Data Network-Based Elevator Control System

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ABSTRACT

Most functions of conventional elevator systems are performed by a single central control unit located in a machine room. However, such designs limit the possibilities for adding new functions and improving system performances. This paper describes a newly developed data-network system in which microprocessor modules located in the machine room, cars, and halls are linked together by a serial-transmission network. Network distributed design has made it possible to increase the system sophistication and performances.

1. INTRODUCTION

As more and more 'intelligent' apparatuses are installed in new buildings, the same qualities (sophisticated systems, high performances, improved man-machine interface, etc.) are also required for elevators. Meanwhile, rapidly progressing micro-electronics technology has achieved large scale integration for microcomputers, memories, serial interface LSIs, etc., which results in higher processing speed, higher reliability and lower prices. In addition, the functions and loads which used to be assigned to a single system are now divided among a number of microcomputer-based systems. Similarly, a single central control system for an elevator can be divided among a number of local microcomputer-based controllers, where each controller is interconnected by a serial-transmission network. In an actual case of application, we have distributed a number of microcomputers in the machine room, cars and halls and linked them in the data network system by providing a new protocol based on the function and response time of each controller. This system is applied in the Grandee Series of elevators, which were released for sale in March 1990, and also in the ACCEL-AI Series of elevators, which were released for sale in January 1992. This report describes the structure and major functions of the data network in the elevator control system.

2. STRUCTURE AND MAJOR FUNCTIONS OF DATA NETWORK SYSTEM

If a central processing method were used to improve functions, performances and extensibility of a system, the central processing unit would be complex in structure and eventually the total system would have losses in performances and availability. To solve this problem, the functions of the entire system must be properly distributed among subsystems which are interconnected by a network system.

2.1 Distributed System

Microcomputers are distributed among subsystems based on the following principles.

(1) Two 16-bit microcomputers are used in the Car Control Unit; one for controlling the car operation and the other for controlling the car speed. Also, two 8-bit microcomputers are used in the Car Control Unit; one for data transmission to car-related devices and the other for transmission to hall-related devices.
This helps to reduce the load on the Car Control Microcomputer.

(2) A Car Station Control Unit located on top of the elevator car consists of three microcomputers. One 16-bit microcomputer is used for controlling the door operation and the other 16-bit microcomputer for controlling the door motor drive.
An 8-bit microcomputer is used for data transmission between these microcomputers and the Car Control Unit.

