

ELEVATOR SPEED CONTROL CIRCUIT

Detailed explanation of the invention

[0001]

Technical field of the invention

The present invention pertains to an elevator speed control circuit that suppresses vibration in the speed control of a multi-inertial system such as a skyscraper elevator, wherein several types of inertia are combined with an elastic system and which has several resonance frequencies.

[0002]

Prior art

Several driving methods are available for elevators. A balanced formed elevator system using a counterweight is constructed as illustrated in Figure 20. That is, both a car (106) and a counterweight (107) are installed on a hoist rope (105) which is applied onto a driving sheave (103) which is turned by a motor (102). The motor speed is detected by a pulse pickup (PP1), and the speed of the car (106) is detected by a pulse pickup (PP2) at a governor part (111). A controller (101) controls the motor (102).

[0003]

In Figure 20, the speed of the car is detected by (PP2) by changing the movement of the governor part (111), that is, of the

governor rope (112) which is moved by the car (106) using a pulley (112) into rotation. It can also be detected in other methods. As illustrated in Figure 21, it can be detected by installing a speed detecting disc (109) on the car (106), which is in contact with a guide rail (110) and is turned by the movement of the car. Also, an accelerometer may be installed on the car, and its integral values may be used.

[0004]

Problems to be solved by the invention

With a low elevator of the past, there occurred no vibration on the hoist rope, and the entire elevator could be considered to be a single inertia. Thus, the sum of the inertia for the entire elevator could be converted for the motor shaft to design the speed control system. Also, because there was no vibration, the speed control could be sufficiently realized by means of a simple speed loop such as I-control.

[0005]

However, with a balanced type elevator used for a skyscraper, the vibration of the rope cannot be ignored. The effect of the counterweight will also be a cause for disturbance. Thus, uncomfortable vibration is generated on the car.

[0006]

The elevator system of Figure 20 is modeled to be a penta-inertial system. Here, however, it is approximated to be a tri-inertial system for the sake of simplicity. The model is illustrated in Figure 22.

[0007]

Here, the motor and the car, and the motor and the counterweight are combined with an elastic system, which in reality is the hoist rope. The characteristic of this model is the fact that inertia exists on both ends of the model, and when the speed or the position of the car are to be controlled using the model, the vibration also occurs on the side of the counterweight, which will be a disturbance to the car speed control.

[0008]

In the model illustrated in Figure 22, the spring constant of the elastic system varies depending on the position of the car, and the following two types of vibration are generated:

[0009]

- 1) In-phase mode, wherein the vibration occurs between (motor + car) and CWT
- 2) Out-of-phase mode, wherein the vibration occurs between (motor + CWT) and car

When the car is at an upper part, the rope between the car and the motor will be nonvibrating, and thus the in-phase mode of 1) will be the main vibration. When the car is at a lower part, the rope between the CWT and the motor will be nonvibrating, and thus the out-of-phase mode of 2) will be the main vibration.

[0010]

Various methods have been proposed to eliminate this vibration. As signals for vibration suppression, car speed and car acceleration are considered. Usually, the speed of the car is measured in one of the following two methods: To measure it in a machine room located at an upper part of the building using a metallic tape, governor rope, etc.; or to measure it near the car using a touch roll, etc. However, problems arise if the building is very tall. In the first method, the effect of the tape or the rope between the car and the machine room cannot be ignored. Vibration or propagation delay will occur. In the latter method, a problem of slipping will occur because the elevator speed will be fast.

[0011]

On the other hand, the aforementioned problems will not occur if car acceleration is used because an acceleration detector is installed on the car, and thus the condition of the car can be measured irrespective of the installation condition of the elevator. However, if a direct feedback of the car acceleration is used, a large enough feedback gain may not be obtained because of the detection noise, the vibration noise

between the car and the guide rail, etc. Also, in terms of the frequency characteristics of an acceleration detector, the detection accuracy at low frequencies is low. Thus, there is also a problem of drift.

[0012]

The present invention was made considering such problems of the past. The objective pertains to a speed control circuit for a multi-inertia system such as an elevator, which can control the speed without vibrating the multi-inertia system, wherein several types of inertia are connected to the motor with an elastic system and which has several resonance frequencies.

[0013]

Means to solve the problems

The present invention controls speed while suppressing vibration as follows: In an elevator speed control circuit that has a speed amp that calculates the deviation between the motor speed instructions and the motor speed by PI, a car speed feedback circuit or a car acceleration feedback circuit are provided that amplify the difference between the speed instructions and the car speed or the difference between the acceleration instructions and the car acceleration, extracts the vibration components of the car by passing it through a bandpass filter, changes the vibration components to the optimum phase by means of a phase filter and provides feedback.

[0014]

To this control circuit a minimum dimension load torque observer, a simple load torque observer or a complete dimension observer that estimates the load torque based on the output signal and the motor speed is preferably applied.

[0015]

A compensating filter that suppresses large variations in the estimation of the load torque is preferably provided after the load torque observer.

[0016]

A compensating circuit that compensates for the car detection delay is preferably provided for the car speed signal circuit. The gain of the car speed feedback circuit, or said gain, the bandpass filter and the phase filter are preferably made variable based on the car position.

[0017]

The gain of the car acceleration feedback circuit, or said gain and the band of the bandpass filter are preferably made variable based on the car position.

[0018]

The speed amp, or said and the gain of the observer amp are preferably made variable based on the motor speed.

[0019]

Application mode of the invention

The definitions of the control parameters that are used in the following explanation are as follows:

[0020]

ω^* :	Speed instruction value
ω_M :	Motor speed detected value
ω_{car} :	Car speed detected value
α^* :	Acceleration instruction
α_{car} :	Car acceleration detected value
τ_M :	Motor torque instruction
H_{car} :	Car position (height) detected value
K_v :	Speed amp gain
T_{m1}^* :	Elevator model (1-inertia converted value units [sec])
K_l :	Load torque observer gain
T_l :	Load torque observer integral index specified number
K_d :	Car speed field back [sic; feedback] gain

Application Mode 1

Figure 1 illustrates an elevator speed control circuit that uses a car speed feedback system. In the figure, (1) is an elevator system controlled by the torque instructions (τ_M), (2)

is a deviation detector that detects said the deviation between the speed instructions (ω^*) and the motor speed detector (ω_M), and (3) is a speed amp that calculates said deviation by PI. The speed amp (3) is comprised of an amp (5), an integrator (6) and an adder (7) that adds the proportional components from the amp (5) and the integral values from the integrator (6).

[0021]

(11)-(14) indicate the car speed feedback system. (11) is a deviation detector that takes the deviation between the speed instruction (ω^*) and the car speed detected value (ω_{car}), removes the frequency components contained in the speed instruction from the car speed detected value and extracts the car vibration components. (12) is a speed amp that amplifies said deviation. (14) is a bandpass filter that extracts the resonance frequency components by the vibration of the rope from the car vibration components that is output from said amp. (16) is a phase compensating filter that extracts the vibration components in an appropriate phase from said extracted resonance frequency components. (19) is an adder that adds said extracted vibration components to the torque instruction from the speed amp (3) and provides feedback.

[0022]

Said speed control circuit takes the difference between the speed instruction (ω^*) and the car speed detected value (ω_{car}), multiplies it by the gain (K_d), extracts the vibration components by the vibration of the rope using a bandpass filter, and

furthermore gives the torque instruction feedback from the speed amp as a vibration suppression signal which is appropriate for feedback using a phase compensating filter. Thus, it can actively suppress the vibration of the car in the elevator speed control.

[0023]

Application Mode 2

Figure 2 illustrates an elevator speed control circuit that uses a car acceleration feedback system. In the figure, (1) is an elevator system, (2) is a deviation detector that detects the deviation between the speed instruction (ω^*) and the motor speed detected value (ω_M), (3) is a speed amp that calculates the deviation by PI, (11) is a deviation detector that detects the deviation between the acceleration instruction (α^*) and the car acceleration detected value (α_{car}), (12) is an acceleration amp that amplifies said deviation, (14) is a bandpass filter that extracts the car vibration components from the signal output from said amp, and (19) is an adder that adds said car vibration components to the torque instruction from the speed amp (3), and provides feedback.

[0024]

Since said speed control circuit uses a car acceleration feedback system wherein the difference between the car acceleration instruction and the car acceleration detected value, which can be obtained relatively stably even with a skyscraper elevator, is amplified and passed through the bandpass filter to

extract the vibration frequency components of the car and to provide feedback to the speed control system, the vibration can be suppressed more actively. Also, since the car acceleration signal (detected value) has a phase that is 90° ahead of the speed information (detected value), no phase compensating filter is needed, and thus the number of adjustment parameters can be reduced.

[0025]

Application Mode 3

Figure 3 illustrates an elevator speed control circuit that uses a minimum dimension load observer. In the figure, (1) is an elevator system, (2)-(19) indicate a control circuit with a car speed feedback system constructed in the same manner as the aforementioned Figure 1, and (21) is a minimum dimension load torque observer that receives both the signal from this control circuit (2-19) and the motor speed detected value (ω_M), estimates the disturbance torque, and suppresses the disturbance.

[0026]

The load torque observer (21) consists of an elevator model (23), an amp (25) and adders (24), (26) and (27). The disturbance torque estimate from the amp (25) is added to the signal from the control circuit (2-19) by the adder (26) to obtain the torque instruction (u_M) of the elevator system (1). At the same time, the difference between this torque instruction and the disturbance torque estimate from the amp (25) is taken by the

adder (27) and added to the elevator model (23). The difference between the output signal from said elevator model and the motor speed detected value (ω_m) is taken by a subtractor (24), multiplied by the gain K_1 by the amp (25), and added to the torque instruction from the adder (19) as the aforementioned disturbance torque estimate.

[0027]

The control circuit (2-19) is a car speed feedback system, and does not consider characteristics to disturbances such as mechanical [energy] loss or load variations in the car. Thus, its disturbance characteristics are poor. Also, PI control is used for the speed control system, and speed overshoot occurs. Thus, it is not suitable for an elevator system. However, with the circuit illustrated in Figure 3, because a minimum dimension load torque observer is applied to the car speed feedback control system, an elevator system control can be realized wherein no overshoot will occur, the speed follow-up difference will be suppressed, and the disturbance suppression effect is high.

[0028]

Also, because the load torque observer assumes the vibration components from the counterweight (Figure 20) to be a disturbance, it also prevents the vibration of the counterweight from being transmitted to the car through the motor. Therefore, it also has a suppression effect on the aforementioned in-phase mode vibration.

[0029]

Application Mode 4

Figure 4 illustrates another example of an elevator speed control circuit that uses a minimum dimension load torque observer. In this speed control circuit, the car speed feedback system (11-16) of the speed control circuit (2-21) that uses a minimum dimension load torque observer (21) in Figure 3 is replaced with the acceleration feedback system (11-14) used in Figure 2.

[0030]

Because this speed control circuit uses a car acceleration feedback system, the vibration of the car can be suppressed more actively than the example illustrated in Figure 3.

[0031]

In the circuits illustrated in Figures 3 and 4, the load torque observer is a minimum dimension load torque observer. Thus, converting it to software will be easy.

[0032]

Application Mode 5

Figure 5 illustrates an elevator speed control circuit that uses a modified load torque observer. In the figure, (1) is an

elevator system, (2)-(19) indicate a control circuit constructed in the same manner as the example in Figure 1, (31) is a simple load torque observer that is a modified minimum dimension load torque observer, and (39) is an adder that adds the signal from the observer (31) to the torque instruction from the control circuit (2-19) and outputs it to the elevator system (1).

[0033]

The load torque observer (31) is comprised of an elevator model (33) to which the signal from the control circuit (2-19) is input, an adder (34) that takes the difference between the signal from this model and the motor speed detected value (ω_M), and an amp (35) that multiplies the output from this adder with the gain (K_1) and outputs it to the adder (39).

[0034]

With this circuit, the signal output from the control circuit (2-19) is input to the elevator model, and the difference between the signal from said model and the motor speed detected value (ω_M) is taken. The disturbance torque is estimated, multiplied by gain by the amp and added to the signal from the control circuit (2-19). Thus, an elevator system control with a high disturbance suppression effect can be realized.

[0035]

Application Mode 6

Figure 6 illustrates another example of an elevator speed control circuit that uses a modified load torque observer. In this speed control circuit, the car speed feedback system (11-16) of the speed control circuit (2-31) that uses a modified load torque observer (31) illustrated in Figure 5 is replaced with a car acceleration feedback system (11-14) used in Figure 2.

[0036]

Because said speed control circuit uses a car acceleration feedback system, the vibration of the car can be suppressed more actively than the example illustrated in Figure 5.

[0037]

The load torque observer (31) in Figures 5 and 6 is more simplified than the minimum dimension load torque observer in Figures 3 and 4. Thus, it can be converted into software more easily.

[0038]

Application Mode 7

Figure 7 illustrates an elevator speed control circuit that uses a complete dimension observer. In the figure, (1) is an

elevator system, (2)-(19) indicate a control circuit with a car speed feedback system that is constructed in the same manner as the example in Figure 1, (41) is a complete dimension load torque observer, and (49) is an adder that adds the signal from the observer (41) to the torque instruction from the control circuit (2-19) and outputs it to the elevator.

[0039]

The load torque observer (41) is comprised of an elevator model (43) to which the torque instruction from the control circuit (2-19) is input, an adder (44) that takes the difference between the signal from this model and the motor speed detected value (ω_M), an amp (45) that multiplies the signal from this adder by gain (K_1), an integral circuit (46) that integrates the output signal of this amp, and an adder (47) that adds the output signal of the amp (45) and the output signal of the integral circuit (46) and outputs it to the aforementioned adder (49).

