

CONTROL SYSTEM FOR PLURAL ELEVATOR CARS

1           The present invention relates in general to an  
elevator control system and in particular concerns a  
system for managing and controlling with the aid of a  
computer a plurality of elevator cars which are driven in  
5 parallel.

As an elevator control system of the type  
described above, there has hitherto been known an  
elevator car operation control system for a plurality of  
elevator cars driven in parallel which system includes  
10 car control apparatus each provided in association  
with a corresponding one of the elevator cars for  
controlling operation only of the associated or corres-  
ponding car and a group supervising control apparatus for  
collectively supervising or managing all the car control  
15 apparatus, as is disclosed in U.S. Patents 3,443,668  
and 3,851,733. The prior art control system suffers  
serious deficiency in that when a failure occurs in the  
group supervising control apparatus, the elevator cars  
will possibly be disenabled to perform services for  
20 hall calls, leading eventually to the shutdown of the  
substantially whole elevator system. To deal with such  
difficulty, it is common in practice to provide the  
control system in duplication or threefold. Moreover,  
although the provision of the group supervising control  
25 system is desirable in the case of a large scale elevator

1 system where a large number of elevator cars have to be  
controlled under supervision or a great number of  
floors have to be serviced, it is not preferred from  
the economical viewpoint to provide independently the  
5 group supervising control apparatus in the case of a  
small scale elevator system in which the number of cars  
is less than four or the number of floors to be serviced  
is less than ten, for example.

As an attempt to solve the problem mentioned  
10 above, there has been proposed an elevator control system  
for controlling a number of cars driven in parallel which  
system includes a number of car control apparatus  
each provided in association with a corresponding one  
of the elevator cars, wherein one of the car control  
15 apparatus is imparted with a group supervising control  
function, as is disclosed in U.S. Patent 4,114,730.

When malfunction or failure occurs in the supervising  
control function, the individual car control apparatus  
perform the operation control for the associated elevator  
20 cars independently from the group supervising control.

Certainly, this control system is also advantageous in  
respect of the expenditure. However, there are numerous  
problems to be solved in this control system. First,  
since the group supervising control function is  
25 imparted only to a given one of the car control apparatus,  
there arise differences in hardware as well as software  
structure among the car control apparatus, which are of  
course undesirable in respect of standardization,

1 production control, exchangeability and maintenance  
of the car control apparatus. Second, when the car  
control apparatus imparted with the group supervising  
control function or a power supply source undergoes  
5 failure, then the group supervising control function will  
be lost, to involve a remarkably degraded operation effi-  
ciency and reliability. For example, two elevator cars  
may respond to a single hall call. To evade the above  
shortcomings, it is conceivable to impart the group  
10 supervising control function to each of the car control  
apparatus to thereby provide the group supervising control  
in duplication or threefold. However, such measures  
mean necessarily an intolerably expensive and complicated  
system, while the car controller as well as the group  
15 supervising controller can not process the service  
requests with a satisfactorily quick response.

Accordingly, an object of the invention is to  
provide an elevator operation control system for managing  
and controlling a plurality of elevator cars driven in  
20 parallel which system is made immune to the drawbacks of  
the hitherto known control system by imparting to each  
of the car control apparatus the function to supervise  
and control the associated cars in conjunction with  
positions and travel direction of the other cars.

25 In view of the above and other objects of the  
invention which will become more apparent as description  
proceeds, it is proposed according to an aspect of the  
invention an elevator operation control system, comprising

1 a plurality of elevator cars adapted to be operated in  
parallel for serving a plurality of floors of a building  
and a plurality of car control apparatus each provided in  
association with a corresponding one of the elevator cars  
5 for controlling individually operation of the associated  
elevator car, wherein each of the car control apparatus  
includes input/output means for transmitting information  
concerning at least position and travel direction of the  
associated car to the other car control apparatus associat-  
10 ed with the other elevator cars and receiving information  
concerning at least positions and travel directions of  
the other elevator cars from the other car control appa-  
ratus, and a supervisory control unit for controlling  
operation of the associated elevator car in consideration  
15 of the information concerning the positions and the travel  
directions of the other elevator cars.

With the terms "supervising control" or "super-  
visory control" as used herein, it is intended to mean  
the controlling of plural cars in mutual conjunction with  
20 one another and encompasses service allocation control  
for the hall calls, a distributed stand-by control in  
the case where no service calls are issued, a regulated  
operation control performed upon earthquake, fire, power  
service interruption and the like event, patterned  
25 operation controls effective at predetermined periods and  
so forth.

The above and other objects, novel features  
and advantages of the present invention will become

1 more apparent from the description of exemplary embodiments of the invention. The description makes reference to the accompanying drawings, in which:

Fig. 1 shows schematically a general arrangement  
5 of an elevator control system according to the teaching of the invention;

Fig. 2 shows in a block diagram a hardware structure of a microcomputer employed in carrying out the invention;

10 Figs. 3 and 4 illustrate processing algorithms on the basis of which the invention may be implemented;

Fig. 5 shows an arrangement of a table of data used in the supervisory control carried out according to an embodiment of the invention;

15 Fig. 6 shows a flow chart to illustrate a supervisory control program used for controlling the associated elevator car in conjunction with operations of the other cars;

Figs. 7 to 13 show flow charts to illustrate  
20 details of important sub-programs included in the supervisory control program shown in Fig. 6;

Fig. 14 shows a flow chart to illustrate an interrupt program for processing acceleration and slow-down commands for the associated elevator car;

25 Fig. 15 illustrates in a flow chart an example of an associated car operation controlling program which is activated for interrupt at a predetermined period; and

Fig. 16 schematically illustrates another example

1 of the supervisory control according to the invention.