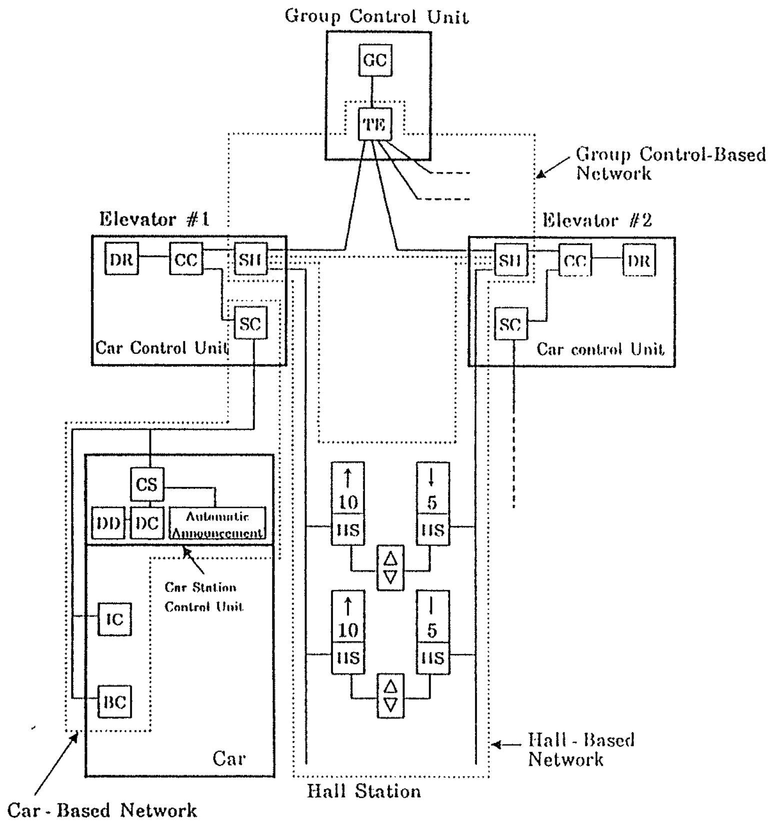

Fig. 1 . Overall Configuration of Elevator Control System

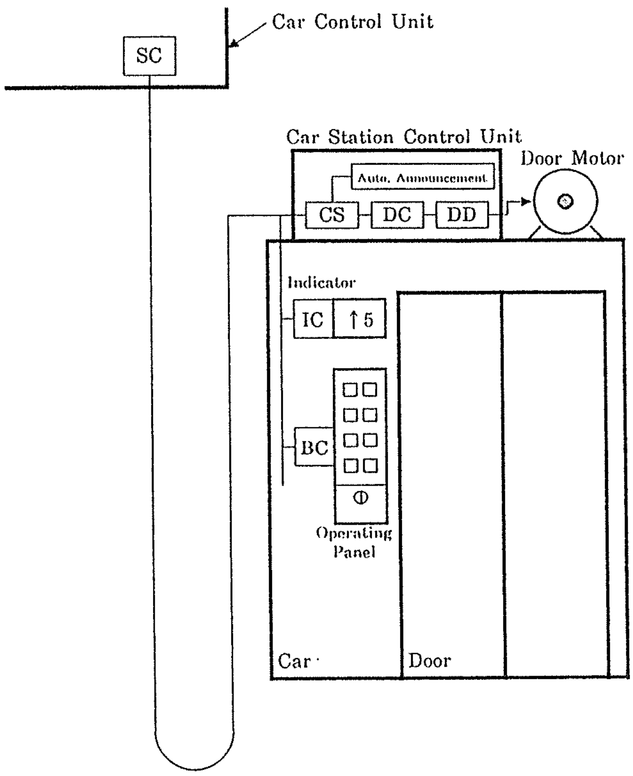

Fig. 2 . System Configuration of Car - Based Network

Table 1 . Names, Locations and Functions of Microcomputers

	Microcomputer Name (Type)	Location	Function
	Car Control Microcomputer CC (16 bits)	Car Control Unit	Controls elevator operation.
	Motor Drive Control Microcomputer DR (16 bits)	Car Control Unit	Controls torque and speed of traction machine drive motor.
	Group Control Microcomputer GC (16 bits/32bits)	Group Control Unit	Controls and allocates hall call signals.
Car - Based	Car Station Microcomputer CS (8 bits one chip)	Car Station Control Unit	Controls serial transmission and car - top devices such as the device for automatic announcement.
Car - Based	Door Control Microcomputer DC (16 bits one chip)	Car Station Control Unit	Controls door operation.
Car - Based	Door Motor Drive Control Microcomputer DD (16 bits one chip)	Car Station Control Unit	Controls torque and speed of door motor.
Car - Based	Indicator Control Microcomputer IC (8 bits one chip)	Inside Car	Controls indicators and indication lamps.
Car - Based	Car Operating Panel Microcomputer BC1 to BC4 (8 bits one chip)	Inside Car	Controls car interior devices such as buttons, switches inside slide cover.
Car - Based	Serial - Transmission Microcomputer to Car SC (8 bits)	Car Control Unit	Controls serial transmission for cars.
Hall - Based	Hall Station Microcomputer HS (8 bits one chip)	Hall Station	Controls hall devices such as hall buttons, hall indicators and lanterns.
Hall - Based	Serial - Transmission Microcomputer to Hall SH (8 bits)	Car Control Unit	Controls serial transmission for halls and group control.
Group Control	Serial - Transmission Microcomputer to Each Car Control Unit (8 bits)	Group Control Unit	Controls serial transmission for group control.

