand by eye and ear what the audio system is doing. An embodiment is shown in Figure 10. LCDs worked effectively not only for this well-organized display of information, but for the realization of multi-functional buttons as well.

3) Improved radio reception

Adoption of an FM diversity circuit, and reduction of multipath noise.

To provide against diversity effects incidental to FM signals, particularly multipath phenomena (signal distortion and noise received while driving due to the arrival of waves from the same origin but via different paths because of reflection from the terrain and buildings), a space diversity antenna was installed in the rear window. To maximize the effect of the space diversity antenna, a new IC was developed for the receiver circuit improved in overall FM reception performance as shown in Table 2. As a result, the reception noise was reduced dramatically.
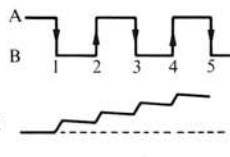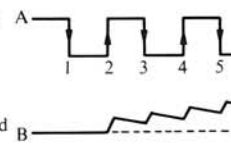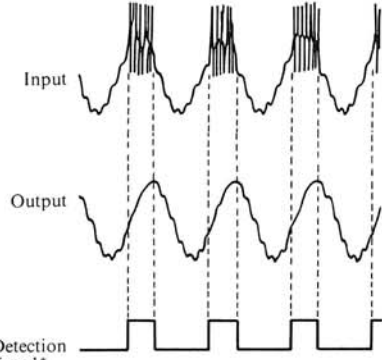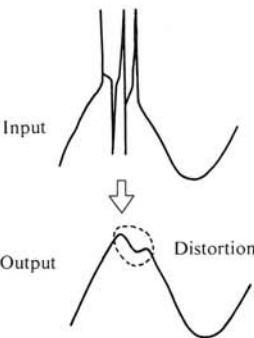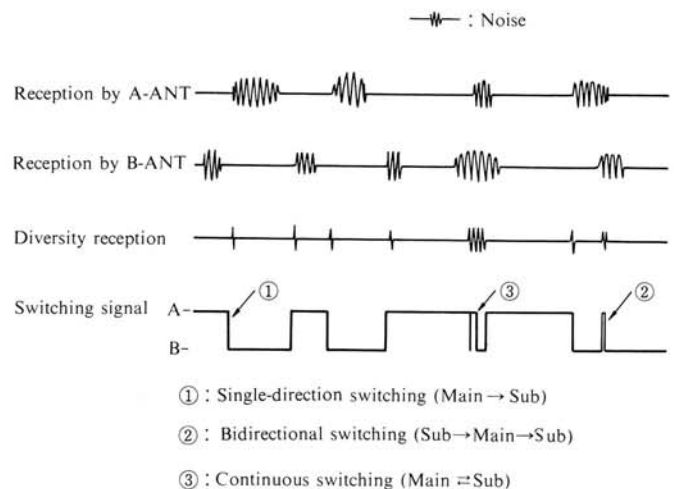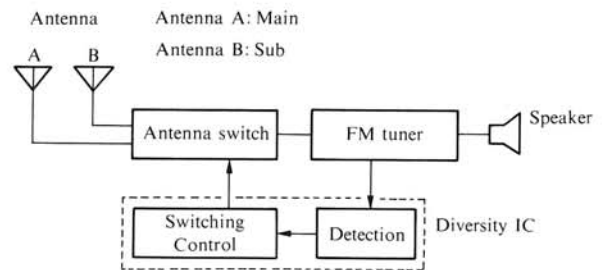

Figure 11. FM diversity reception system, and its operation

Table 2. Comparison of FM reception performance

	New	Conventional
Multipath detection	Detection of amplitude change in stereo pilot signal (19 kHz) in case of multipath phenomena Improved detection sensitivity: ARI (57 kHz) for export specification	Detection of 3rd harmonic (57 kHz) of stereo pilot signal (19 kHz) in case of multipath phenomena
Switching control	The continuous switching conditions are the same as in the 200H. A change was made to bring the switching threshold level timing into effect from the first switching. Antenna switching signal Switching threshold level Prevention of unwanted changeover	Continuous switching if the ON status continues more than 1 ms. The switching threshold level is raised from the second switching. Antenna switching signal Switching threshold level
Antenna switching	Switching element: PIN diode Changeover between forward and reverse bias status Improvement of characteristics for suppressing strong noise such as from TV circuit	Switching element: FET On/off control of source resistor
Multipath canceler	TDMC (TEN dynamic multipath canceler) Multipath detection and filtration for reduced noise Input Output Detection signal* *Different from diversity More effective measure against multipath phenomena	Provision of measure against multipath phenomenon between two antennas Removal of pulse noise in case of multipath phenomena Input Output Distortion

The diversity reception that suppresses multipath noise is schematically shown in Figure 11.