Now, the invention will be elucidated in more detail in conjunction with the exemplary embodiments thereof by referring to the accompanying drawings. In  
5 the following, the supervisory control functions will be described primarily in conjunction with the processings of services for the hall calls with the aid of a 8-bit general purpose microcomputer such as one commercially available from Hitachi Ltd. of Japan under the trade name  
10 "HMCS-6800", by way of example only. Further, to simplify the description, the invention will be described as applied to an eight landing structure served by two elevator cars which are subjected to the supervisory control.

Fig. 1 schematically illustrates a general  
15 arrangement of an elevator control system according to an embodiment of the invention.

A block H referred to as the hall call signaling unit represents in a set all the hall call button switches provided at individual floors. The hall call  
20 signals as produced are supplied to car control apparatus  $L_1$  and  $L_2$  and stored in respective memories through associated parallel interface adapters PIA. On the other hand, data exchange between the car control apparatus  
 $L_1$  and  $L_2$  is performed through asynchronous interface  
25 adapter ACIA. Data as exchanged includes at least those informations which are required for the supervisory controls inherent to the individual cars  $EL_1$  and  $EL_2$ , respectively, wherein data for the travel direction and

- 1 the position of the cars are indispensable. Further,  
data concerning operation modes such as exclusive or  
independent operation mode, for example, may be included,  
as occasion requires. In this connection, it should
- 5 be mentioned that the data for the car position indicates  
a position which is ahead of the actual position of the  
running car so that it can respond to a stop command  
smoothly. Such indication or designation of the advance  
car position is effected in a well known manner.
- 10 The data exchanges are periodically performed through the  
asynchronous interface adaptors ACIA at a predetermined  
time interval, whereby data as exchanged are stored in  
the memories of the associated microcomputers,  
respectively.
- 15           The entry means for inputting the data required  
for operations of the car as described above includes  
car button switches CA provided in the individual cars  
for registering floors at which the car is to be stopped,  
door condition detecting switch for detecting the opened
- 20 or closed state of the car and or floor door, safety  
limit switches for detecting up and down travel limits  
of the car and the like. These data are stored in the  
car memory through the parallel interface adaptor  
circuit PIA. On the other hand, data for commanding the
- 25 opening and closing of the car and/or floor door as well  
as data required for driving the car, lighting of display  
lamps in response to the car calls and the hall calls  
and so forth are delivered through the parallel interface

1 adaptor circuit PIA.

A salient feature of this invention resides in that the microcomputer destined for implementing the control functions required for the controls of operations of the car with which the said microcomputer is associated is additionally imparted with a supervisory control capability which allows the microcomputer to perform the supervisory control function SM for controlling operation of the associated car in consideration of the operating states of the other car. Accordingly, the car control units of all the individual cars are utterly identical with each other in respect of hardware and software realizations.

Fig. 2 schematically illustrates a hardware configuration of a car control apparatus  $L_1$  for the car No. A which can be realized by using a microcomputer. It goes without saying that the other car control apparatus  $L_2$  is of a similar hardware configuration.

The heart of the car control apparatus  $L_1$  is a main processing unit MPU destined for executing arithmetic operations. Connected through a control bus C, an address bus A and a data bus D to the main processing unit MPU are a random access memory RAM for storing data temporarily, a read-only memory ROM for storing control programs which will be described hereinafter, and the parallel interface adaptor circuit PIA and the asynchronous interface adaptor circuit ACIA for allowing data exchange with the external system outlined above. These components

1 perform operations in accordance with the instructions  
issued from the main processing unit MPU, wherein importance  
is set on the sequential processing procedures, that is,  
the control program.

5 In the following, description will be made on  
the procedure for servicing the hall calls or, to say  
in other words, the arithmetic or logical processing  
program for servicing the hall calls which is important  
above all in the supervisory control.

10 It should first be mentioned that the arithmetic  
processing program for servicing the hall calls is allotted  
with a lower priority level for execution as compared  
with a car operation control program described herein-  
after, in view of the fact that the car operation control  
15 program for controlling the opening and closing of door,  
acceleration and deceleration or slow-down of car and the  
like is determinant for the security, precision of the  
landing level, comfortableness in ride or the like and  
for this reason has to be executed rapidly with a high  
20 priority. In contrast, the processing of the hall call  
to be serviced has lesser influence to the important  
performances described above and thus need not be performed  
with a quick response.

Before entering into description of the arithmetic  
25 processing program for the hall call service, algorithm  
of the arithmetic operation will briefly be elucidated.

In Fig. 3, there are illustrated a procedure  
for processing the hall calls. Since an elevator cage or

1 car is operated in two direction, i.e. up-direction UP and  
down-direction DN, the floors serviced by the elevator  
car may be considered as being arrayed in a loop, as  
illustrated in Fig. 3 at (a). The corresponding data  
5 pattern for the microcomputer is organized in such a  
manner as illustrated in Fig. 3 at (b). As can be seen  
from this figure, the floors to be serviced in the up-  
direction and those serviced in the down-direction are  
serially stacked. More specifically, a floor table of  
10 two bytes (on the assumption that the number of floors  
is eight) is reserved in the memory, whereby the first  
byte is allotted to the floor services in the up-direction  
UP with the second byte being correspondingly assigned  
to the floor services DN in the down-direction. In  
15 this connection, attention should be paid to the fact  
that in the case of the floor service in the down-direc-  
tion DN, the sequential order of the floor identifying  
numbers of the building is reversed.

Fig. 4 shows a chart for illustrating algorithm  
20 of arithmetic operations for processing the hall calls.