[0040]

This observer (41) is made into a circuit with complete dimension with the circuits (46) and (47) added to the circuits (43)-(45), constructed in the same manner as the minimum dimension observer (31) of Figure 5. Thus, it can estimate more strict load torque than the circuit of Figure 3, and the effect of suppressing vibration and disturbances is improved.

[0041]

Application Mode 8

Figure 8 illustrates another example of an elevator speed control circuit that uses a complete dimension observer. In this speed control circuit, the car speed feedback circuit (11-16) part of the speed control circuit (2-41), which uses a complete dimension observer (41) illustrated in Figure 7, is replaced with the car acceleration feedback circuit (11-14) used in Figure 2.

[0042]

Because a car acceleration feedback system is used in this speed control circuit, the vibration of the car can be suppressed more actively than in the example in Figure 7.

[0043]

Application Mode 9

Figure 9 illustrates an elevator speed control circuit that compensates for observer gain.

[0044]

In Figure 9, (1) is an elevator system, (2-35) indicate a control circuit that is constructed in the same manner as Figure 5, (51) is a compensating filter that is connected after the load torque observer (31), and (59) is an adder that adds the

output signal of the compensating filter (51) to the output signal of the circuit (2-19) and outputs the torque instruction (u) to the elevator system (1).

[0045]

The compensating filter (51) adds a cushion to the input changes before outputting, and the cushion time is a value that depends on the speed detection accuracy and the motor speed.

[0046]

In the aforementioned load torque observer of Figures 3-8, the observer gain must be large in order to improve the disturbance suppression effect. In general, the upper limit of the observer gain depends on the speed detection accuracy. Therefore, if a large observer gain cannot be obtained because enough speed detection accuracy cannot be obtained, then a sufficient disturbance suppression effect cannot be obtained. However, as mentioned above, since a compensating filter (51) with a cushion time that depends on the speed detection accuracy and the motor speed is provided after the load torque observer, the disturbance caused by speed detection errors will be suppressed, and the observer gain will be large.

[0047]

Application Mode 10

Figure 10 illustrates another example of an elevator speed control circuit that compensates for the observer. In this speed control circuit, the car speed feedback system (11-16) of the speed control circuit (2-51) that uses a load torque observer (31) and a compensating filter (51), that is illustrated in Figure 9, is replaced with a car acceleration feedback system (11-14), which is used in Figure 2.

[0048]

Because a car acceleration feedback system is used in this speed control circuit, the vibration of the car can be suppressed more actively than in the example in Figure 9.

[0049]

Application Mode 11

Figure 11 illustrates an elevator speed control circuit that uses a car detection delay compensating circuit. In Figure 11, (1) is an elevator system, (2-59) indicate a control circuit that is constructed identically to the circuit illustrated in the aforementioned Figure 5, and (61) is a detection delay compensating circuit that compensates for the detection delay of the car speed detected value (ω_{car}), which is provided as feedback from the elevator system (1) to the adder (11).

[0050]

If an elevator system (1) detects the car speed at the governor part through a governor rope as illustrated in Figure 20, if the elevator is for a skyscraper, the distance between the governor and the car will be long, and the car speed detection will be delayed due to the delay in the transmission speed of the governor rope. Thus, the effect of suppressing the car vibration will decrease even if a load torque observer (31) and a compensating filter (51) are provided.

[0051]

However, with this circuit (Figure 11), the detection delay compensating circuit (61) compensates for the delay in the detection of the car speed detected value (ω_{car}). Thus, even if there is a detection delay of the car speed detected value (ω_{car}), a control without decreased effect of car vibration suppression can be realized.

[0052]

Application Mode 12

Figure 12 illustrates another example of an elevator speed control circuit that uses a car speed detection delay compensating circuit. In Figure 12, (62) is a detection delay compensating circuit with variable compensating amount that compensates for the car speed detected value (ω_{car}) detection delay, which is provided in the feedback circuit of the car

speed. It is constructed in a manner that the amount of compensation for the detection delay will vary upon receiving the car position signal (H_{car}) from the elevator system (1). The other circuit (2-59) parts are constructed identically to those in Figure 1.

[0053]

With this circuit, the amount of compensation for the car speed detection delay of the detection delay compensating circuit (62) varies depending on the position (height) of the car. Thus, the detection delay of the car speed based on the changes in the distance between the governor and the car can be compensated for corresponding to the height of the car.

[0054]

Application Mode 13

Figure 13 illustrates an elevator speed control circuit with variable car speed feedback gain. In Figure 13, (13) is a speed amp of variable gain that replaces the speed amp (12) with fixed gain of the car speed feedback system illustrated in Figure 11. It is constructed in a manner that the gain will be controlled by the car position signal (H_{car}) from the elevator system (1). The other circuit parts are constructed identically to those in Figure 11.

[0055]

The gain of the amp (12) was a fixed value in the systems of Figures 11 and 12. As the characteristics of the elevator vary depending on the position of the car, by applying a speed amp (13) with variable gain that varies depending on the position of the car as mentioned above, the vibration suppression effect can be increased.

[0056]

Application Mode 14

Figure 14 illustrates an elevator speed control circuit with variable car speed feedback gain. In Figure 14, (15) and (17) are respectively a variable bandpass filter and a variable phase compensating filter, which respectively replace the bandpass filter (14) and the phase compensating filter (16) in Figure 13. They are constructed in a manner that they will respectively have the bandwidth and the phase to be compensated for controlled by the car position signal (H_{car}) from the elevator system (1). The other circuit parts are constructed identically to those in Figure 13.

[0057]

As described earlier, the characteristics of the elevator varies depending on the position of the car. Thus, by making the bandwidth and the phase of the bandpass filter and the phase

compensating filter variable as described above, the vibration suppression effect can be increased.

Application Mode 15

Figure 15 illustrates an elevator speed control circuit with variable car speed feedback gain. In Figure 15, (14₁) and (14₂) are bandpass filters to which the output signal of the variable gain amp (13) is input, (16₁) and (16₂) are phase compensating filters to which the output signals of the filters (14₁) and (14₂) are input, and (SW1) is a changeover switch that switches the output signals of the filters (16₁) and (16₂) between the cases when the car is located higher than the predetermined position or lower, upon receiving the car position signal (H_{car}) from the elevator system (1), and outputs it to the adder (19). The other circuit parts are constructed identically to those in Figure 13.

[0058]

The characteristics of the elevator are significantly different for the cases when the car is at an upper part or at a lower part. Thus, as described above, by switching the bandpass filters (14₁) and (14₂) and the phase compensating filters (16₁) and (16₂) upon receiving the car position signal, the vibration suppression effect will improve compared to a case when the circuit in Figure 13 is used.

[0059]

Application Mode 16

Figure 16 illustrates a vibration suppression circuit with variable car speed feedback gain. In Figure 16, (4) is a speed amp with variable gain that is used instead of the speed amp (3) in Figure 15, and (32) is a load torque observer that is the same as the load torque observer (31) in Figure 15 except for the fact that the amp (35) is replaced with a variable gain amp (36). The gains of the amps (4) and (36) are constructed in a manner that they will respectively vary in inverse proportion and in proportion to the motor speed detected value (ω_M). The other circuit parts are constructed identically to those in Figure 15.

[0060]

Because the observer gain cannot be increased in a low speed zone, the observer gain must be made small. However, because the gain of the amp (36) varies in proportion to the motor speed detected value (ω_M) in this circuit, the observer gain will be small in a low speed zone. Also, in a low speed zone, the speed deviation will be small. In this circuit, because the gain of the speed amp (4) varies in inverse proportion to the motor speed detected value (ω_M), the speed responsiveness in a low speed zone will improve.

[0061]

Application Mode 17

Figure 17 illustrates an elevator speed control circuit with variable car acceleration feedback gain. In Figure 17, (13) is a variable gain acceleration amp that replaces the acceleration amp (12) with fixed gain of the acceleration feedback system in Figure 10, and the gain of this amp is controlled by the car position signal (H_{car}) from the elevator system (1). The other circuit parts are constructed identically to those in Figure 10.

[0062]

Since the characteristics of the elevator vary depending on the position of the car, by adopting an acceleration amp with variable gain that varies depending on the car position, the vibration suppression effect will increase.

[0063]

Application Mode 18

Figure 18 illustrates another example of an elevator speed control circuit with variable car acceleration feedback gain. In Figure 18, (13) and (15) are an acceleration amp with variable gain and a variable bandpass filter that replace the acceleration amp with fixed gain (13) and the bandpass filter with fixed band (14) in the acceleration feedback system in Figure 10. The gain of the amp and the band of the filter are controlled by the car

position signal (H_{car}) from the elevator system (1). Otherwise, the circuit is constructed identically to that in Figure 10.

[0064]

Since the gain of the acceleration amp and the bandwidth of the bandpass filter are variable depending on the car position in this control circuit, the vibration suppression effect is further increased.

[0065]

Application Mode 19

Figure 19 illustrates an elevator speed control circuit wherein the gain of the speed amp, the observer gain and the vibration suppression gain are made variable.

[0066]

In Figure 19, (4) and (36) are a variable gain speed amp and a variable gain amp of a load torque observer wherein the gain varies depending on the motor speed detected value (ω_M), (13) is a variable gain acceleration amp wherein the gain varies depending on the motor speed detected value (ω_M) and the car position detected value (H_{car}), and (15) is a variable bandpass filter wherein the bandwidth varies depending on the car position detected value (H_{car}). Otherwise, the construction is identical to that in Figure 18.

[0067]

In this speed control circuit, the speed amp gain, the observer gain and the vibration suppression gain vary depending on the motor speed detected value (ω_M). They become small in a very low speed zone. Thus, even if the motor speed detected value (ω_M) becomes rough in a very low speed zone, no chattering will occur.

[0068]

Effect of the invention

The present invention has the following effect:

[0069]

(1) The vibration of the car can be actively suppressed in an elevator speed control for a skyscraper.

[0070]

(2) Even with a taller building and a higher speed, the car information can be obtained using an acceleration detector, and thus the vibration can be suppressed.

[0071]

(3) A speed control suitable for elevator control can be performed without generating overshoot by applying a load torque observer.

[0072]

(4) Because the system considers changes in torque characteristics depending on the position of the elevator, the vibration can be suppressed irrespective of the position of the elevator.

[0073]

(5) The passenger comfort at the time when the elevator is about to stop can be improved by varying various gains in a very slow speed zone.

[0074]

(6) In-phase vibration can also be suppressed.

[0075]

(7) Disturbance elements caused by speed detection errors can be suppressed.

[0076]

(8) Even if there is a car speed detection delay, the vibration can be suppressed.

[0077]

(9) The vibration can be suppressed irrespective of the position of the car.

Brief description of the figures

Figure 1 is a block diagram illustrating an example of an elevator speed control circuit that uses a car speed feedback system.

Figure 2 is a block diagram illustrating an example of an elevator speed control circuit that uses a car acceleration feedback system.

Figure 3 is a block diagram which illustrates an example of an elevator speed control circuit which uses a minimum dimension observer.

Figure 4 is a block diagram which illustrates another example of the same speed control circuit.

Figure 5 is a block diagram which illustrates an example of an elevator speed control circuit which uses a modified load torque observer.

Figure 6 is a block diagram which illustrates another example of the same speed control circuit.

Figure 7 is a block diagram illustrating an example of an elevator speed control circuit which uses a complete dimension observer.

Figure 8 is a block diagram illustrating another example of the same speed control circuit.

Figure 9 is a block diagram illustrating an example of an elevator speed control circuit that compensates for the observer gain.

Figure 10 is a block diagram illustrating another example of the same speed control circuit.

Figure 11 is a block diagram illustrating an example of an elevator speed control circuit that applies detection delay compensation.

Figure 12 is a block diagram which illustrates another example of the same speed control circuit.

Figure 13 is a block diagram illustrating an example of an elevator speed control circuit wherein the car speed detection feedback gain is made variable.

Figure 14 is a block diagram illustrating another example of the same speed control circuit.

Figure 15 is a block diagram illustrating another example of the same speed control circuit.

Figure 16 is a block diagram illustrating another example of the same speed control circuit.

Figure 17 is a block diagram illustrating an example of an elevator speed control circuit wherein the car acceleration feedback gain is made variable.

Figure 18 is a block diagram illustrating another example of the same speed control circuit.

Figure 19 is a block diagram illustrating an example of an elevator speed control circuit wherein the speed amp gain, the observer gain and the vibration suppression gain are made variable.

Figure 20 is a structural explanatory diagram of a balanced type elevator.

Figure 21 explains a speed detection method of the case wherein the car speed is detected at the car part.

Figure 22 is a diagram of a tri-inertia model for an elevator.

Explanation of the symbols

1	Elevator system controlled by torque instruction
3, 4	Speed amp
12, 13	Speed or acceleration amp of car speed or car acceleration feedback system
14, 14 ₁ , 14 ₂ , 15	Bandpass filter
16, 16 ₁ , 16 ₂ , 17	Phase compensating filter
21, 31, 32	Load torque observer
23, 33	Elevator model for observer
25, 35, 36	Amp for observer
51	Compensating filter that compensates for observer gain
61, 62	Car speed detection delay compensating circuit
ω^*	Speed instruction value
ω_M	Motor speed detected value
ω_{car}	Car speed detected value
α^*	Acceleration instruction value
α_{car}	Car acceleration detected value

Claim

1. An elevator speed control circuit characterized by the fact that, in an elevator speed control circuit that has a speed amp that calculates the deviation between the motor speed instructions and the motor speed by PI [proportional integration],

there is provided a car speed feedback circuit that amplifies the difference between the speed instructions and the car speed, extracts vibration components of the car by passing them through a bandpass filter, and changes the vibration components to the optimal phase with a phase filter and feeds them back, and car vibration is actively suppressed.

2. An elevator speed control circuit in accordance with Claim 1 wherein a minimum dimension load torque observer, which estimates the load torque based on the output signal and motor speed, is used for the speed control circuit, and the speed follow-up characteristics and the disturbance suppression effect are improved.