3.2 Audio ECU

The audio ECU serves as a key station interconnecting audio and visual systems of the AVC system. It plays the following two roles. First, it communicates with the CRT ECU via the common digital bus to forward audio status graphic data to the CRT ECU. Second, it undertakes CD-ROM data transmission and control. The development of a CD-ROM decoder with new functions and the prevention of erroneous operations were the keys to this audio ECU.

3.2.1 Circuit configuration

As shown in Figure 12, the audio ECU is divided into a transmission control unit and a CD-ROM decoder unit. An 8-bit one-chip microcomputer with a 16K ROM is used to control these two units,
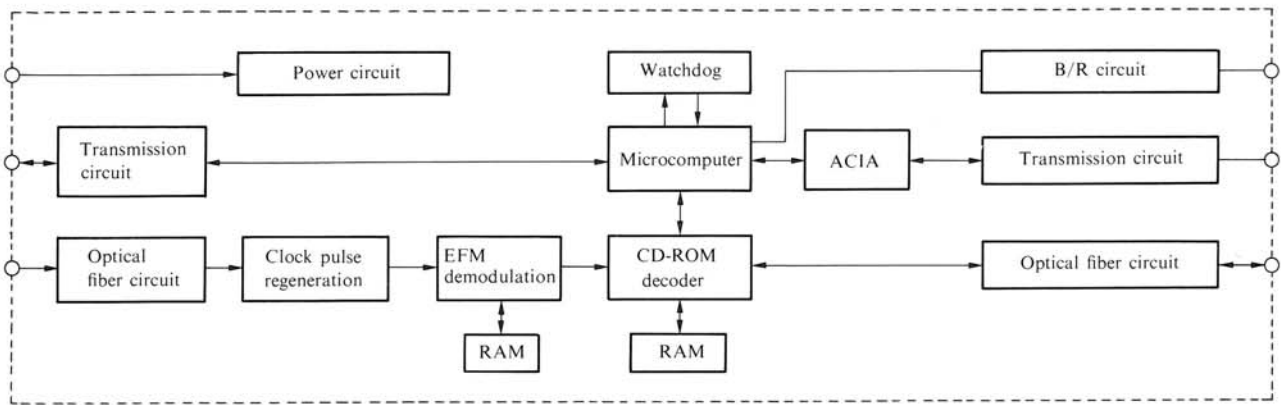
Figure 12. Audio ECU block diagram

simplifying the overall circuitry. The transmission control unit is composed of an ACIA circuit for serial communication with the bus line and a transmission I/O circuit. A photocoupler with high noise resistance is employed in the transmission circuit.

The CD-ROM decoder is composed of a circuit for demodulating the EFM signal sent from the CD player of the audio assembly (demodulator circuit), a circuit for decoding CD-ROM data (decoder circuit), and an optical fiber circuit for transmitting and receiving CD-ROM data. We developed a customized IC for the decoder circuit to reduce the number of components, which would reach several hundred if discrete ICs were used.

3.2.2 CD-ROM decoder
The CD-ROM decoder of the AVC system

reproduces some 1,800 image frames of maps, highways, and service stations from a 120-mm-diameter CD-ROM. The CD-ROM is driven by the music-CD player for reproduction. The CD-ROM's innermost track provides lead-in data by which the CD-ROM for information is discriminated from the music-CD.

The reproduced image signals are processed as shown in Figure 13.

When a CRT switch is operated, the CD-ROM address of image data to read is sent from the CRT ECU to the audio ECU microcomputer to give a lead-in instruction to the CD player. The data read from the CD-ROM is sent to the CD-ROM decoder through the optical fiber cable, then is sent to the CRT ECU via optical fiber cable and displayed in graphic images.