It is now assumed that the position  $P_A$  of the  
one car labelled with a letter A corresponds to the fourth  
floor in the course of running in the up-direction, while  
the position  $P_B$  of the other car denoted by a letter B  
25 corresponds to the sixth floor in the course of travel  
in the down-direction. These situations may be given by  
expressions  $P_A = 4U$  and  $P_B = 6D$ , respectively, on the  
basis of illustration at (a) in Fig. 4.

1           Next, zone vectors  $Z_A$  and  $Z_B$  are produced, as  
 illustrated in Fig. 4 at (b). With the term "zone vector",  
 it is intended to mean, so to say, a bar-like table which  
 is expansible and contractible in dependence on the posi-  
 5 tion and the traveling direction of the associated car and  
 which is constituted by the binary digits "1" corres-  
 ponding to the hatched area of the floor service table  
 of two bytes in the up- and down-directions UP and DN,  
 respectively. However, the zone vector does not encompass  
 10 the current position of the elevator car.

A service zone representative of the floors to  
 be serviced by the elevator car is prepared by the  
 associated microprocessor, as illustrated in Fig. 4 at  
 (c). The service zone is logically determined in the  
 15 manner described below. For determination of the service  
 zone  $SZ_A$  of the car No. A, following logical expressions  
 apply valid.

$$SZ_A = Z_A \oplus Z_B, \text{ when } P_A < P_B, \text{ and}$$

$$SZ_A = \overline{Z_A} \oplus Z_B, \text{ when } P_A \geq P_B$$

where the logic symbol  $\oplus$  represents exclusive-OR  
 function. In the case of the example illustrated in  
 20 Fig. 4 at (c), the service zone  $SZ_A$  of the car No. A  
 covers currently the fourth to eighth floors in the up-  
 direction and the seventh floor in the down-direction,  
 while the service zone  $SZ_B$  of the elevator car No. B

- 1 extends from the sixth to the first floor in the  
down-direction and hence to the third floor in the up-  
direction. Consequently, the hall calls issued in the  
service zones  $SZ_A$  and  $SZ_B$  may be selected as the hall  
5 calls to be processed. When expressed logically,

$$AH_A = H_A \cdot SZ_A$$

$$AH_B = H_B \cdot SZ_B$$

where  $AH$  represents the service to the hall call which  
in turn is denoted by  $H$ , and a dot "." symbol represents  
a logical product..

- An algorithm for processing the hall calls to  
10 be serviced has been briefed. Next, an example of the  
program executed on the basis of the above algorithm will  
be described in concrete..

- Fig. 5 illustrates a structure of a table made  
use of in executing a program for processing arithmetically  
15 the hall calls to be serviced by the control apparatus  
 $L_1$  of the elevator car No. A. It should be noted that  
the control apparatus  $L_2$  for the elevator car No. B  
makes use of a same table. The following description  
also makes reference to a flow chart shown in Fig. 6  
20 which illustrates a processing flow of the program  
executed for arithmetically processing the hall call  
to be serviced. This program is imparted with a lower  
priority than the car control program described hereinafter.

1 Accordingly, unless interrupt for the program of higher  
priority occurs, this hall call processing program is  
repeatedly executed as a background processing. The hall  
call processing program is activated instantly upon  
5 power-on of a power supply source. In the first place,  
interrupt is masked for initialization at a step 10.  
When the initialization has been completed, the inter-  
rupt mask is removed at a step 30. The initialization  
effected at the step 20 includes the clearing of the  
10 random access memory or RAM, setting of register incorporat-  
ed in the parallel interface adaptor PIA and the  
asynchronous interface adaptor ACIA, setting of the  
stack pointer and the like.

Next, at a step 40, supervisory control or  
15 management data is received from the car control  
apparatus of the other car and/or the data for supervisory  
control is transmitted to the control unit of the other  
elevator car. Such supervision or management data  
includes informations concerning the car position, the  
20 traveling direction (UP or DN) of the car, operation  
mode and the like. The data for the operation made  
includes informations or instructions concerning the  
exclusive or independent operation which is carried out  
independently from the other car, data of failure which  
25 has disabled the supervisory control and the stoppage  
of operation in the stalled state. The mutual exchange  
of the supervisory control data mentioned just above  
is performed through the asynchronous interface adaptors

1 ACIA shown in Fig. 2 in a serial manner. An example of  
the program for processing the reception and transmission  
(i.e. exchange or transfer) of data for supervisory  
control is illustrated in Fig. 7 in a flow chart..

5 Referring to Fig. 7, this processing may be  
typically classified into the processing for data trans-  
mission and the processing for data reception, wherein  
the former is first executed.

Since the transmission processing of the super-  
10 visory control data is executed periodically at a pre-  
determined interval, it is verified at a step 40-1  
whether now is the time for data transmission. If the  
result is affirmative "YES", then subsequent processing  
steps for the data transmission are executed. In more  
15 particular, at a step 40-2, preparatory processing such  
as setting of the leading address and the number of  
data to be transmitted is performed, which is followed  
by a decision step 40-3 at which it is checked whether  
a transmission buffer register T of the asynchronous  
20 interface adaptor ACIA is emptied, i.e. whether or  
not the data transmission is allowed. When affirmative  
(YES), then the data transmission takes place at a step  
40-4. On the other hand, when the result of the decision  
step 40-3 is negative, i.e. "NO", the processing preceding  
25 to the step 40-3 is repeated in a looped manner while  
checking the time-out for the transmission processing  
at a step 40-8. When the time-out occurs at the step  
40-8, i.e. when the result of the decision step 40-8 is

1 negative "NO", it is determined that failure has occurred  
in the asynchronous interface adaptor ACIA. In that  
case, a communication anomaly flag shown in Fig. 5 is  
set to "1" at a step 40-9, with the result that the  
5 transmission processing is terminated.