3. An elevator speed control circuit in accordance with Claim 1 characterized by the fact that a simple load torque observer comprised of an elevator model to which the output signal of the aforementioned speed control circuit is input and a circuit that amplifies the difference between the output signal from this model and the motor speed is provided.

4. An elevator speed control circuit in accordance with Claim 1 characterized by the fact that a complete dimension observer that estimates the load torque based on the output signal and motor speed is used for the speed control circuit, and a strict estimate of the load torque is obtained.



5. An elevator speed control circuit in accordance with one of Claims 1-4 characterized by the fact that a compensating filter that suppresses large variations in load torque estimation is provided after the load torque observer to stabilize the load torque observer.

6. An elevator speed control circuit in accordance with one of Claims 1-5 characterized by the fact that a detection delay compensating circuit, which compensates for the detection delay of the car speed, is provided in a car speed signal circuit.

7. An elevator speed control circuit in accordance with Claim 6 characterized by the fact that the detection delay compensating circuit is configured in a manner that the amount of compensation varies depending on the car position signal, and thus the compensating effect for detection delay is increased.

8. An elevator speed control circuit in accordance with one of Claims 1-7 characterized by the fact that the gain of the car speed feedback circuit is made variable based on the car position signal, and thus vibration can be suppressed corresponding to elevator characteristics.

9. An elevator speed control circuit in accordance with one of Claims 1-7 characterized by the fact that the gain of the car speed feedback circuit, the bandwidth of the bandpass filter, and the phase compensated by the phase filter are respectively made variable based on the car position signal, and thus the respective vibration suppression effects at the position of the car are increased.

10. An elevator speed control circuit in accordance with one of Claims 2-9 characterized by the fact that the gain of the speed amp that does the PI computation of the speed deviation and the gain of the load torque observer are respectively made



variable based on the motor speed signal, and thus the speed controllability is maintained.

11. An elevator speed control circuit characterized by the fact that, in an elevator speed control circuit that has a speed amp that calculates the deviation between the motor speed instructions and the motor speed by PI,

there is provided a car acceleration feedback circuit that amplifies the difference between the acceleration instructions and the car acceleration, extracts the vibration components of the car by passing them through a bandpass filter, and provides feedback, and the vibration of the car is actively suppressed.

12. An elevator speed control circuit in accordance with Claim 11 wherein a minimum dimension load torque observer, which estimates the load torque based on the output signal and motor speed, is used for the speed control circuit, and the speed follow-up characteristics and the disturbance suppression effect are improved.

13. An elevator speed control circuit in accordance with Claim 11 characterized by the fact that a simple load torque observer comprised of an elevator model to which the output signal of the aforementioned speed control circuit is input and a circuit that amplifies the difference between the output signal from this model and the motor speed is provided.

14. An elevator speed control circuit in accordance with Claim 11 characterized by the fact that a complete dimension observer, which estimates the load torque based on the output signal and motor speed, is used for the speed control circuit, and a strict estimate of the load torque is obtained.

15. An elevator speed control circuit in accordance with one of Claims 11-14 characterized by the fact that a compensating



filter, which compensates for the disturbance elements caused by speed instruction errors, is provided after the load torque observer to stabilize the load torque observer.

16. An elevator speed control circuit in accordance with one of Claims 11-15 characterized by the fact that the gain of the car acceleration feedback circuit is made variable based on the car position signal, and thus vibration can be suppressed corresponding to the elevator characteristics.

17. An elevator speed control circuit in accordance with one of Claims 11-16 characterized by the fact that the gain of the car acceleration feedback circuit and the bandwidth of the bandpass filter are respectively made variable based on the car position signal, and thus the respective vibration suppression effects at the car position are increased.

18. An elevator speed control circuit in accordance with one of Claims 12-17 characterized by the fact that the gain of speed amp that does the PI computation of the speed deviation and the gain of the load torque observer are respectively made variable based on the motor speed signal, and thus the speed controllability is maintained.

19. An elevator speed control circuit in accordance with one of Claims 12-18 characterized by the fact that the gain of the speed amp, the gain of the load torque observer, and the gain of the car acceleration feedback circuit are respectively varied based on the motor speed.

ABSTRACT

ELEVATOR SPEED CONTROL CIRCUIT

Problems

To control elevator vibration while controlling the speed of a super-fast elevator that has a resonating frequency.

Means to solve

In an elevator speed control circuit that has a speed amp (3) that calculates the deviation between speed instruction ω^* and motor speed ω_M by PI, there is provided a car speed feedback circuit that amplifies the difference between speed instruction ω^* and car speed ω_{car} with amp (12), extracts car vibration characteristics by passing them through band-pass filter (14), and changes these vibration components to the optical phase using phase [correction] filter (16) and feeds them back. In addition, there is provided load torque observer (21) that estimates load torque from signals from circuits ((2)-(19)) and from motor speed ω_M to improve speed feedback characteristics and the effectiveness of external disturbance suppression in elevator speed control.

Selected Figure

Figure 3

ω_m Motor torque instruction
 H_{car} Car position (height)

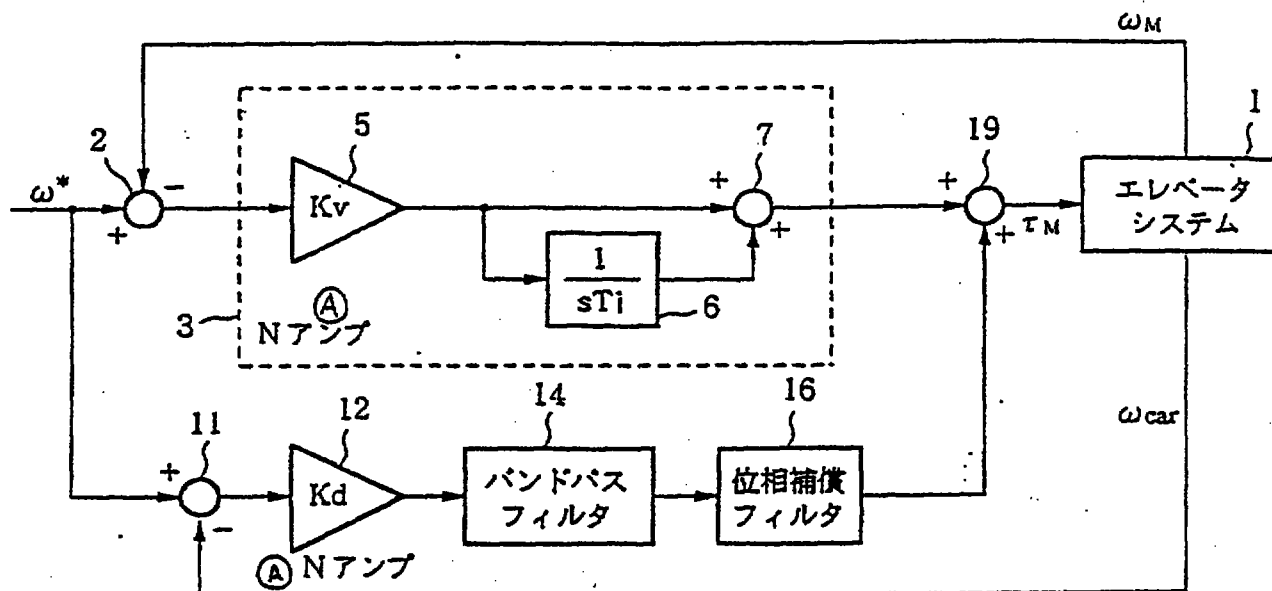


Figure 1. Speed control circuit using car speed feedback system

ω^* Speed command
 ω_m Motor speed detection value
 ω_{car} Car speed detection value

Key: A N amp
 1 Elevator system
 3 N amp
 14 Bandpass filter
 16 Phase compensation filter

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☒	Drawing(s)	: paged 1	to paged 22
☐	Abstract	: paged	to paged

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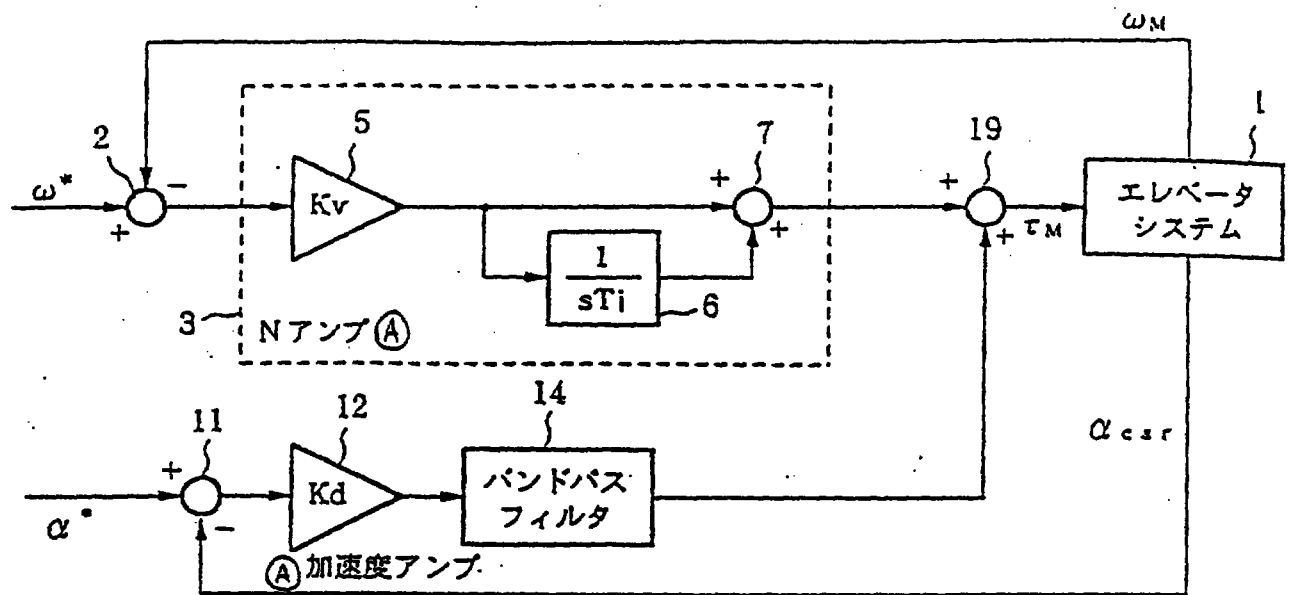


Figure 2. Speed control circuit using car acceleration feedback system

α^* Acceleration level command
 α_{car} Car acceleration level detection value
 ω^* Acceleration command
 ω_m Motor speed detection value
 ω_{car} Car speed detection value

Key: A Acceleration level amp
 1 Elevator system
 3 N amp
 14 Bandpass filter



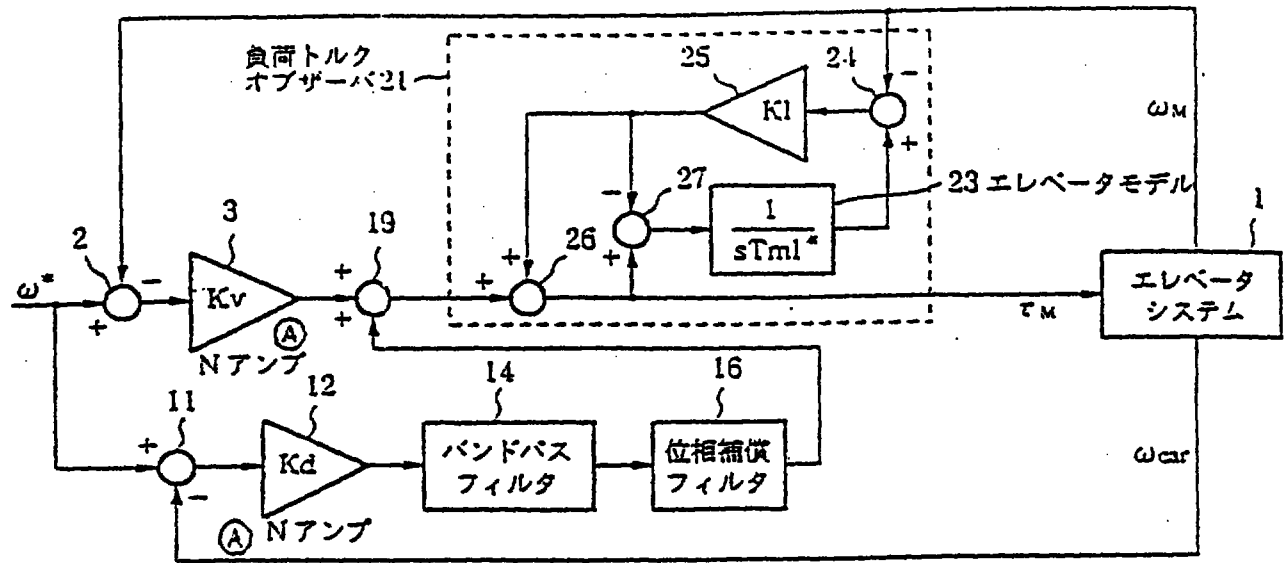


Figure 3. Speed control circuit using minimum dimension observer

- Key: A N amp
- 1 Elevator system
 - 14 Bandpass filter
 - 16 Phase compensation filter
 - 21 Load torque observer
 - 23 Elevator model