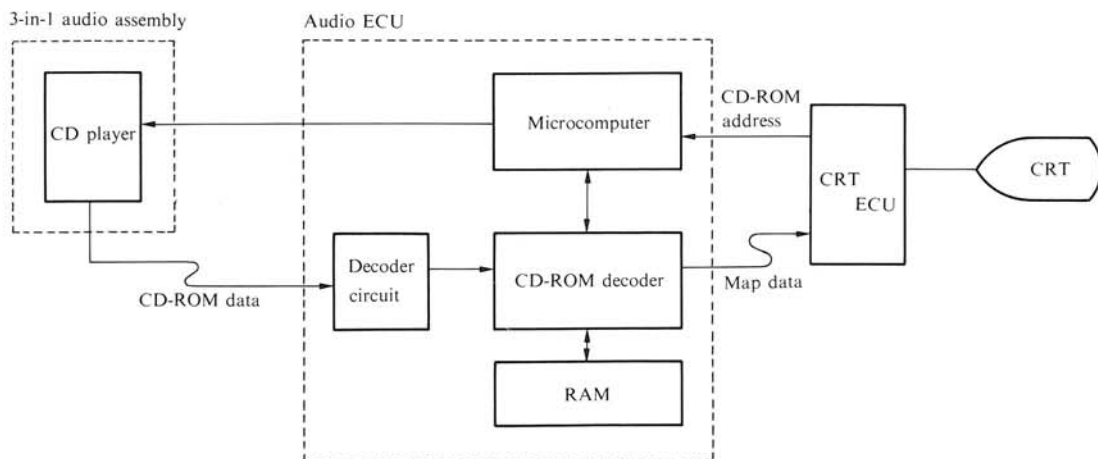In order to achieve this function, Fujitsu TEN

Figure 13. CD-ROM flow

Table 3. Signal processing specifications

Synchronization	Clock signal
Data format CDP − CD-ROM	EFM signal
CD-ROM − CRT	Demodulated signal
Clock frequency	384 kbps
Error detection	EDC check (error rate = $1/2^{32}$)
Error correction	5-out-of-32 symbol error correction
Data length	max. 4-block transmission (2,056 characters per block)

developed an IC using a C-MOS gate array with 2,600 gates for the CD-ROM decoder. Optical fiber cables are used for data transmission between the CD player and audio ECU and between the audio ECU and CRT ECU and for the transmission of the timing clock signal to eliminate noise interference with other electronic devices.

Signal processing specifications are shown in Table 3. For map display, an error check is particularly important. For this reason, the prevention of bouncing error in the audio assembly, the EDC check and 5-out-of-32 symbol error check and other strict error controls are applied. In addition, the recording area of the ROM disk is divided into three, each recorded with the same data to minimize reproduction failure due to contamination and deterioration of the disk. The recording format is in accordance with Toyota's specifications because there is no established standard in the market for this kind of ROM disk.
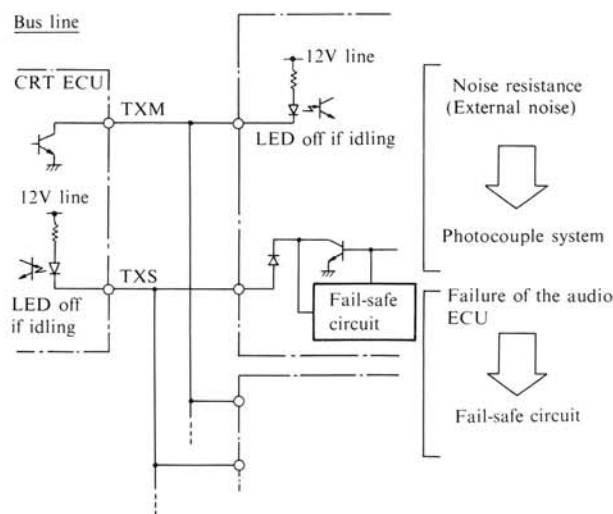
3.2.3 Technical problems

The problems that stood in the way of developing the audio ECU were how to prevent trouble due to noise and how to protect the entire system from the harmful effects that might be brought about should a trouble occur. These problems were solved chiefly by the following three measures.

(1) To protect the system from noise

A photocoupler system in the bus line as illustrated in Figure 14 eliminates external noise interference with the transmission line.

(2) To protect the entire system from the harmful effects of failure or runaway of the audio ECU

A fail-safe circuit in the transmission circuit as shown in Figure 15 cuts off the output if the transmission output is anomalous.

(3) To protect against microcomputer runaway

A watchdog timer circuit monitors the output and thus, the status of the microcomputer.

In addition, various software measures, including a KILL command, are provided. Another problem was radiation noise interference with TV and radio. Radiation noise is developed by lines and enclosures. Measures taken to reduce the noise level below a target value included a filter in the wire harness line and ground bonding of the enclosure.