In succession to the data transmission at the  
step 40-4, execution of the data transmission is repeated  
with some delay time to the preceding data transmission  
(step 40-4) until decision is made at a step 40-6 to  
10 the effect that all data has been completely transmitted.  
After the completed transmission of all data, posterior  
processing is executed at a step 40-7, whereupon all the  
data transmission processing comes to an end.

Next, the data reception processing is performed  
15 in a substantially same flow as the data transmission  
processing described above.

The data reception processing differs from the  
data transmission processing merely in that the former  
involves no delay time (the aforementioned step 40-5)  
20 and that a communication error check at a step 40-13  
is added to the reception processing. Except for these  
differences, the reception processing is carried out in  
a manner similar to the processing for the data transmis-  
sion described above.

25 It should be noted that the delay time involved  
at the step 40-5 of the data transmission processing  
is to assure the reception of data without fail  
regardless of delay possibly involved in the processing

1 be software between the transmission and the reception  
of data. Accordingly, such delay time need not be  
provided in the data reception processing. The step  
40-13 is added for checking whether data error ascribable  
5 to noises possibly admixed during the data reception or  
the like events is present or not.. This error check may  
be realized in the asynchronous interface adaptor  
circuit ACIA by resorting to a parity check or the like.  
The result of the error check is stored at a communica-  
10 tion anomaly flag shown in Fig. 5.

After completion of the transmission/reception  
processing of the supervisory control or managment  
data at the step 40 shown in Fig. 6, decision is made  
at a step 50 as to the possible presence of transmission  
15 anomalies as well as the operation modes such as the  
exclusive or independent operation and the stoppage of  
operation on the basis of the contents of the communication  
anomaly flag and the associated car operation mode table.  
When the result of the decision step 50 is affirmative  
20 or "YES", all the contents of the associated car service  
zone table shown in Fig. 5 are all set to logic "1"  
so that all the floors included in the whole service  
zone of the associated car can be serviced. This  
processing is executed for contrlling the operation of  
25 the associated elevator car independently from the  
other car in the case where the latter is in a failure  
or stalled state, whereby the supervisory control is  
rendered invalid or impossible.

1           When the result of decision made at the step  
50 in negative or "NO", the car operation is performed  
under the supervisory control. A routine for setting a  
dummy direction at a step 60 is executed in a manner  
5 illustrated in a flow chart of Fig. 8. In the first  
place, it is decided whether both the cars No. A and  
No. B are in the direction-free state or not on the  
basis of the content concerning the car direction of the  
table shown in Fig. 5. The direction-free state is  
10 represented by the table contents of "00". By the way,  
with the terms "direction-free state", it is intended  
to mean that neither hall call nor car or cage call  
is issued. In this state, the elevator car may be  
allotted with an appropriate service zone.

15           When it is decided at the step 60-1 that both  
the cars No. A and No. B are in the direction-free state,  
then contents concerning the positions  $P_1$  and  $P_2$  of  
the cars No. A and No. B are read out from the table  
shown in Fig. 5 and compared with each other. When  
20 the comparison results in that  $P_1 \geq P_2$ , the up-direction  
UP is written in the table shown in Fig. 5 at a section  
labelled with "DUMMY DIRECTION OF CAR NO. A", while the  
down-direction DN is set at a section labelled "DUMMY  
DIRECTION OF CAR NO. B". To the contrary, when  $P_1 < P_2$ ,  
25 the setting of the above contents is reversed. If the  
result of decision at the step 60-1 is "NO", then it is  
decided at a step 60-2 whether either of the cars No. A  
or No. B is in the direction-free state on the basis

1 of the relevant contents of the table shown in Fig. 5.  
When the result of decision at the step 60-2 is "YES",  
then the table contents concerning the travel direction  
of the direction-bound car (i.e. the elevator car which  
5 is not in the direction-free state) is entered into the  
associated table section labelled "DUMMY DIRECTION",  
while the contents representative of the direction  
opposite to the direction-bound car is placed in the  
associated table section "DUMMY DIRECTION" assigned for  
10 the direction-free car (step 60-4). When the result of  
decision at the step 60-2 is "NO", the contents set at  
the table sections "CAR DIRECTION" and representing  
the actual directions of the cars No. A and No. B  
are placed, as they are, in the table sections "DUMMY  
15 DIRECTION" for these cars at a step 60-2.

Referring again to Fig. 6, after the dummy  
direction has been set at the step 60, setting of the  
dummy positions of the elevator cars are effected at a  
step 70 and at the same time comparison of these  
20 position data is performed. The dummy position data  
is represented by the vector value having a direction  
corresponding to the car travel direction and a magnitude  
corresponding to the car position as illustrated in  
Fig. 4 at (a). An exemplary processing program PGM2  
25 for setting the dummy position and the comparison of  
positional magnitude is illustrated in Fig. 9.

At first, the dummy position table section  
for the car No. A is located or determined. At a step

1 70-1, the table section "DUMMY POSITION OF CAR No. A"  
(Fig. 5) is cleared. At a step 70-2, the contents of the  
table section "DUMMY DIRECTION OF CAR No. A" is checked.  
When the dummy direction is the up-direction UP, the  
5 contents of one byte of the table section "POSITION OF  
CAR No. A" is set at the first byte of the table  
section "DUMMY POSITION OF CAR No. A" at a step 70-3.  
As described hereinbefore, each of the table sections  
"DUMMY POSITION" is constituted by two bytes with first  
10 byte being allotted to the up-direction UP, while the  
second byte is allotted to the down-direction DN  
(refer to Fig. 3(b)). When the dummy direction is  
decided as the down-direction DN at the step 70-2, then  
the contents of the table section labelled "CAR POSITION"  
15 is reversed in respect of the bit position (i.e. the  
more significant bits are relocated to the less signifi-  
cant bit positions and vice versa) and set at the second  
byte of the table labelled "DUMMY POSITION" at a step  
70-4 in consideration of the fact that the up-direction  
20 UP and the down-direction DN follow contiguously each  
other in a closed loop, as illustrated in Fig. 3 at (a).  
For example, assuming that the contents of the table  
section "CAR POSITION" is "00100000" and that the  
travel direction is down DN, the contents of the table  
25 "DUMMY POSITION" is "00000100" which corresponds to the  
ordinal reversion of "00100000".