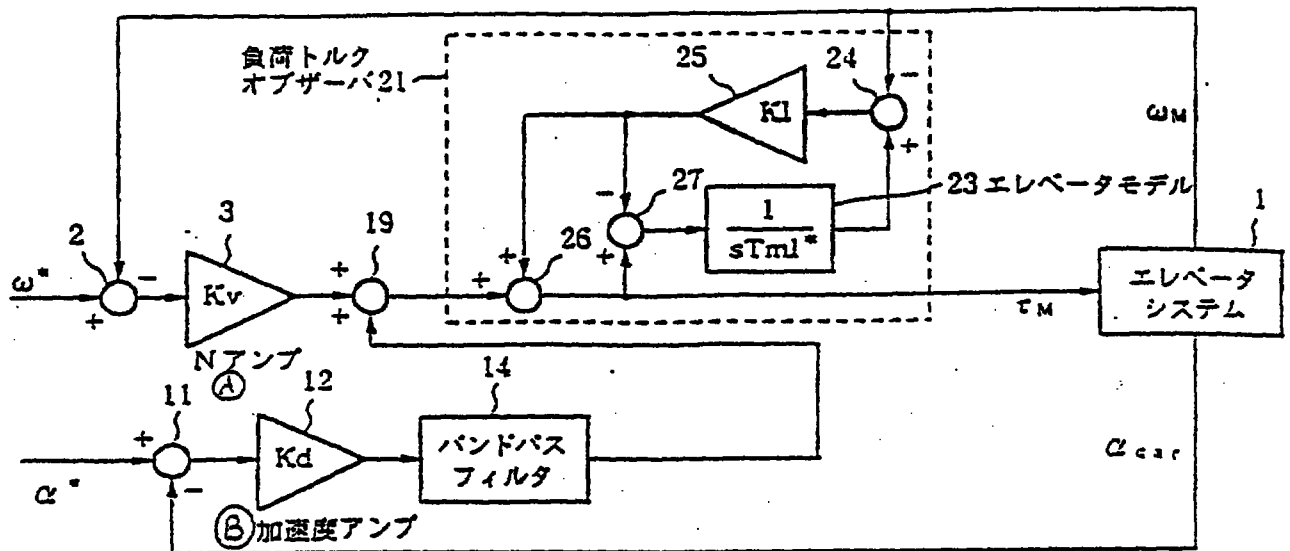


Figure 4. Speed control circuit using minimum dimension observer

- Key: A N amp
 B Acceleration level amp
 1 Elevator system
 14 Bandpass filter
 21 Load torque observer
 23 Elevator model

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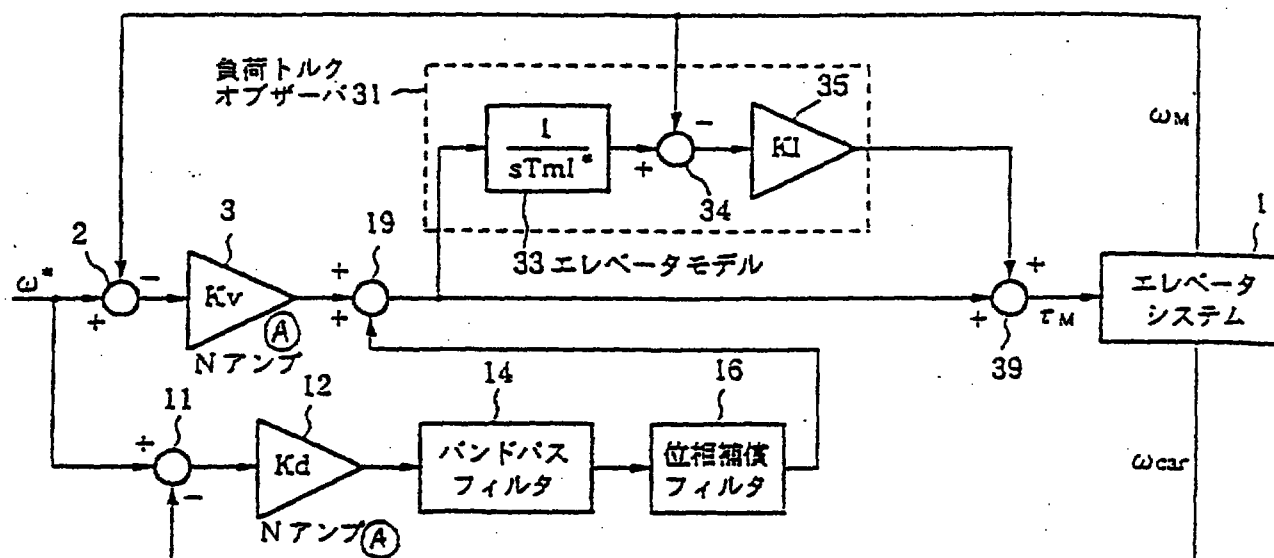


Figure 5. Speed control circuit using modified load torque observer

- Key: A N amp
- 1 Elevator system
 - 14 Bandpass filter
 - 16 Phase compensation filter
 - 31 Load Torque observer
 - 33 Elevator model

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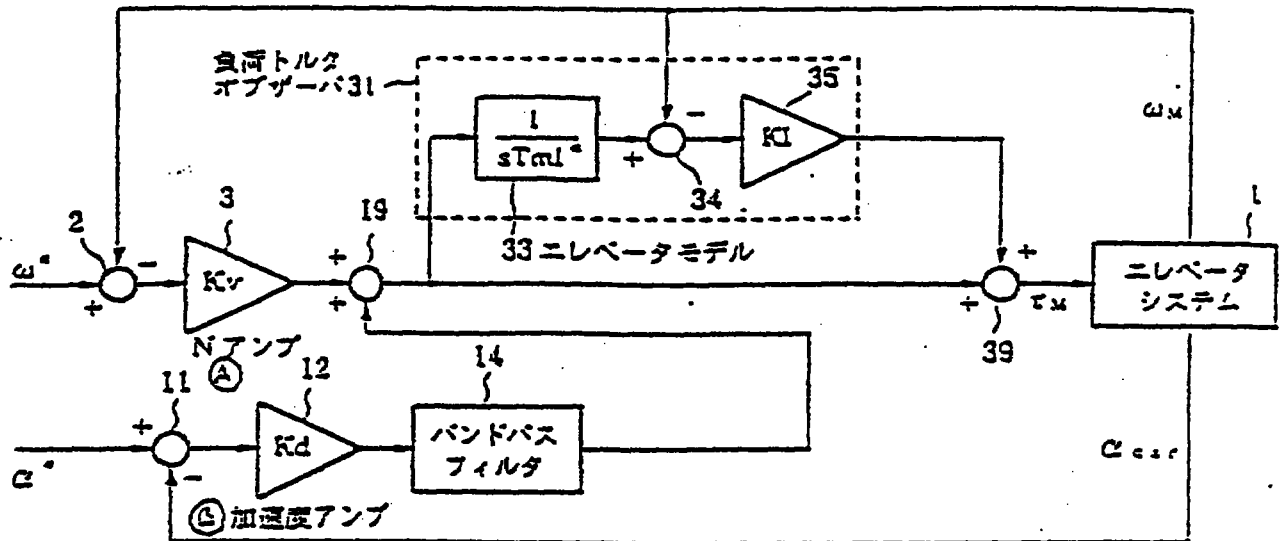


Figure 6. Speed control circuit using modified load torque observer

- Key: A N amp
 2 Acceleration level amp
 1 Elevator system
 14 Bandpass filter
 31 Load Torque observer
 33 Elevator model



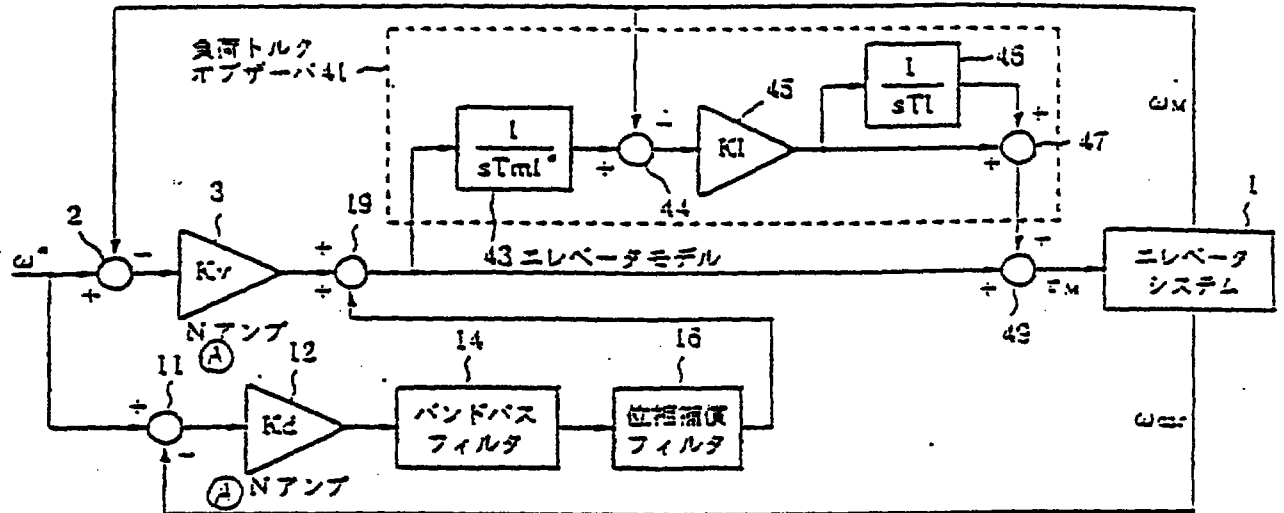


Figure 7. Speed control circuit using complete dimension observer

- Key: A N amp
- 1 Elevator system
 - 14 Bandpass filter
 - 16 Phase compensation filter
 - 41 Load torque observer
 - 43 Elevator model



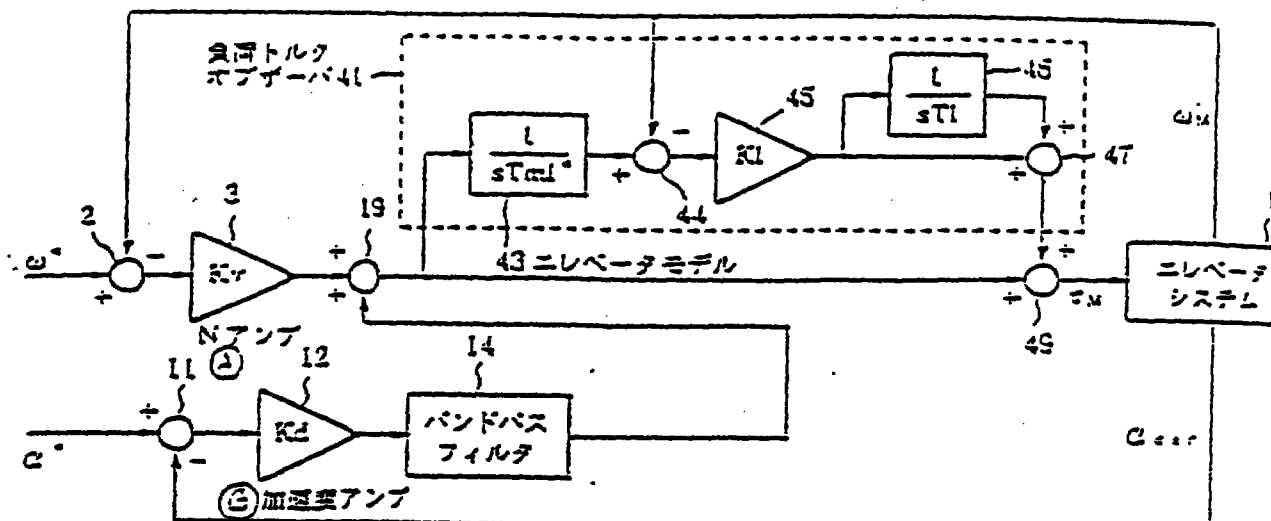


Figure 8. Speed control circuit using complete dimension observer

Key: A	N amp
B	Acceleration level amp
1	Elevator system
14	Bandpass filter
41	Load torque observer
43	Elevator model

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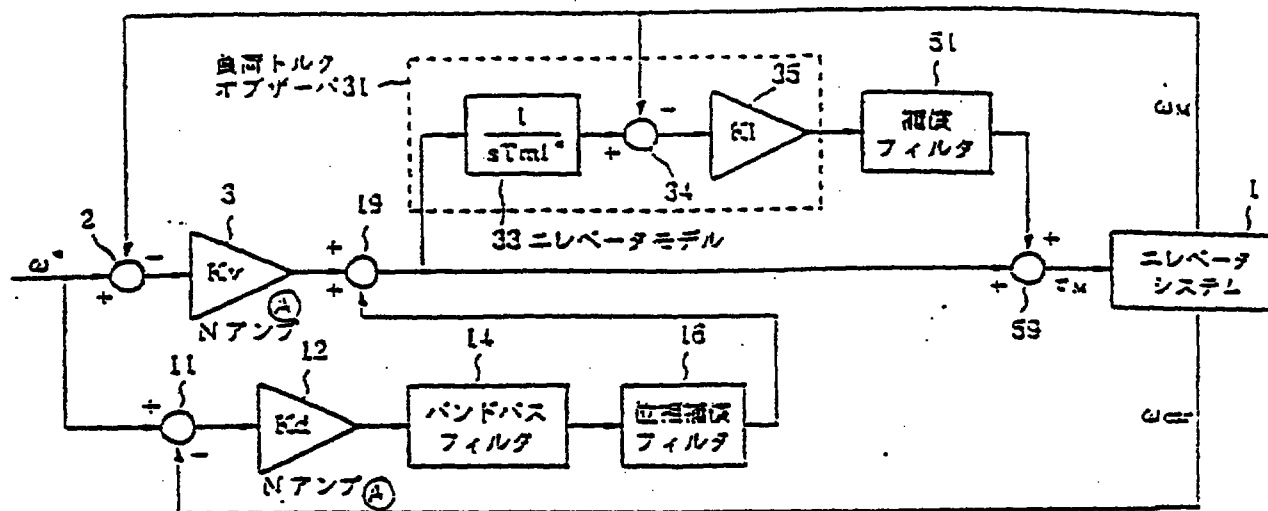