4. Product evaluation system

The AVC system was a mass-production pro-

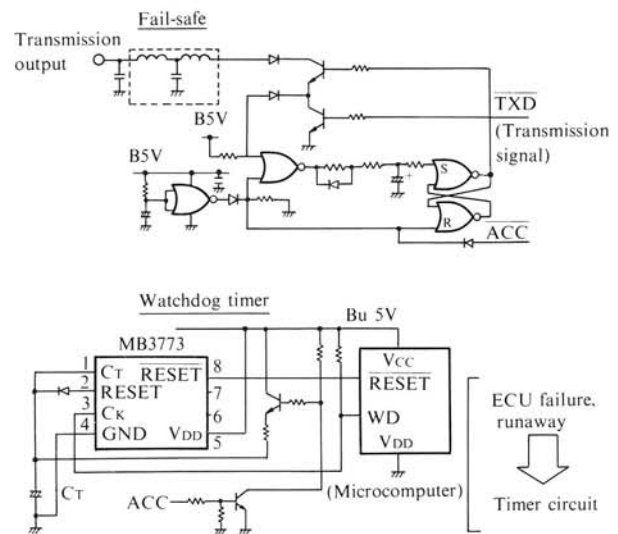Figure 14. Bus line circuit

Figure 15. Fail-safe circuit

duct new to us. In addition, it was to be manufactured in cooperation with Nippondenso Co., Ltd. It was expected that our conventional mass-production techniques alone would not be enough to overcome various problems including quality assurance. To make its mass production a success, we introduced various new techniques with special emphasis on the following.

4.1 Efficient evaluation in production line

The audio assembly that is the heart of the audio system is an integrated AM/FM tuner unit, cassette unit, and CD player unit, composed of no less than 1,000 parts. It also has many functions. The audio ECU is an interface between the total system and the subsystem we are assigned to produce, and cannot be checked and evaluated by conventional techniques because it has no operation buttons nor audio and video I/O terminals.

There was a large gap between the system quality assurance and our conventional in-process evaluation techniques. To minimize this gap, we had to develop an evaluation system that would improve the efficiency and effectiveness of quality assurance in production and inspection stages.

The basic schematic of this evaluation system is shown in Figure 16, and an application example in Figure 17.

The evaluation system designed for inspecting the components and parts of the audio assembly uses a personal computer to simulate the operations of front panel pushbuttons, satellite/rear wired remote controller pushbuttons and the signals from the audio ECU, and to control test equipment via GP-IB for setting test conditions such as supply voltage, standard signals, etc. The sound generated as a test result is checked by an audio analyzer, and the output of the audio analyzer is subjected to pass-fail judgment by the personal computer. In order to implement this evaluation system, a part of the test program is incorporated into the microcomputers of the product.

This evaluation has eliminated troublesome front panel operations during inspection while making it possible to test all functions and performance without omission. Another benefit of this system is the reduction of manhours to about one fifth as compared with our conventional inspection system. A similar evaluation system has already been developed and put to use for the testing and inspection of audio ECUs.

4.2 Design evaluation

The AVC system uses many microcomputer-applied components that call for strict checkup. To prevent trouble, it is necessary to build quality into the product with due consideration given to voltage variations. In view of this, Fujitsu TEN has developed a power supply simulation system for evaluation of the resistance of the AVC system against voltage variations.

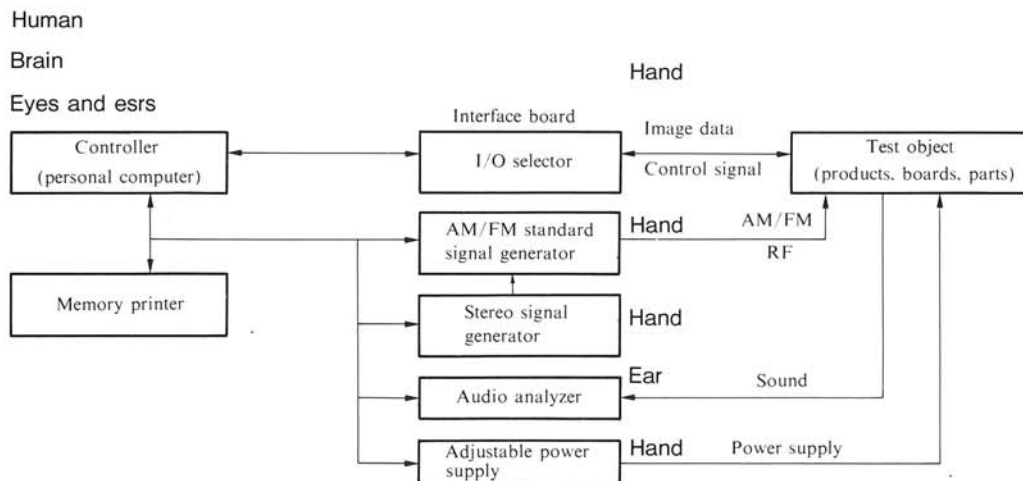The basic configuration of this simulation system