The processing described above is executed  
for the car No. B in a similar manner through the steps

1 70-5 to 70-8.

When the dummy position table sections have been set, magnitudes of the contents set in the position table section are compared with each other at a step

5 70-9. To this end, when the contents  $P_B$  (two bytes) of the table section "DUMMY POSITION OF CAR No. B" is subtracted from the contents  $P_A$  (two bytes) of the table section "DUMMY POSITION OF CAR No. A", the resultant is reflected to a carry flag in dependence on the signs  
10 (positive or negative) of the difference.

The carry flag is set at the table section labelled "MAGNITUDE FLAG OF DUMMY POSITION" shown in Fig. 5. Thus, the contents of the table "MAGNITUDE FLAG OF DUMMY POSITION" is "1" only when the dummy position  
15 of the car No. A is smaller than the dummy position of the elevator car No. B.

Referring agent to Fig. 6, a program routine PGM3 for preparing the zone vectors is executed at a step 80 for determining the zone vectors  $Z_A$  and  $Z_B$   
20 described hereinbefore in conjunction with Fig. 4. This subprogram PGM3 is illustrated in a flow chart in Fig. 10. The zone vectors  $Z_A$  and  $Z_B$  can be easily determined simply by subtracting "1" from the contents (two bytes) of the tables "DUMMY POSITION" at a step 80-1. For example,  
25 for the elevator car No. A,

"0001000000000000" (table contents of dummy position  
of car No. A)

- "0000000000000001"

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"0000111111111111"

1           The resultant difference represents the contents  
of the zone vector table section for the car No. A,  
i.e. the table section labelled "ZONE VECTOR FOR CAR  
No. A" and thus set at this table. Similar processing  
5 is effected for the car No. B at a step 80-2.

Next, at a step 90 shown in Fig. 8, a program  
routine PGM4 for preparing the service zones is  
executed. The development of this sub-program PGM4  
is illustrated in a flow chart of Fig. 11.

10           Referring to Fig. 11, preparation of the  
service zones  $SZ_A$  and  $SZ_B$  can be accomplished through the  
exclusive OR function of the zone vectors  $Z_A$  and  $Z_B$   
at a step 90-1, as described hereinbefore in conjunction  
with Fig. 4(c). In this connection, it should however  
15 be mentioned that there may arise a case where the  
complement of the result of the above logical operation  
has to be determined in dependence of the magnitude  
flags of the dummy positions. For example, for deter-  
mining the service zone  $SZ_A$  of the elevator car No. A,  
20 it is assumed that the car No. A is positioned at the  
fourth floor in the up-direction UP, while the elevator  
car No. B is positioned at the sixth floor in the down-  
direction DN (refer to Fig. 4(a)). Then, the service  
zone  $SZ_A$  is determined in the manner as follows:

25            $Z_A = "0000000000001111"$

$Z_B = "0000001111111111"$

Thus,  $Z_A \oplus Z_B = "0000001111110000"$

In this case, since  $P_A < P_B$ , the contents of the magnitude

- 1 flag of the dummy position of the car No. A is "1".  
Accordingly, the contents which is set at a table labelled  
"ASSOCIATED CAR'S SERVICE ZONE" is:

$$SZ_A = Z_A \oplus Z_B$$

- On the other hand, when the positional magnitude of the  
5 car No. A is greater than that of the car No. B, the  
corresponding magnitude flag of the dummy position is  
"0", with the result that the decision at a step 90-2  
involves "NO". In this case, the complement of the  
contents set at the table section "ASSOCIATED CAR'S  
10 SERVICE ZONE" is determined and placed in the same table  
section in this case, the following logical expression  
applies:

$$SZ_A = \overline{Z_A} \oplus Z_B = "11111110000001111"$$

- When the associated car's service zone (that  
is, the service zone for the elevator car No. A in this  
15 exemplary case) is determined, then the associated  
car's hall calls are processed. A procedure to this  
end is illustrated in a flow chart in Fig. 12. More  
particularly, assuming that the car in concern is the  
elevator car No. A and that a hall call of up-direction  
20 UP is issued at the sixth floor, while a hall call of  
down-direction DN is issued at the fourth floor, as  
illustrated in Fig. 4, then a logical product of the  
contents set, respectively, at the table section  
"ASSOCIATED CAR'S SERVICE ZONE" and "HALL CALL" shown

- 1 in Fig. 5 is determined, whereby the hall call  $AH_A$  to be serviced by the car No. A is determined as follows:

$$\begin{aligned}SZ_A &= "0000001111110000" \\H_A &= "0001000000100000" \\AH_A &= SZ_A \cdot H_A = "0000000000100000"\end{aligned}$$

The resultant  $AH_A$  is then set at a table labelled "HALL CALL FOR ASSOCIATED CAR" shown in Fig. 5. On the other hand, the hall call UP at the sixth floor is serviced by the car No. B.