Table 2 . Specifications of Data Network System

		Car - Based	Hall - Based	Group Control - Based
Range of Application	Number of Stops	128 floors or less	Same as left	Same as left
Range of Application	Number of Elevators for Group Control	–	–	8 or less
Transmission Signal	Type	Button Indicator Car - Top Switch Door Switch inside slide Cover Automatic Announcement, etc.	Button Indicator Hall Lantern Operation Indicating Lamp Key-Operated Switch, etc.	Hall Button Car Position Car Allocation, etc.
Transmission Signal	Total Capacity	140 bytes approx.	100 bytes approx.	1.4K bytes approx.

Two 8-bit microcomputers are used inside the elevator car, one for the car operating panel and the other for the car indicator.

(3) A hall-station is provided on every floor to enhance operability and extensibility. An 8-bit microcomputer is used in each hall-station to control the hall-related devices.

(4) Either a 16-bit microcomputer or a 32-bit microcomputer is used for the Group Control Unit in the machine room, depending on the grade of the elevator.
An 8-bit microcomputer is used for data transmission between the Group Control Unit and the Car Control Unit.

The names, locations and functions of the above mentioned microcomputers are shown in Table 1. The overall system configuration is shown in Figure 1.

2.2 Network Structure

The microcomputers in the distributed controllers are interconnected by the three independent networks.

(1) Car-Based Network
(2) Hall-Based Network
(3) Group-Based Network

The most suitable transmission method is selected for each type of network based on response time, reliability and extensibility. Each of these networks is referred to as a 'Data Network System', with specifications as shown in Table 2.

The elevator control system incorporating this data network system is called a 'Data Network based Elevator Control System'.

2.3 Car-Based Network

The car-based network is used to control the car buttons, the car indicator and also to control the door operation. Figure 2 shows the system configuration, while Table 3 shows the data transmission specifications. A maximum of four microcomputers (BC1 to BC4) can be connected to the SC in order to satisfy the requirements of 128-floor buildings.

The transmission is controlled by the polling method as described below. The Serial-Transmission Microcomputer to Car (SC) functions as a master station and sends/receives data to/from substations such as Indicator Control Microcomputer (IC), Car Operating Panel Microcomputer (BC1 BC4) and Car Station Microcomputer (CS).

Transmission is executed in a specified sequence for each station.

Figure 3 shows a conceptual diagram of the data transmission between the master station (SC) and the substations. The transmission period for this network is 100ms. This means the SC sends/receives a specified number of data units, whose length is also specified, within 100ms. Also, the SC and each substation are synchronized by means of a silence (or a non-signal period) inserted between each transmission period.

If the SC polls every substation one by one, a signal from a certain substation would be delayed for one polling period in the worst case. To eliminate such delays especially for CS signals, the polling frequency for CS has been increased to provide the CS with priority transmission over the other substations. Conversely, a low polling frequency is applied to the IC, which transmits data to the indicator, etc. which has a low frequency of change.

As a result of these measures, a substantially high transmission rate has been achieved without sacrificing EMC characteristics.

2.4 Hall-Based Network

The hall-based network is used to control hall buttons and a hall indicator on each floor. Figure 4 shows the system configuration, while Table 3 shows the data transmission specifications.

The hall-based network is provided with high extensibility --- a maximum of 128 (HS)