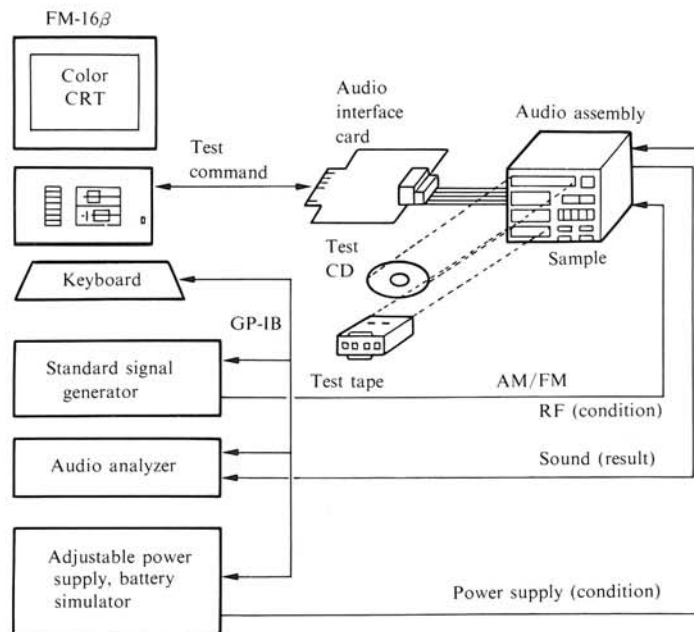Figure 16. Basic schematic of evaluation system

Figure 17.   Audio assembly-evaluation system

is shown in Figure 18. It consists of a storage oscilloscope for storing car battery voltage waveforms temporarily during data logging, a personal computer for storing and processing waveform data and controlling waveform reproduction, and a programmable power supply that supplies voltage to a test object according to the directions of the personal computer. Figure 19 shows a sequence of evaluation operations by this newly developed simulation system. The voltage waveforms reproduced and applied to test objects can closely simulate actual car conditions. According to this simulation system, momentary power interruption can be simulated freely by the personal computer with duration, voltage, and repetition cycle, etc., as parameters.

At present, we use 82 different modes of power

supply status determined due to supply voltage variation, and momentary isolated or repeated voltage drops in evaluating the AVC system. Unlike the conventional power switchbox inspection system and field testing system which are always accompanied by heavy dispersions in evaluation conditions or with limitations in scope and period of tests and leave much to be desired for efficient and effective evaluation for the formulation and verification of improvement measures, the new simulation system has proven to be truly effective in improving the design and engineering of the AVC system.

5. Conclusion

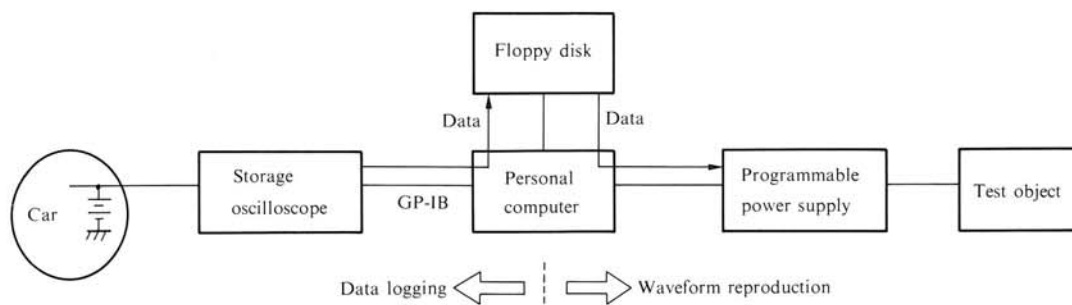Our audio and interface computer systems developed for the world's first mobile multi-