In addition to the procedures and the arithmetic operations for processing the hall calls to be serviced, the supervisory control includes a dispersed stand-by control procedure (step 120 of Fig. 6), according to which the elevator cars are located at various floors in a stand-by state in a predetermined dispersion or distribution pattern. This distributed stand-by control can be accomplished in a facilitated manner by issuing the dummy calls. A procedure to this end is illustrated in Fig. 13. In the first place, it is checked at a step 120-1 whether or not the service call or calls are present. If the result of the check is "YES", the distributed or dispersed stand-by control is unnecessary. Accordingly, this subprogram PGM6 comes to an end. When there is issued no call, it is decided whether the associated elevator car is positioned at an allocated stand-by floor at a step 120-2. This

1 check is accomplished through comparison of the contents  
set, respectively, at the tables "HALL CALL" and "POSITION  
OF CAR No. A" shown in Fig. 5. If the result of the  
check is affirmative or "YES", the execution of this  
5 program PGM6 comes to an end. When the check results  
in "NO", a dummy call signal for commanding the dis-  
persed stand-by is read out from the read-only memory  
ROM and set at the table section "HALL CALL" at  
a step 120-3. Consequently, the decision at the step  
10 120-2 is made on the basis of the dummy call set at the  
step 120-3.

Referring once again to Fig. 6, a regulated  
operation processing step 130 and a patterned operation  
processing step 140 are additionally executed. With  
15 the terms "regulated operation", it is intended to mean  
that operations of the individual elevator cars are  
restrictively regulated upon occurrence of fire,  
earthquake, power service interruption and so forth for  
the purpose of assuring security of the passengers, as  
20 is well known in the art. For example, it is known  
that upon occurrence of power service interruption, a  
number of cars which is determined in dependence on  
capacity of the associated non-utility generation system  
are driven to the respective nearest floors. In more  
25 particular, operation of an elevator system demands  
usually a large electric power. Accordingly, if the  
elevator cars, say, the cars No. A and No. B are to be  
driven by resorting to the non-utility generation, there

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- 1 may arise such a case that the power supply becomes inadequate before both cars has reached the respective nearest floors. To evade such deficiency, the regulation control is made in such a manner that the associated car
  - 5 is driven to its nearest floor only after the arrival of the other car at the nearest floor has been confirmed.

With the terms "patterned operation", it is intended to mean that the operation of the elevator system is carried out in accordance with specific

- 10 operation patterns at the office opening time, the closing time and the lunch time. For example, at the office opening time, preference is put on the car operation in the up-direction from a lobby floor (usually the first floor), while at the closing time
- 15 preference is usually put on the down-operation toward the lobby floor. Further, at the lunch time, a concentrated operation to a dining hall or floor is conducted. Thus, at the patterned operation processing step 140, the car No. A will be dispatched to the lobby
- 20 floor at express speed at the office opening time, when the other car, say, the car No. B is not present or dispatched to that floor, by way of example. These pattern operations are carried out during preselected periods determined by a time piece. Further, the pattern
- 25 operations are made possible by storing contents of a pattern operation read out from the read-only memory in the table "ASSOCIATED CAR'S SERVICE ZONE" or alternatively by setting appropriate contents in the table section

- 1 "HALL CALL FOR ASSOCIATED CAR", as the case may be.

Next, description will be made on a program for controlling the individual car operations. Fig. 14 illustrates in a flow chart a subprogram for processing speed command for the elevator car No. A. Every time the car has reached a predetermined acceleration or deceleration time point or position, an interrupt request IRQ1 is issued to the main processing unit of the car operation control system, resulting in that the program shown in Fig. 6 and being executed at that time is temporarily interrupted and the logical processing of the acceleration or deceleration command is performed in a hitherto known manner. For acceleration of the car, a speed command voltage which varies in a step-like manner at predetermined time interval is utilized. When the car is driven at a constant speed, the speed command voltage is fixed. Finally, for the deceleration of the car, a speed command varying at a predetermined distance interval is made use of to park the car at a predetermined landing floor. When the processings mentioned above have been completed, the program being interrupted until then is restored.

Fig. 15 shows a flow chart to illustrate a car signal control processing for the elevator car No. A. The car signal control processing program is activated periodically by a clock signal of a predetermined frequency, whereupon the supervisory control processing illustrated in Fig. 6 and being executed by the main

- 1 processing unit MPU is temporarily interrupted for  
executing the car signal control processing program.  
It goes without saying that the supervisory control  
processing (Fig. 6) is restored upon completed execution  
5 of the car signal control processing (Fig. 15).

Now, referring to Fig. 15, a watch dog timer  
is first set at a step 3001 for supervising if a sequence  
processing has been completed within a predetermined  
time duration. Further, timer values are utilized in the  
10 logical processing of door control and the like which  
are carried out under control of the timer. At a  
second step 3002, car control signals such as the car  
position signal, the car call signal and other signals  
indicative of operating conditions of various safety means  
15 or the like are fetched as the input signals. The posi-  
tion of the elevator car is determined on the basis of  
the contents of an up-down counter which is destined for  
incrementing the count contents in response to pulses  
generated from a pulse generator when the car runs in the  
20 up-direction and count down the contents correspondingly  
when the car is traveling in th down-direction. The  
pulse generator produces these pulses in proportion to  
a driving quantity of the elevator driving system.  
The car or cage call is activated by pushing a cage call  
25 is activated by pushing a cage call button CA provided  
within the car (Fig. 1) and registrated in the random  
access memory RAM. The safety means include limit  
switches for detecting the upper and the lower limits of

- 1 a car maneuver range, detector switches for detecting  
opened or closed state of the car door, and the like  
detecting or sensor means. The car control inputs  
include a signal indicative of the manually set.
- 5 independent operation mode, a signal indicative of  
operation stoppage mode, a signal representative of the  
set pattern operation and so forth.