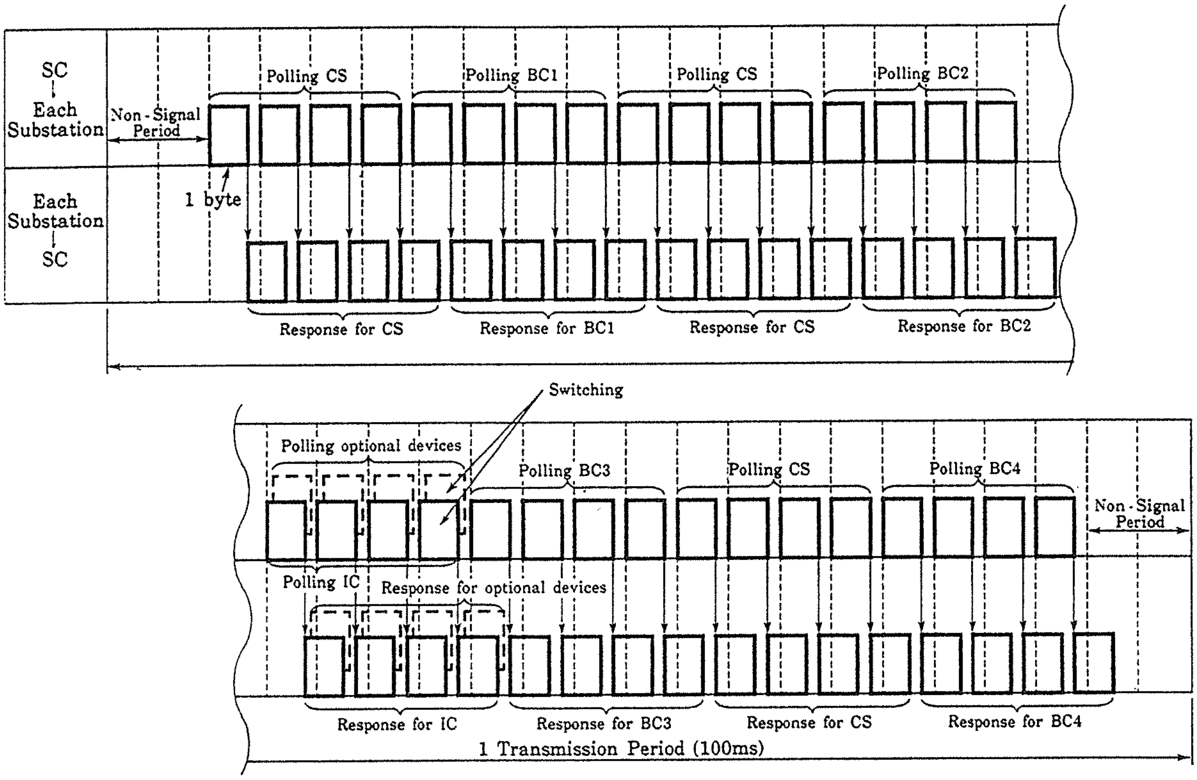

Fig. 3 . Diagram of Transmission between SC and Substations

Table 3 . Specifications of Data Transmission

	Car-Based	Hall-Based	Group Control-Based
Cable Type	Cable for Wiring		Optical Fiber Cable
Max. Number of Substations	14(7×2 related)	128	8
Max. Transmission Distance	300m		100m
Network Form	Bus		Star
Transmission Method	Full Duplex Base Band Transmission		
Signal	8-bit Data		
Synchronizing Method	Start-Stop Transmission		

microcomputers can be connected to the Serial-Transmission Microcomputer to Hall (SH). (This means 128 'UP' buttons and 128 'DOWN' buttons. The word, DOWN, shall be abbreviated to 'DN' hereafter in this paper.)

When polled by SH, HS transmits a button signal (UP/DN) in the form of a data bit. Also, when two or more HS send button signals simultaneously, the signals will be logically ORed bit by bit on the transmission circuit.

Figure 4 shows the address allocation (zone, block, bit) for all the hall buttons, where eight buttons form one block and eight blocks form one zone.

Figure 5 illustrates communications between SH and HS. The period of data transmission between SH and HS is 50ms. Similar to the car-based network, a silence is inserted at the beginning and also at the end of each transmission period so that each HS may be synchronized with SH at each period.

SH receives hall button signals in the following procedure. When a certain zone is polled by SH, one of the activated HS in the zone, if any, will send back the information on which block in the zone it belongs to. In the same manner, when that specific block is polled by SH, the HS will send back the information of which bit in the block it belongs to. In this way, SH polls each zone, and as soon as a button signal is detected, SH polls that particular block.

Figure 6 shows a flowchart of this polling procedure. If a total of 128 HSs are to be polled one by one, the delay time may amount to seconds rather than milliseconds. However, by using the method shown here the delay time can be minimized to tens of milliseconds. The protocols described above enable effective transmission of a large quantity of data without any significant delay.