Figure 9. Speed control circuit which compensates for observer gain

- Key: A N amp
- 1 Elevator system
 - 14 Bandpass filter
 - 16 Phase compensation filter
 - 31 Load torque observer
 - 33 Elevator model
 - 51 Compensation filter

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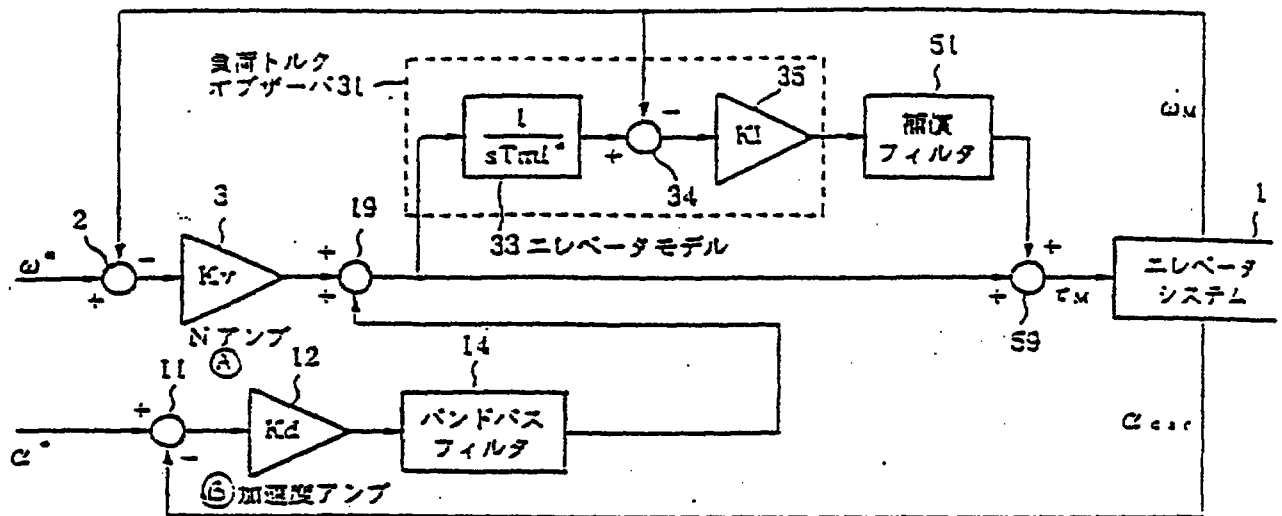


Figure 10. Speed control circuit which compensates for observer gain

- Key: A N amp
 B Acceleration level amp
 1 Elevator system
 14 Bandpass filter
 31 Load torque observer
 33 Elevator model
 S1 Compensation filter

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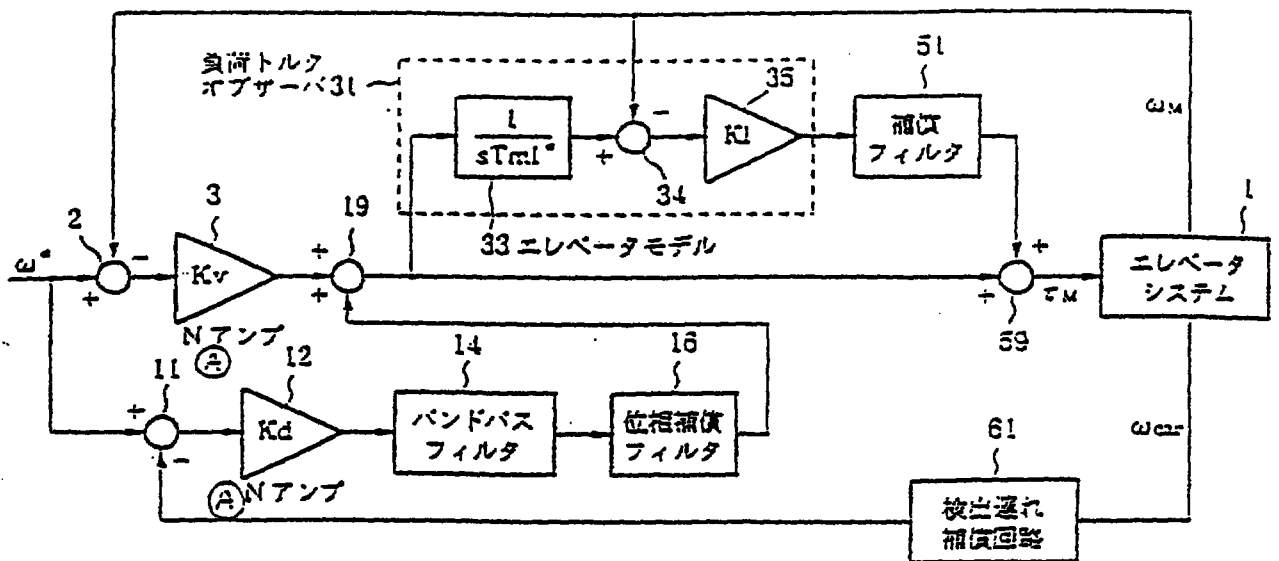


Figure 11. Speed control circuit using detection delay compensating circuit

- Key: A N amp
- 1 Elevator system
 - 14 Bandpass filter
 - 16 Phase compensation filter
 - 31 Load torque observer
 - 33 Elevator model
 - 51 Compensation filter
 - 61 Detection delay compensation circuit



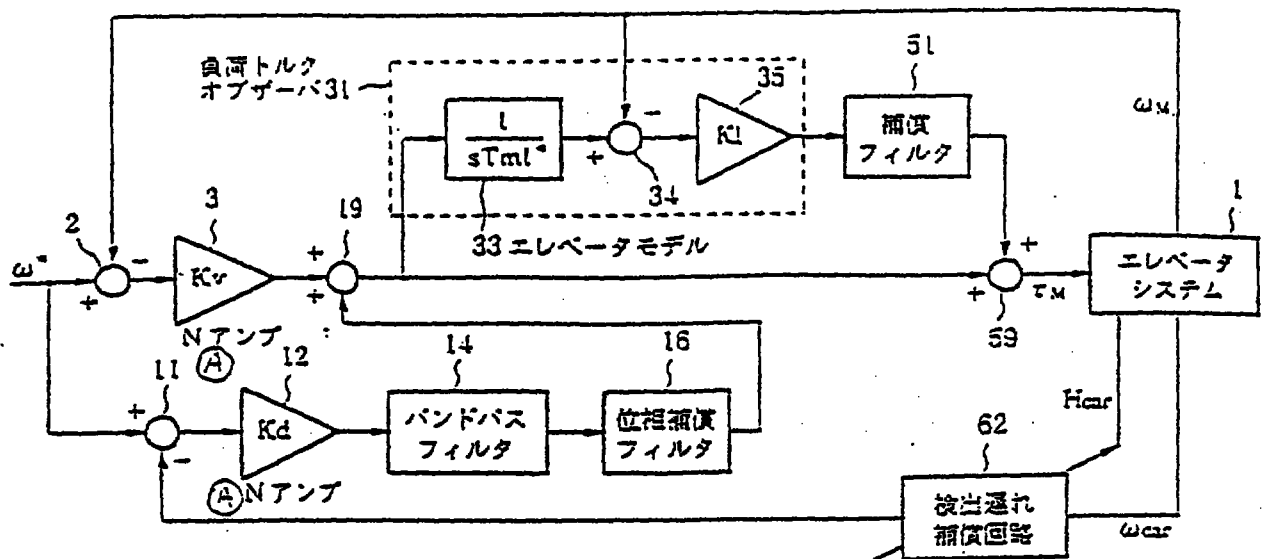


Figure 12. Speed control circuit using detection delay compensating circuit.

H_{car} Car position

Key: A N amp

1	Elevator system
14	Bandpass filter
16	Phase compensation filter
31	Load torque observer
33	Elevator model
51	Compensation filter
62	Detection delay compensation circuit



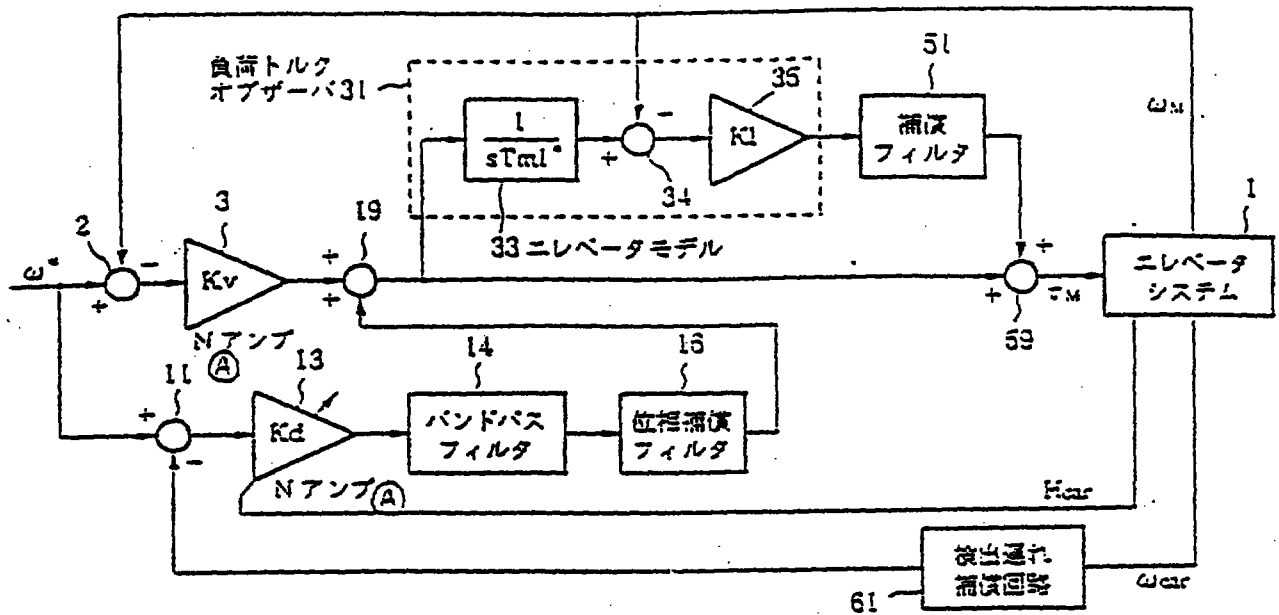


Figure 13. Speed control circuit wherein the car speed feedback gain is made variable

- Key: A N amp
- 1 Elevator system
 - 14 Bandpass filter
 - 16 Phase compensation filter
 - 33 Elevator model
 - 51 Compensation filter
 - 6 Detection delay compensation circuit



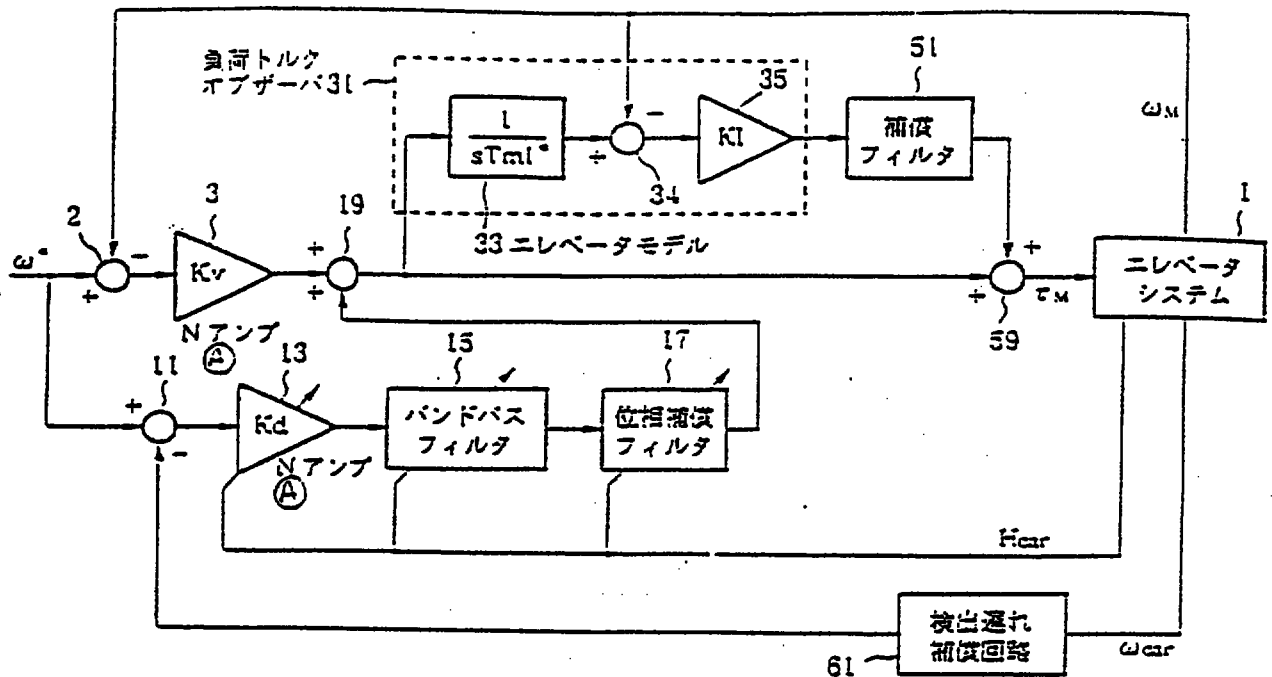


Figure 14. Speed control circuit wherein the car speed feedback gain is made variable

- Key: A N amp
- 1 Elevator system
 - 15 Bandpass filter
 - 17 Phase compensation filter
 - 31 Load torque observer
 - 33 Elevator model
 - 51 Compensation filter
 - 61 Detection delay compensation circuit