At a step 3003, the operation mode as well  
as other required operating conditions are selected on  
10 the basis of the input signals fetched at the step 3002  
to thereby effect required settings. The operation mode  
selected at this step is stored in the associated table  
labelled "OPERATION MODE" shown in Fig. 5.

At a step 3004, control is so made that the  
15 door is opened and closed smoothly without giving rise to  
any danger to the passengers. This control may be  
carried out in a manner known in the art.. At a step 3005,  
the car position is determined on the basis of the contents  
in the up-down counter described above in conjunction with  
20 the step 3002 and set in the associated table section  
labelled "CAR POSITION" shown in Fig. 5. At a step 3006,  
the car or cage call fetched at the step 3002 is regist-  
rated in a car call table prepared in the random access  
memory RAM. At a step 3007, the hall call fetched at the  
25 step 3002 is entered in the hall call table section  
"HALL CALL" shown in Fig. 5. At a step 3009, selective  
determination is made as to the operating direction  
(i.e. UP, DN or direction-free) of the associated car

1 on the basis of the car call, hall call and car position  
signals fetched at the step 3002 and entered in the  
allocated table section "TRAVEL DIRECTION". At a step  
3010, running controls such as start, stop, acceleration  
5 and slow-down controls are performed on the basis of the  
data obtained through logical processing of the program  
illustrated in Fig. 14 by supplying appropriate commands  
to relevant relays, contactor or a motor. At a step 3011,  
a floor next to be serviced is selected on the basis  
10 of the contents stored in the tables "HALL CALL FOR  
ASSOCIATED CAR" and "CAR CALL" shown in Fig. 5, whereby  
a command to stop or park the car at the selected floor  
is set.

As a step 3012, the reasonability of the program  
15 sequence is checked in a known manner. In case there  
arises a trouble which disenables the safety operation  
under the supervisory control, for example, in case the  
elevator is instructed to move when the door is opened,  
a binary bit "1" is set at an operation failure flag of  
20 the allotted table section "OPERATOIN MODE" shown in  
Fig. 5. At a step 3014, the current position or location  
of the car (a position ahead of the car when it is running)  
is displayed in a car position indicator provided in the  
car and the halls. This step is executed on the basis of  
25 the contents stored in the allotted car position table  
section "CAR POSITION". Further, a flicker display may  
be made in the vicinity of parking floor hall, as the  
case may be.

1           Although description has been made as to the  
destinations to which the control commands of the elevator  
care are directed upon execution of every step, it should  
be understood that the results of the processings  
5 performed at the various steps are supplied to the  
relevant parts through associated interface circuits at  
the step 3015. At a step 3016, the reset signal is  
applied to the watch dog timer which is constructed of  
a hardware structure so as to monitor a runaway of the  
10 computer program, that is a failure of the microcomputer.  
If the watch dog timer is not triggered by the reset  
signal from the software within a predetermined time set  
to the watch dog timer, the decision is made as the  
microcomputer is in failure. In this case, since the  
15 car control apparatus cannot keep in communication with  
the another car control apparatus, at step 3003, a binary  
bit "1" is set at the failure flag of the table section  
"OPERATION MODE" shown in Fig. 5.

          In the foregoing, an example of the operation  
20 control program for the elevator car No. A has been  
described by referring to Fig. 15. It will, however,  
be appreciated that the operation control program for  
the car No. B is executed in a similar manner.

          The exemplary embodiment of the present inven-  
25 tion described above involves following advantages  
effects.

          First, by virtue of such system feature that  
the control program for supervising a group of elevator

1 cars is provided in each of the computers provided in  
the control apparatus of the individual elevator cars,  
respectively, it is unnecessary to provide additionally  
a central supervisory control apparatus, whereby not  
5 only the expenditure for the hardware but also the  
maintenance cost can significantly be reduced, to an  
advantage.

Second, since the system for supervising a  
group of elevator cars according to the invention is  
10 implemented in such manner that each control apparatus  
performs the operation control of its own car on the  
basis of data or informations about its own car as well  
as the data received from the other cars (i.e. the  
control apparatus determines arithmetically or logically  
15 the hall calls to be serviced by the associated car in  
consideration of the operating conditions of the other  
cars), a same processing program can be employed for all  
the car control apparatus, which in turn means that the  
corresponding hardwares can be implemented in the same  
20 configuration, to a great advantage in respect to the  
standardization, production control, exchangeability and  
the maintenance of the car control apparatus.

Third, even when another car is brought to  
shutdown for some reasons, the remaining cars can  
25 continue to perform the services under the control of  
their own control apparatus, respectively, whereby an  
improved reliability can be assured.

Fourth, since the supervisory control

1 processing program is imparted with a lower preference  
or priority than the car operation control program which  
has to be executed with quick response, any adverse  
influence to the latter can be positively suppressed.

5 Fifth, since the communications between or  
among the individual cars can be effected serially in  
a facilitated manner, the supervisory control can be  
realized in a simplified arrangement without involving  
any substantial increase in the number of conductors or  
10 wires for the mutual communication.

Next, another exemplary embodiment of the  
invention will be described by referring to Fig. 16.  
In the case of the example described above, it has been  
assumed that the number of the cars to be supervised is  
15 two. It goes, however, without saying that the invention  
can be applied to the supervisory control for the  
elevator system including more than two elevator cars.  
Fig. 16 illustrates algorithm for arithmetically proces-  
sing the hall calls to be serviced by three cars. The  
20 dummy direction is determined in the same manner as  
described hereinbefore. Preparations of the dummy  
position tables as well as the zone vectors can be made  
in the similar manner. However, for the elevator system  
which includes three or more cars, the magnitude flags  
25 of the dummy positions can be no more used. Instead,  
the dummy positions of the individual cars can be  
discriminated by identifying them by the lowest position  
 $P_L$ , a middle position  $P_M$  and the highest position  $P_H$ .