2.5 Group Control-Based Network

The group-based network is composed of a Serial-Transmission Microcomputer to Each Car Control Unit (TE, located in the Group Control Unit) and a Serial-Transmission Microcomputer to Hall (SH, located in the Car Control Unit). Table 2 shows the specifications for this network, while Table 3 shows the data transmission specifications. TE and SH take two different forms of data link as follows.

(1) GC ---TE/SH --- CC

(2) GC ---TE/SH --- HS

(1) is used by GC to control the allocation of button signals.

(2) is used by GC to control hall buttons and hall indicators.

Optical fibers used for the data transmission channel increase the transmission rate. This allows GC to perform more precise allocation of the button signals. If the Group Control Unit should fail, the button signals will be sent directly to the respective Car Control Units.

The exclusive transmission channel, in which the button signals were directly transmitted to the Group Control Unit, has been replaced by a common transmission channel to provide more reliable transmission.

3. CHARACTERISTICS OF DATA NETWORK-BASED ELEVATOR CONTROL SYSTEM

In designing an elevator control system, we must take into account safety, reliability and extensibility as well as operability and amenity. The following paragraphs explain the main details of the data network-based elevator control system.

3.1 Signal Transmission

3.1.1 Serial and Parallel Transmission

The signals related to cars or halls are for the most part transmitted through serial channel. The signals concerning safety and emergency, on the other hand, are transmitted through