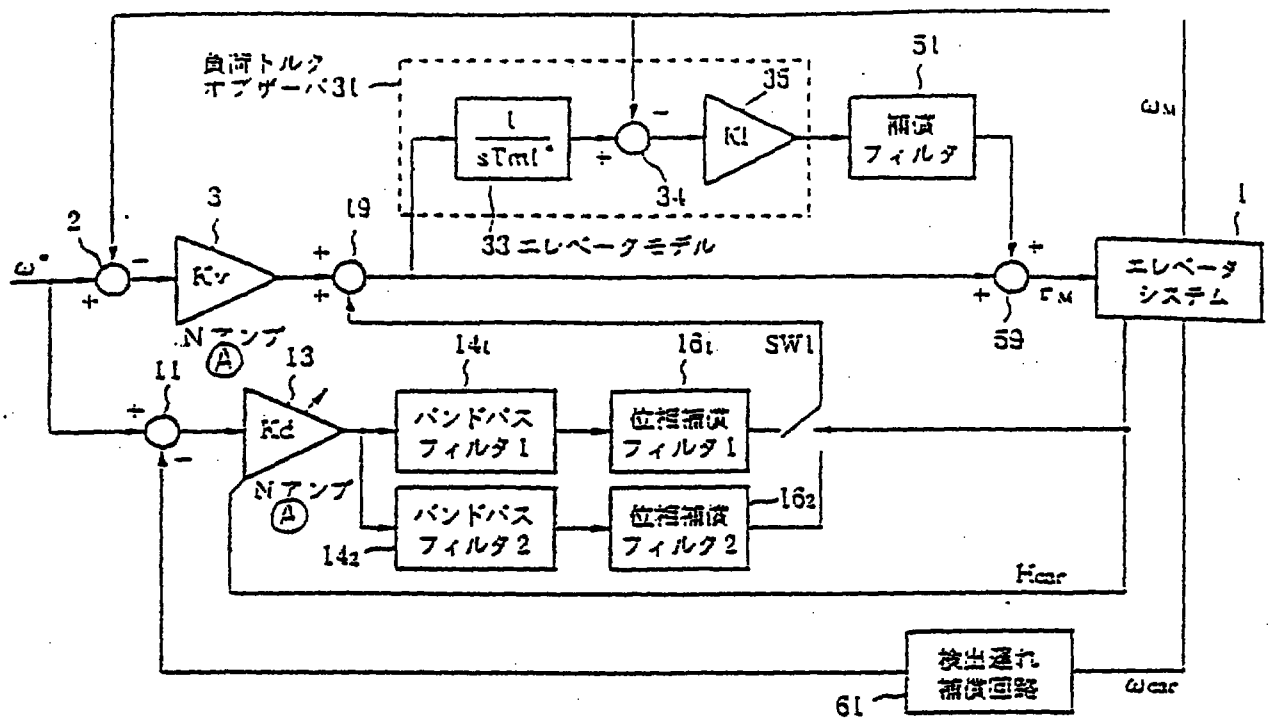


Figure 15. Speed control circuit wherein the car speed feedback gain is made variable

- Key: A N amp
- 1 Elevator system
 - 14₁ Bandpass filter 1
 - 14₂ Bandpass filter 2
 - 16₁ Phase compensation filter 1
 - 16₂ Phase compensation filter 2
 - 31 Load torque observer
 - 33 Elevator model
 - 51 Compensation filter
 - 61 Detection delay compensation circuit



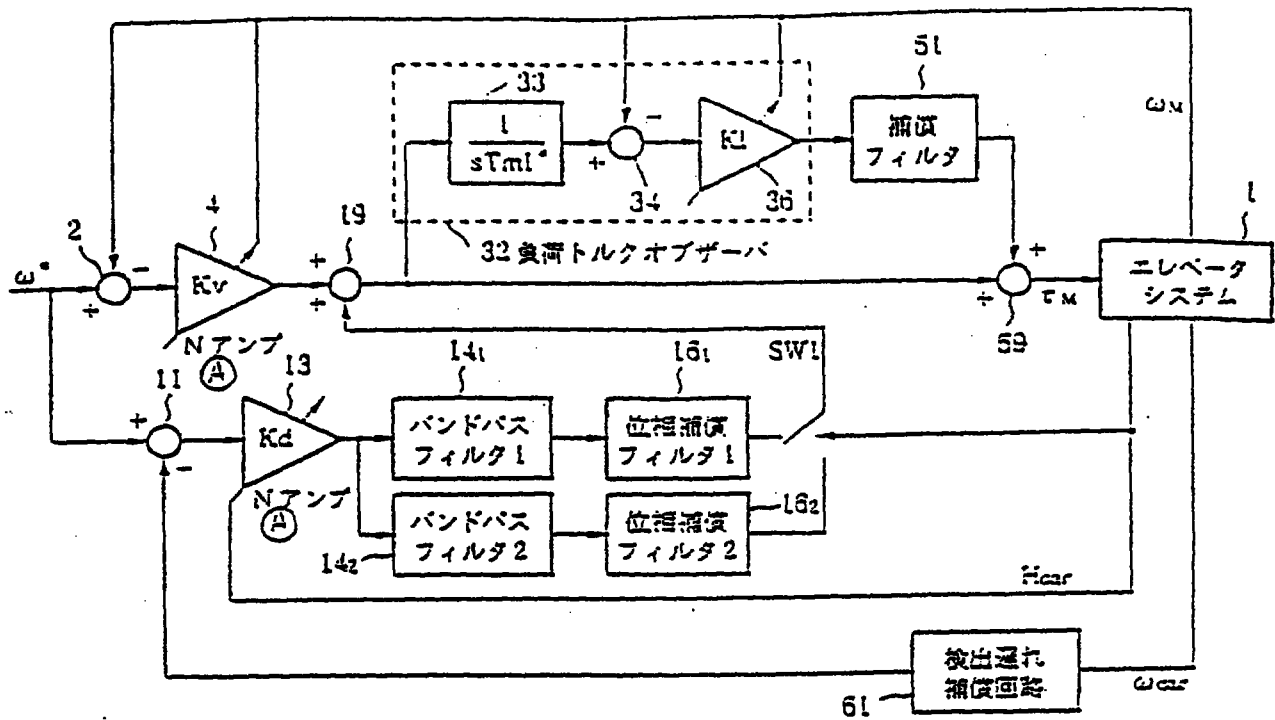


Figure 16. Speed control circuit wherein the car speed feedback gain is made variable

- Key: A N amp
- 1 Elevator system
 - 14₁ Bandpass filter 1
 - 14₂ Bandpass filter 2
 - 16₁ Phase compensation filter 1
 - 16₂ Phase compensation filter 2
 - 32 Load torque observer
 - 51 Compensation filter
 - 61 Detection delay compensation circuit



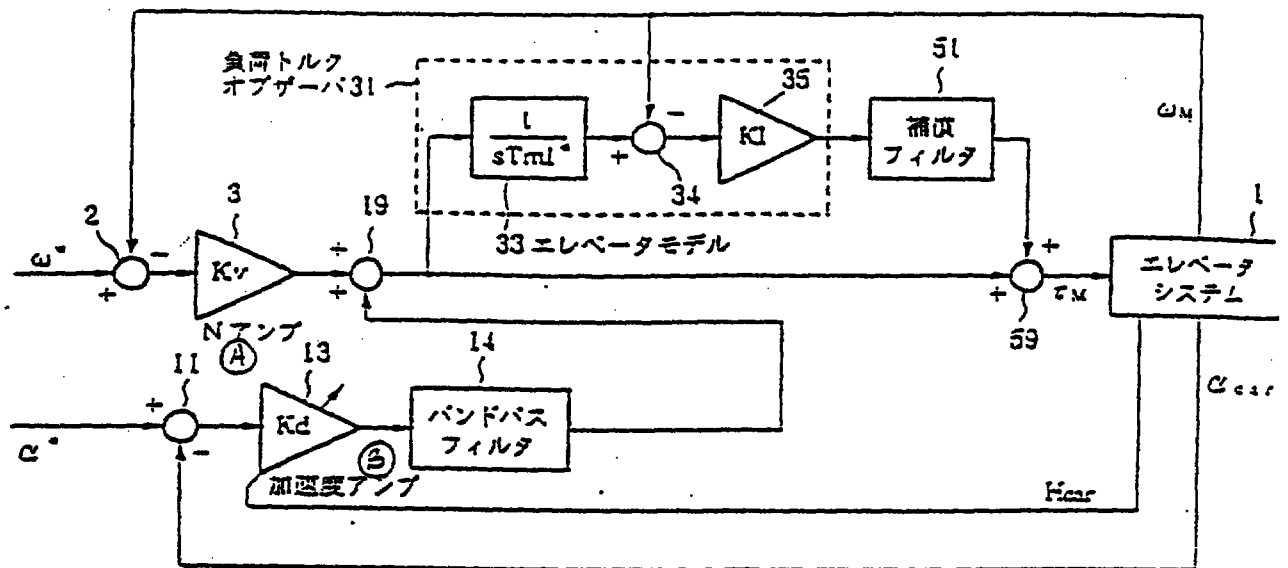


Figure 17. Speed control circuit wherein the car acceleration feedback gain is made variable

- Key: A N amp
 B Acceleration level amp
 1 Elevator system
 14 Bandpass filter
 31 Load torque observer
 33 Elevator model
 51 Compensation filter



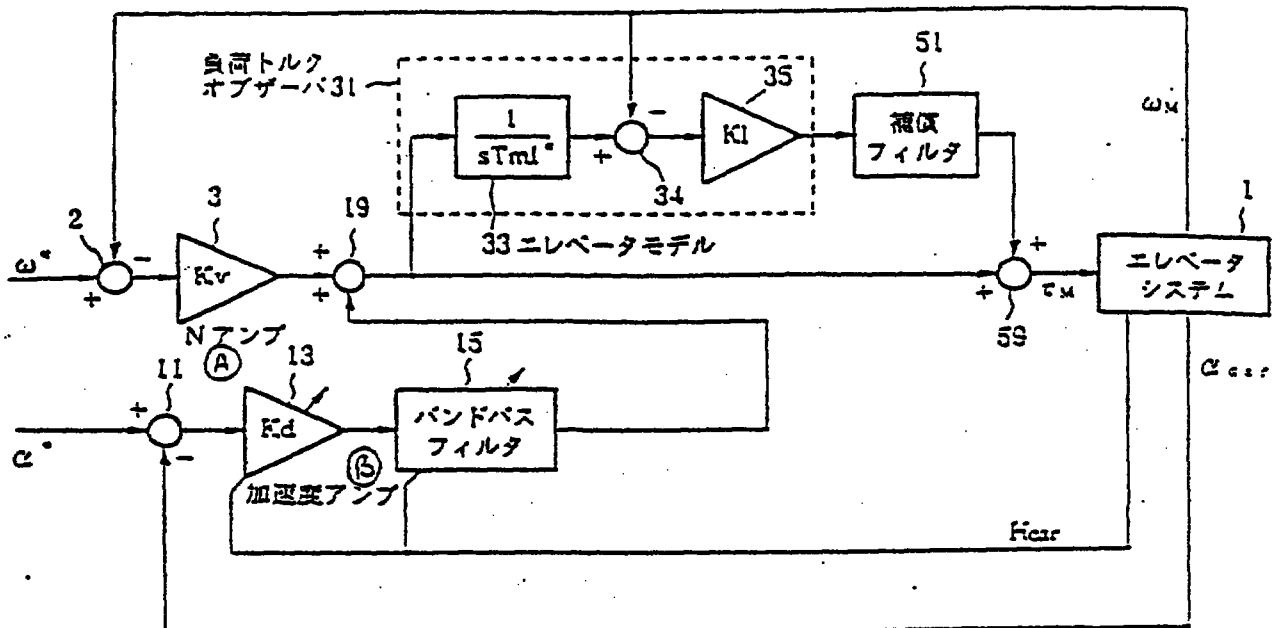


Figure 18. Speed control circuit wherein the car acceleration feedback gain is made variable

Key: A N amp
B Acceleration level amp
1 Elevator system
15 Bandpass filter
31 Load torque observer
33 Elevator model
51 Compensation filter



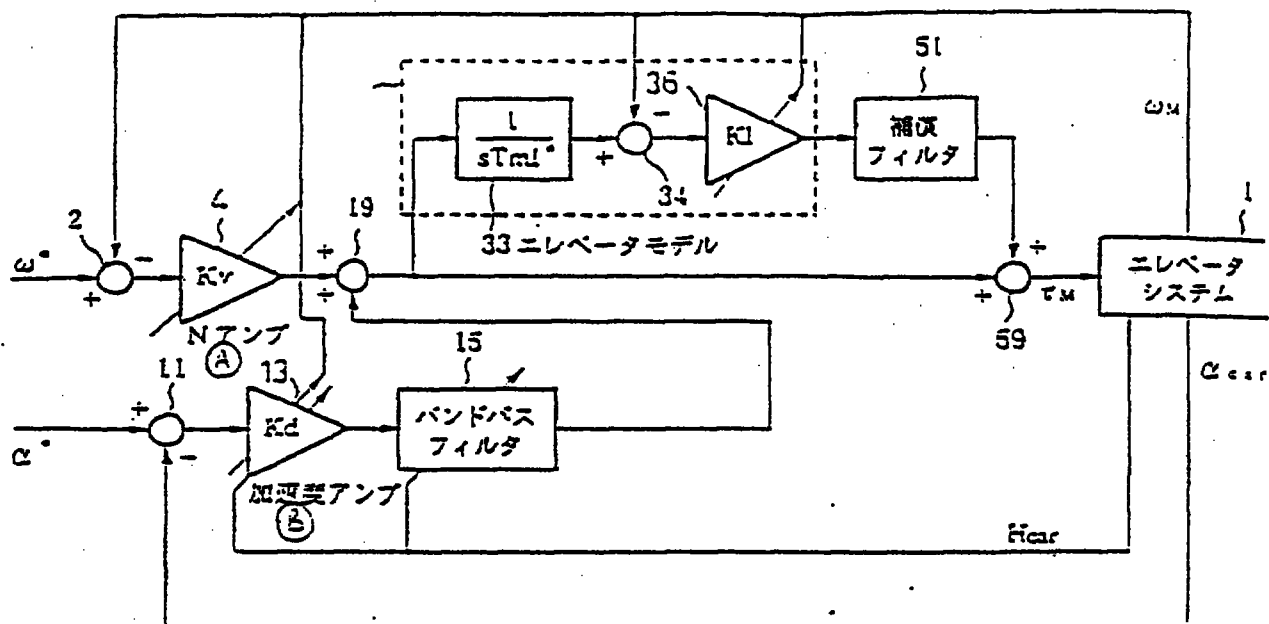


Figure 19. Speed control circuit wherein the car speed amp gain, observer gain and vibration suppression gain are made variable