1 In the case where two or three cars are located at a same floor, the car labelled with a smaller ordinal car number may be considered as the car located at a lower position. In this way, the zone vectors  $Z_L$ ,  $Z_M$  and  $Z_H$  as well as the service zones  $SZ_L$ ,  $SZ_M$  and  $SZ_H$  can be determined as illustrated in Fig. 16. As can be seen from this figure, it is sufficient to previously prepare a table of correspondences between the elevator car numbers A, B and C and the floor levels L, M and H.

10 The service zones  $SZ_L$ ,  $SZ_M$  and  $SZ_H$  are given by the following logical expressions:

$$SZ_L = Z_L \oplus Z_M$$

$$SZ_M = Z_M \oplus Z_H$$

$$SZ_H = \overline{Z_H \oplus Z_L}$$

For example, for the dummy positions illustrated at (a) in Fig. 16, following relations apply valid:

$$P_L = P_B$$

$$P_M = P_A$$

$$P_H = P_C$$

15 Therefore, the service zones of the individual elevator cars are as follows:

$$SZ_A = SZ_M$$

$$SZ_B = SZ_L$$

$$SZ_C = SZ_H$$

1           The service zones for more than three cars can be determined in a similar manner.

          The relevant processing program will readily occur to those skilled in the art from the beforemen-  
5   tioned processing programs for the elevator system including two cars and thus description will be omitted. It will be appreciated that even when one of three or more cars is brought to shutdown or set to the independent operation mode for failure or the like reason,  
10 other elevator cars can be operated under the supervisory group control on the basis of the contents in the operation mode tables, whereby the supervisory operating performance and reliability can be significantly improved.

15           It will now be understood that the invention has provided an improved elevator car operation control apparatus which is capable of performing with a high reliability a supervisory control for a number of elevator cars adapted for parallel operation in a  
20 simplified arrangement in which the functions for the supervisory control are distributed among the digital control apparatus each provided for the individual cars so that the digital control apparatus for one car is

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- 1 able to control the call servicing operation of the associated (i.e. its own) car on the basis of data input from the other car.



CLAIMS:

1. An elevator operation control system, comprising a plurality of elevator cars adapted to be operated in parallel for serving a plurality of floors of a building and a plurality of car control apparatus each provided in association with a corresponding one of said elevator cars, respectively, for controlling individually operation of the associated elevator car, wherein each of said car control apparatus includes input/output means for transmitting information concerning at least position and travel direction of said associated car to the other car control apparatus associated with the other elevator cars and receiving information concerning at least positions and travel directions of the other elevator cars from the other car control apparatus, and a supervisory control unit for controlling operation of said associated elevator car in consideration of the information concerning the positions and the travel directions of said other elevator cars.
2. An elevator operation control system according to claim 1, wherein said supervisory control unit includes a memory means for storing a supervisory control program for managing and controlling services to be carried out by said associated elevator car on the basis of the information received from the other car control apparatus and an associated car control program for controlling operation of said associated elevator



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car, and a processing unit for executing program controls in accordance with said two types of programs.

3. An elevator operation control system according to claim 2, wherein said associated car control program is imparted with a higher processing priority than said supervisory control program.

4. An elevator operation control system according to claim 3, wherein said supervisory control program is adapted to be processed in a closed loop.

10 5. An elevator operation control system according to claim 3 or 4, wherein said associated car control program is adapted to be periodically activated at a predetermined time interval.

6. An elevator operation control system according to claim 1, wherein said supervisory control unit includes means for determining hall calls to be serviced by the associated elevator car on the basis of the information concerning the positions and the travel directions of said other cars and said associated car.

20 7. An elevator operation control system according to claim 6, wherein said hall call determining means includes means for determining a service zone of said associated elevator car on the basis of the information concerning the positions and the travel directions of  
25 said other elevator cars and said associated cars, and means for commanding said associated elevator car to perform services in response to those hall calls, and only those hall calls which are issued within said service zone.



8. An elevator operation control system according to claim 1, wherein provided that a direction-free elevator car whose travel direction is not determined is present among said plurality of elevator cars, said  
5 supervisory control unit includes means for setting the travel direction of said direction-free elevator car in conjunction with the position of said direction-free elevator car as well as the positions and the travel directions of the other elevator cars.

10 9. An elevator operation control system according to claim 1, wherein when at least given one of said plural elevator cars becomes insusceptible to the supervisory control, said supervisory control unit is adapted to perform the supervisory control on the basis of the  
15 information concerning the positions and the travel directions of the other elevator cars.

10. An elevator operation control system according to claim 1, wherein said input/output means is further adapted to transmit information about operation modes  
20 of the associated elevator car to the car control apparatus of the other elevator cars and receive information about operation modes of said other elevator cars, said car control apparatus being adapted to manage and control the associated elevator car in accordance  
25 with the received information about the operation modes.

11. An elevator operation control system according to claim 10, wherein said operation modes include at least one of an independent car operation mode, an



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operation failure mode and a shutdown mode.

12. An elevator operation control system according to claim 1, wherein said supervisory control unit includes means for determining a floor at which the associated car is to be parked in a predetermined standby car distribution pattern when no service calls are present.

13. An elevator operation control system substantially as hereinbefore described with reference to, and as illustrated in, Fig. 1; or Fig. 2; or Figs. 3 and 4; or Fig. 5; or Figs. 6 to 13; or Fig. 14; or Fig. 15; or Fig. 16 of the accompanying drawings.

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