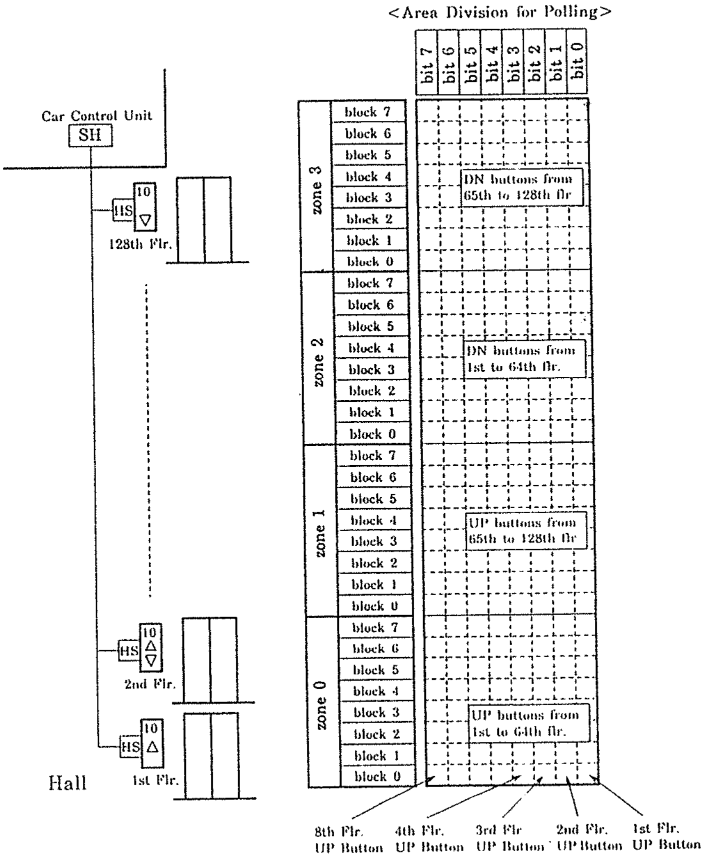

Fig. 4 . System Configuration of Hall - Based Network

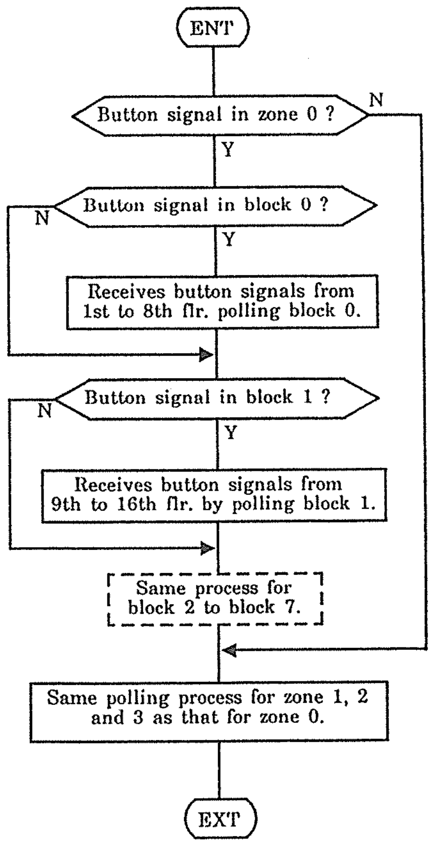

Fig. 6 . Polling Method

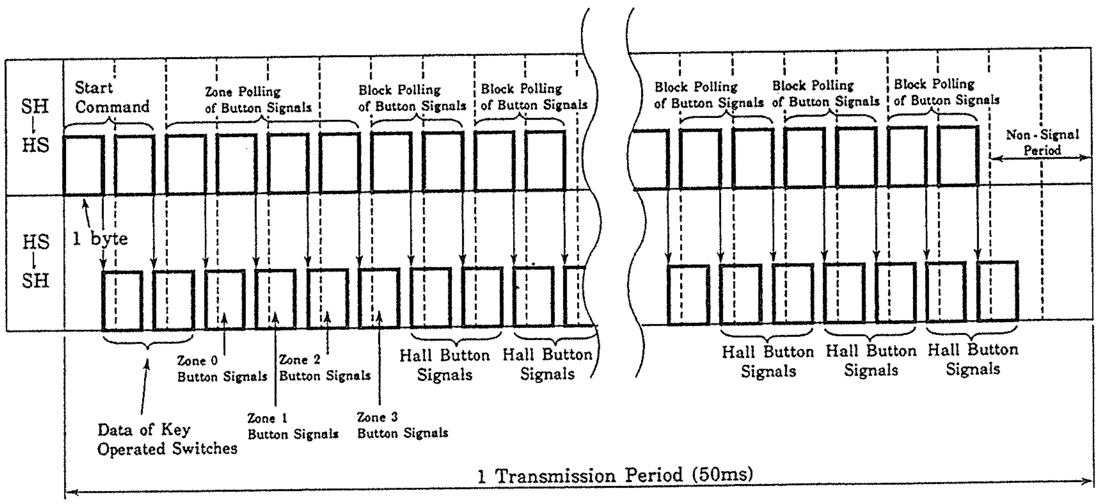

Fig. 5 . Diagram of Transmission between SC and Each HS

parallel channels. The following case of emergency door opening action is an example of an optimum serial/parallel allotment. The elevator doors are equipped with safety devices which detect the presence of passengers.

When the safety device senses a passenger touching (or standing close to) the closing doors, they must be re-opened immediately. Since transmission through serial channel is not as fast as that of parallel channels, safety-related signals are sent through parallel channels. First they are transmitted to the Car Control Microcomputer (CC) through parallel channels, and as soon as they are received, the CC outputs a door-open signal to the Door Control Microcomputer (DC), again through parallel channels. Since signals from safety devices need to be nullified while the elevator is running, a nullifying signal is transmitted from CC through serial channel of the car-based network. With parallel transmission and microcomputer-based door control method, we have improved emergency door control.

3.1.2 Transmission within Car Control Unit

The Car Control Microcomputer (CC) is the kernel microcomputer in the car control system which is interconnected with the Motor Drive Control (Digital Regulator) Microcomputer (DR), the Serial-Transmission Microcomputer to Car (SC) and the Serial-Transmission Microcomputer to Hall (SH). Since data transmission increases in quantity as the system gets upgraded, we have employed a 2-port RAM for transmission between CC and other microcomputers so that large volume, high speed data transmission is possible.

Data transmission between CC and SC is synchronized based on its urgency and accuracy requirements. (CC is the master in synchronization.) Data transmission between CC and DR and between CC and SH are not synchronized because extensibility and flexibility take precedence over other requirements.

3.2 Safety and Reliability

3.2.1 Dual Monitoring System

To ensure safe and reliable elevator operation, a dual monitoring system has been employed. The dual monitoring system as related to the data network system is shown in Table 4. The major functions are explained below.