- Key: A N amp
 B Acceleration level amp
 1 Elevator system
 15 Bandpass filter
 33 Elevator model
 S1 Compensation filter



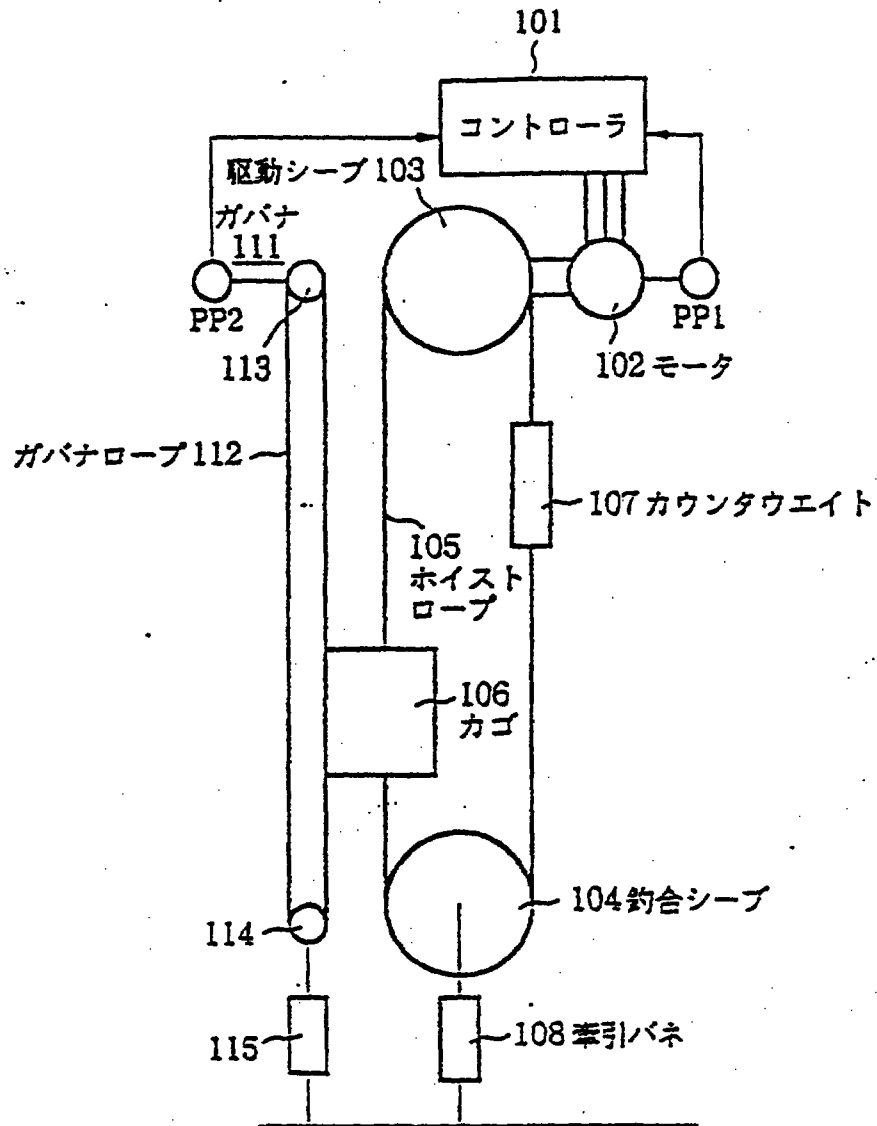


Figure 20. Elevator system

- Key: 101 Controller
102 Motor
103 Driving sheave
104 Balancing sheave
105 Hoist rope
106 Car
107 Counterweight
108 Towing spring
111 Governor
112 Governor rope

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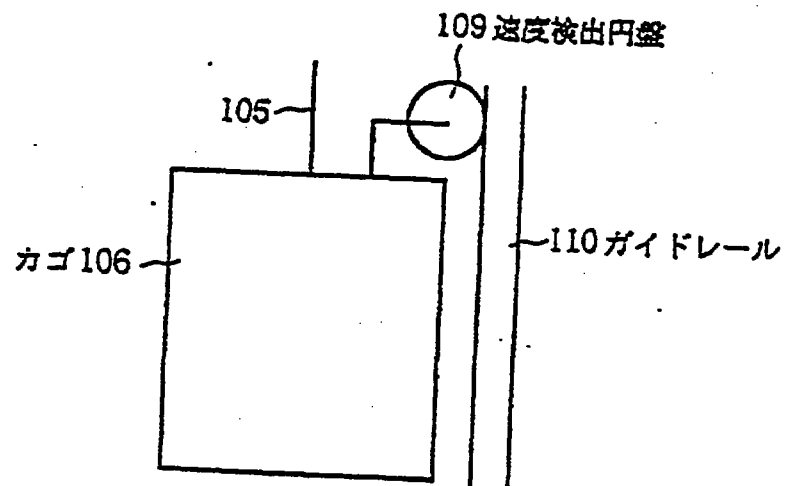


Figure 21. How to detect car speed at the car part

Key: 106 Car
109 Speed detection disc
110 Guide rail



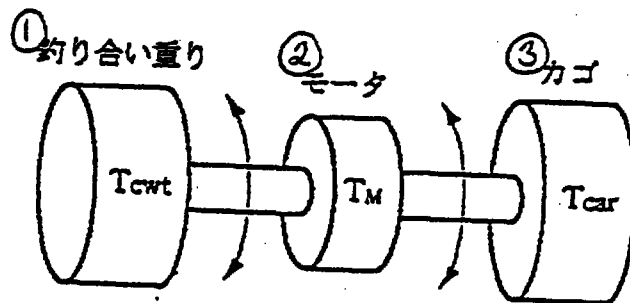


Figure 22. Tri-inertia model

T_m Mechanical time constant of motor [sec]
 T_{car} Mechanical time constant of car [sec]
 T_{cwt} Mechanical time constant of CWT [sec]

Key: 1. Balancing weight
 2 Motor
 3 Car



FIG. 1

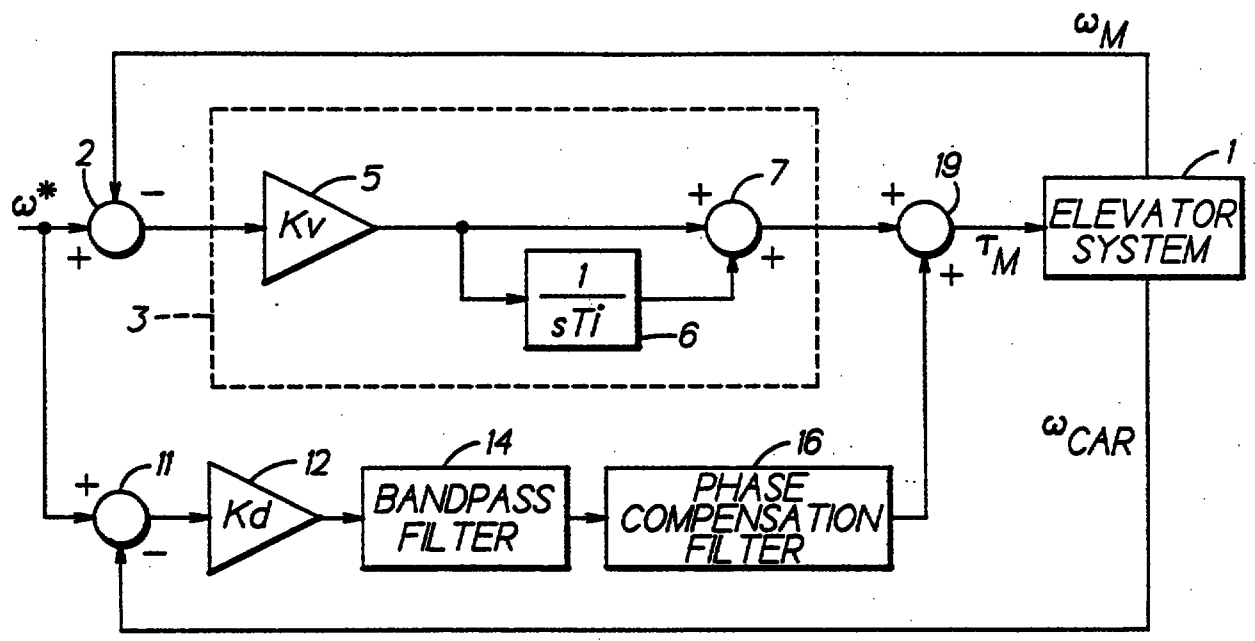
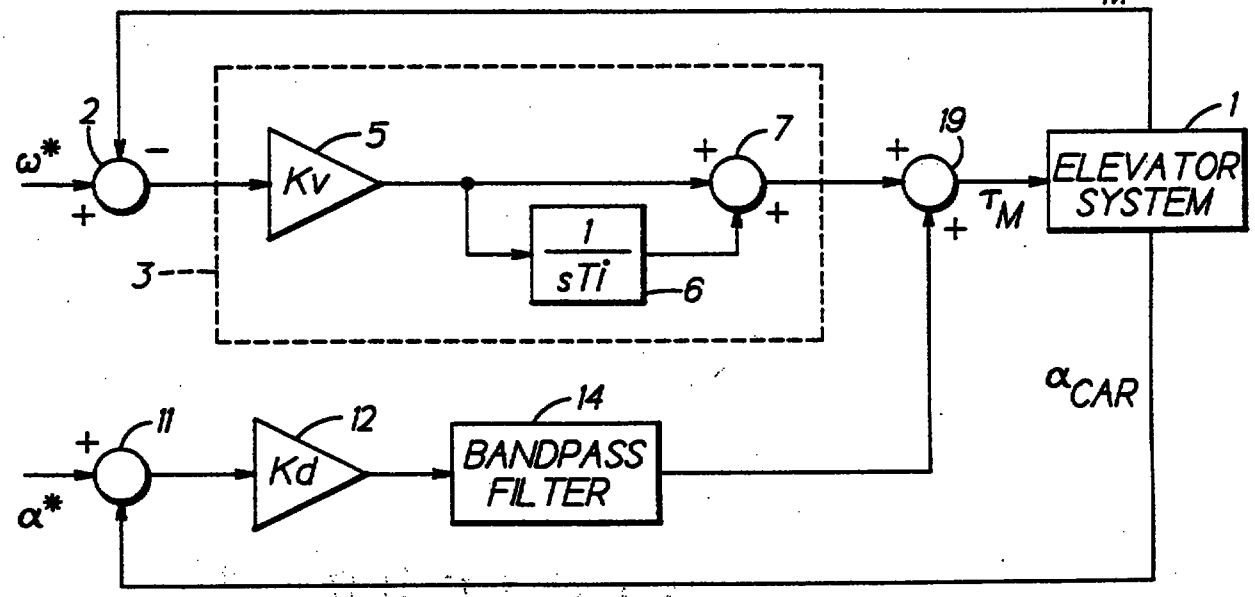