Figure 18.   Basic configuration of power supply simulator
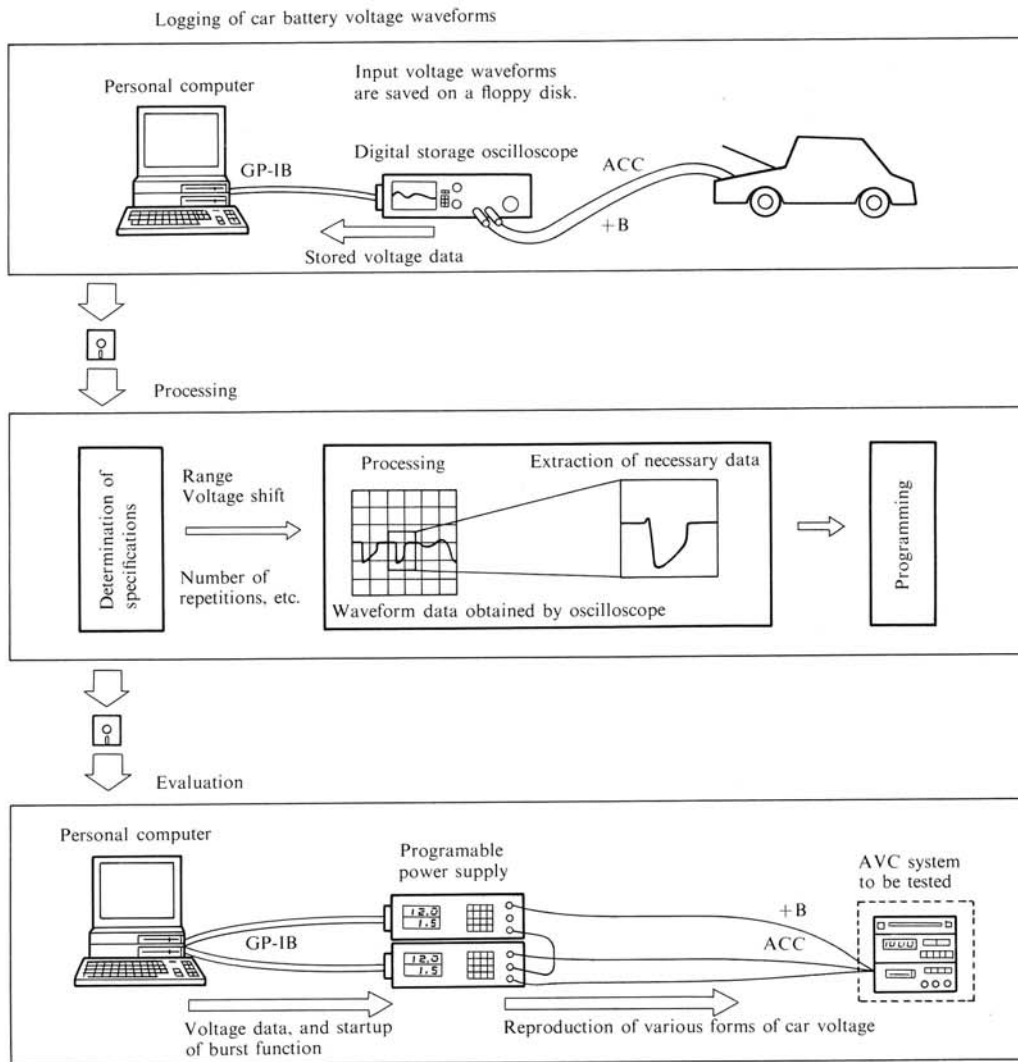
Logging of car battery voltage waveforms

Figure 19. Evaluation procedures

information AVC system in anticipation of the new media era are full of new features, technologies and communication systems. They have been designed and engineered to revolutionize AM/FM reception performance, acoustic characteristics, operability and user-friendliness. Our efforts have been embodied in a compact multi-functional audio system (3-in-1 in 2 DIN size) with many appealing features, including a wide LCD display for improved visibility and 3 multi-function keys for improved operability, all backed by our advanced CD-ROM system technology and high-performance radio reception technology. While we presume that our systems are really successful and will be well received by the customers, we are committed to improving and refining them further.

In closing this paper, we would like to thank the researchers and engineers of Toyota Motor Corporation and Nippondenso Co., Ltd. for their unstinting assistance extended to us in developing our system.

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Entered the company in 1974, where he has been engaged in developing car audio equipment. He is currently with the 1st Audio Products Division's Inspection Department.