As for the CC-SC connection, CC is assigned to stop the car at the nearest floor as soon as SC abnormality is detected. Then CC checks SC status by parallel transmission and as soon as the abnormality is cleared, CC allows SC to engage in normal operation.

As for CC-SH connection, CC stops the car at the nearest floor as soon as SH abnormality is detected. Then CC checks SH status by parallel transmission and as soon as the abnormality is cleared, CC allows SH to engage in normal operation. CC can also detect malfunction of the Hall Station Controller through SC and also detect malfunction of the Car Station Controller through SH. If any malfunction is detected, CC takes the most appropriate steps to ensure safety and reliability, based on the functional gravity of each controller.

3.2.2 Group Control System

To prevent system failure or to minimize its influence on the overall operation, the Group Control Unit and the data link are monitored every moment for possible failures. If any failure occurs, the function of the car control unit gets cut off from the entire control system so that single-car operation (individual operation) becomes possible. In this mode, the hall button signals will be sent to CC (not to GC).

3.3 Extensibility

3.3.1 Car-Based Network

Many optional devices such as serviceable floor indication lamps, etc. can be connected to the car-based network. Also another car-based network can be added to the existing one. Both networks would be capable of connection to the Car Station Control Unit and other car-based devices. This is useful for double entrance elevators, because the front door circuitry and the rear door circuitry can be independently connected. The double network is also useful for single-entrance elevators with a large number of controllers.

3.3.2 Hall-Based Network

The Hall Station Microcomputer controls dot-matrix digital indicators to display various types of characters. (This helps to improve visibility of the indicator.) Also HS can be easily connected to indicator lamps, hall lanterns or various display instruments. This network provides the same level of extensibility as the car-based network.

3.4 New Functions

Use of the data network system has made possible the following improvements.

(1) Auto Announcement

In case of emergency, this device informs the passengers on board of the state of abnormality and of the necessary actions to take. As shown in Figure 1, the car control microcomputer (CC) monitors elevator operation and, if any abnormality is detected, sends a signal to the Auto Announcement device to initiate the appropriate preset announcement.

(2) Manual Cancellation of Car Call

When a car call button is mispressed, it can be cancelled by pressing the button twice more.

This function can minimize unnecessary stops caused by such misoperation and thus improves the total operational efficiency. The car operating panel microcomputer (BC) will transmit the cancel signal to CC through the car-based network.

(3) Off-Service Floor Selection

This function allows users to cut off selected floors from service to improve operational efficiency. The off-service floors can be selected by activating the switch located behind the slide cover on the car operating panel and then by selecting the floors with the floor selection buttons. The car operating panel Microcomputer (BC) sends the information to CC through the car-based network.

Table 4 . Dual Monitoring System of Microcomputers

Microcomputers	Dual Monitoring		Abnormality Detection Method	Countermeasures
	Monitoring	Monitored		
CC↔SC	CC	SC	Handshake Abnormality	Stops car at nearest floor.
	SC	CC	Handshake Abnormality	Holds transmission of car-based network.
CC↔SH	CC	SH	Handshake Abnormality	Stops car at nearest floor.
	SH	CC	Handshake Abnormality	Holds transmission of Hall-based network.
GC↔TE	GC	TE	Handshake Abnormality	Resumes operation when the abnormality has been cleared.
	TE	GC	Handshake Abnormality	Resports GC abnormality to CC. (Single car operation)
TE↔SH	TE	SH	Transmission Abnormality	Cuts off abnormal elevator from service.
	SH	TE	Transmission Abnormality	Cuts off group control unit (for starting single-car operation).

4. SUMMARY

This concludes the explanation of the structure and function of the data network system for the elevator control system. This system has already been incorporated in low and medium speeds Grandee Series of elevators, and also in the ACCEL-AI Series of elevators whose travelling speeds range from low to high speeds. Research is now being made into applying it to super-high-speed elevators.

We are sure that microelectronics will continue to progress even more rapidly and that computer technology, communications technology and control technology will be integrated into even more advanced systems. We hope such high-tech elements applied to future elevators will provide autonomy of subsystems, connection with in-house LAN, coordination with in-house equipments, and improved man-machine interface.

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