FIG. 2

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FIG. 3

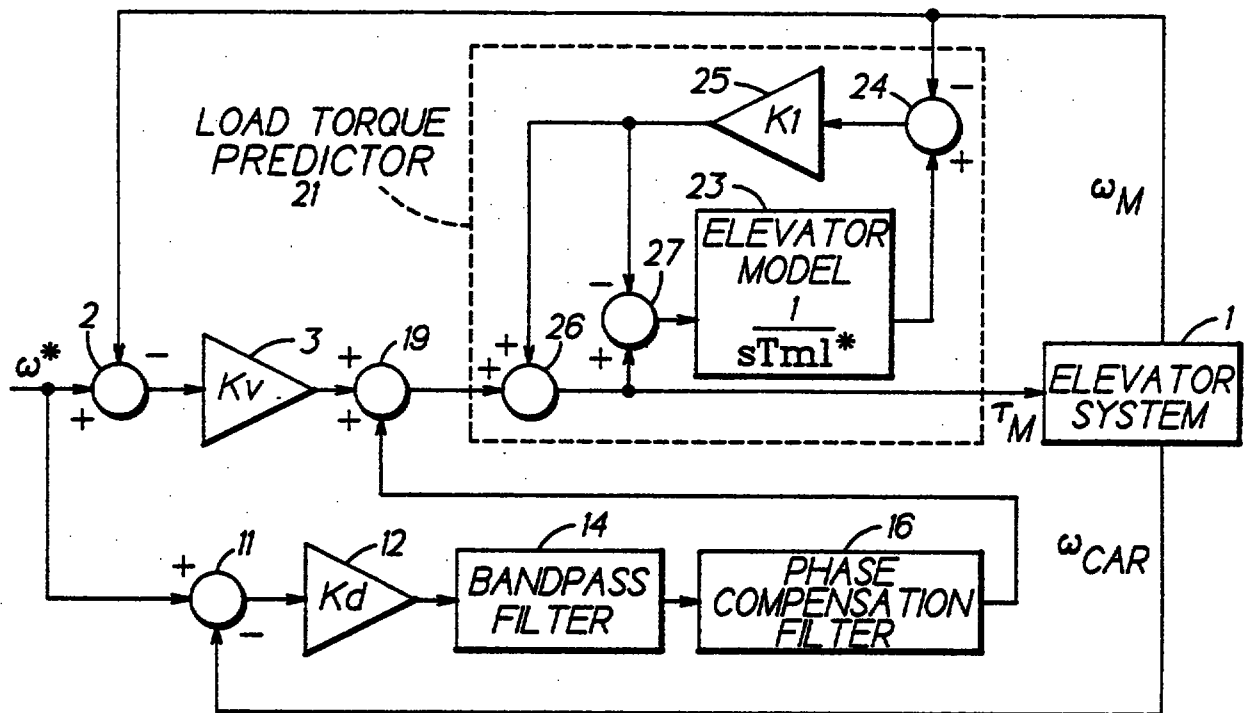
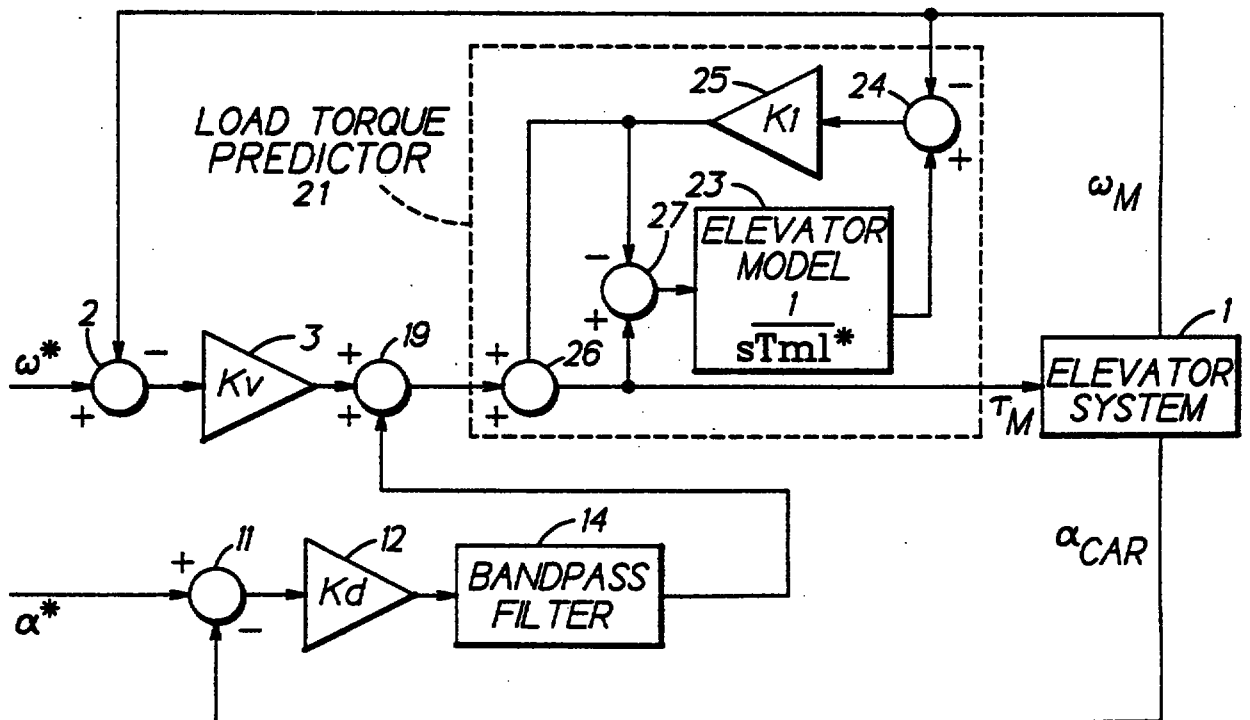


FIG. 4



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FIG. 5

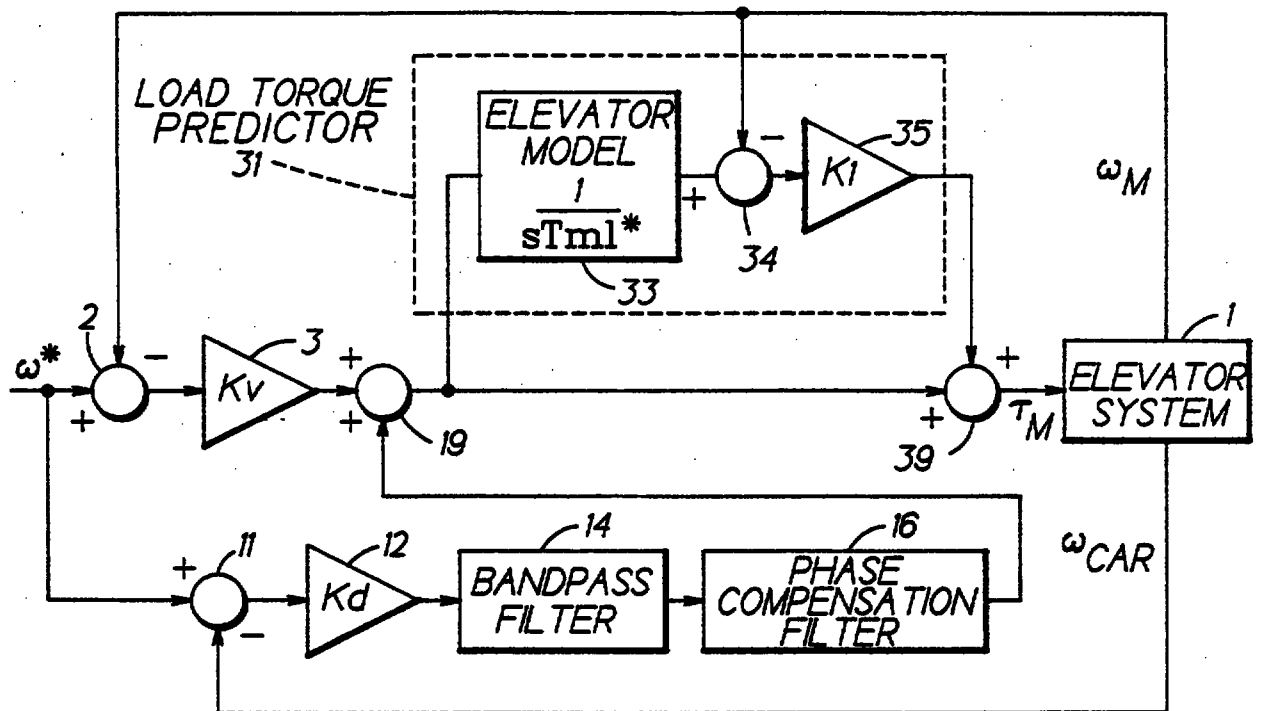


FIG. 6

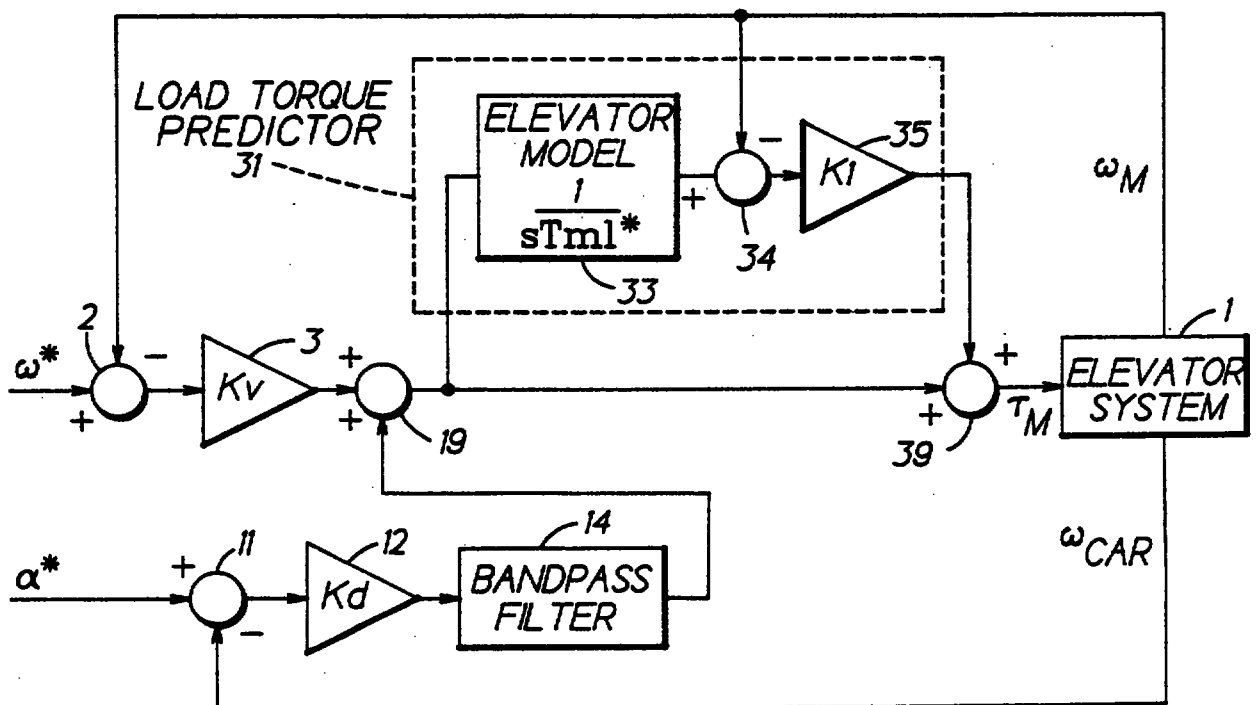
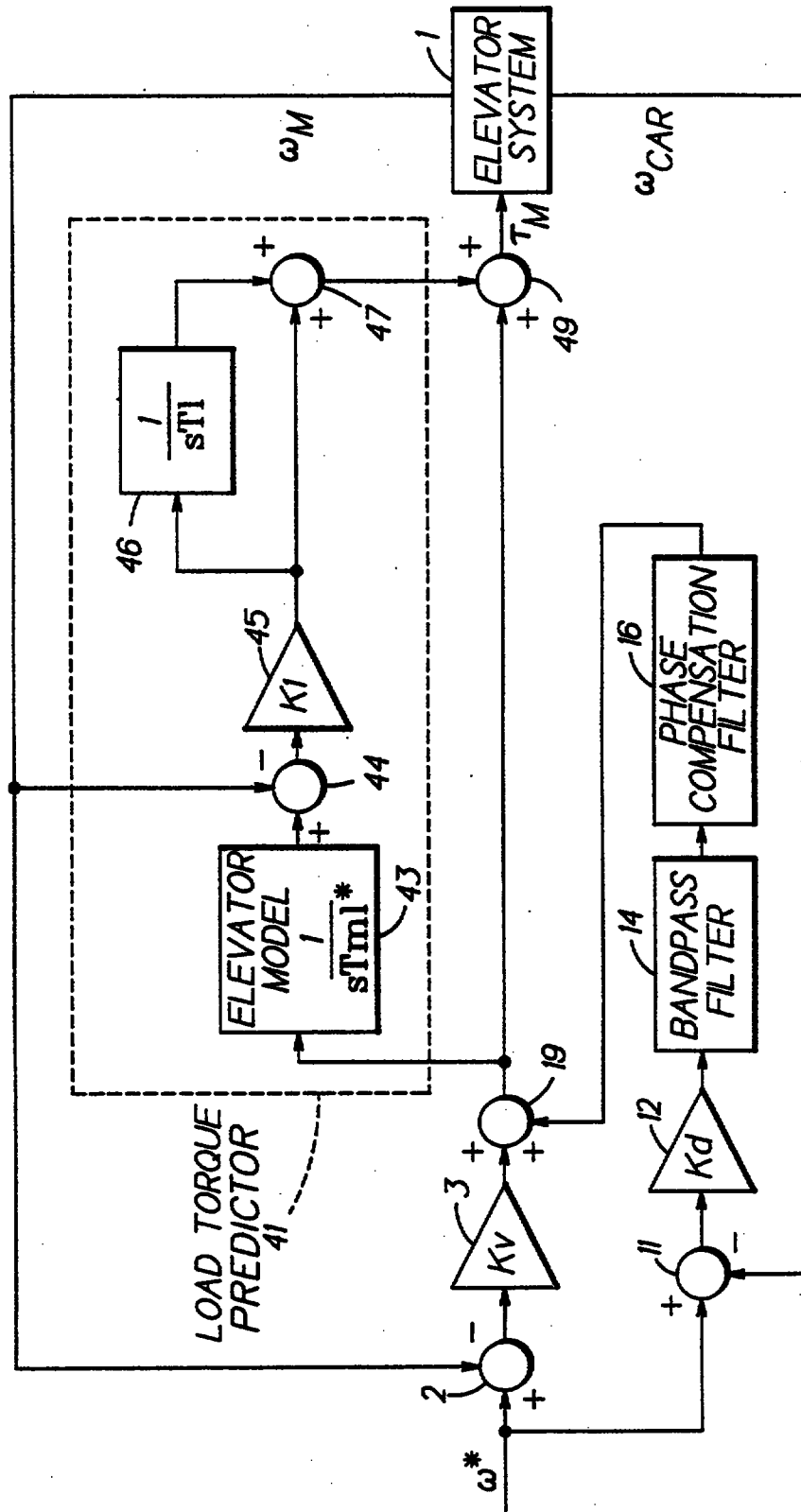


FIG. 7



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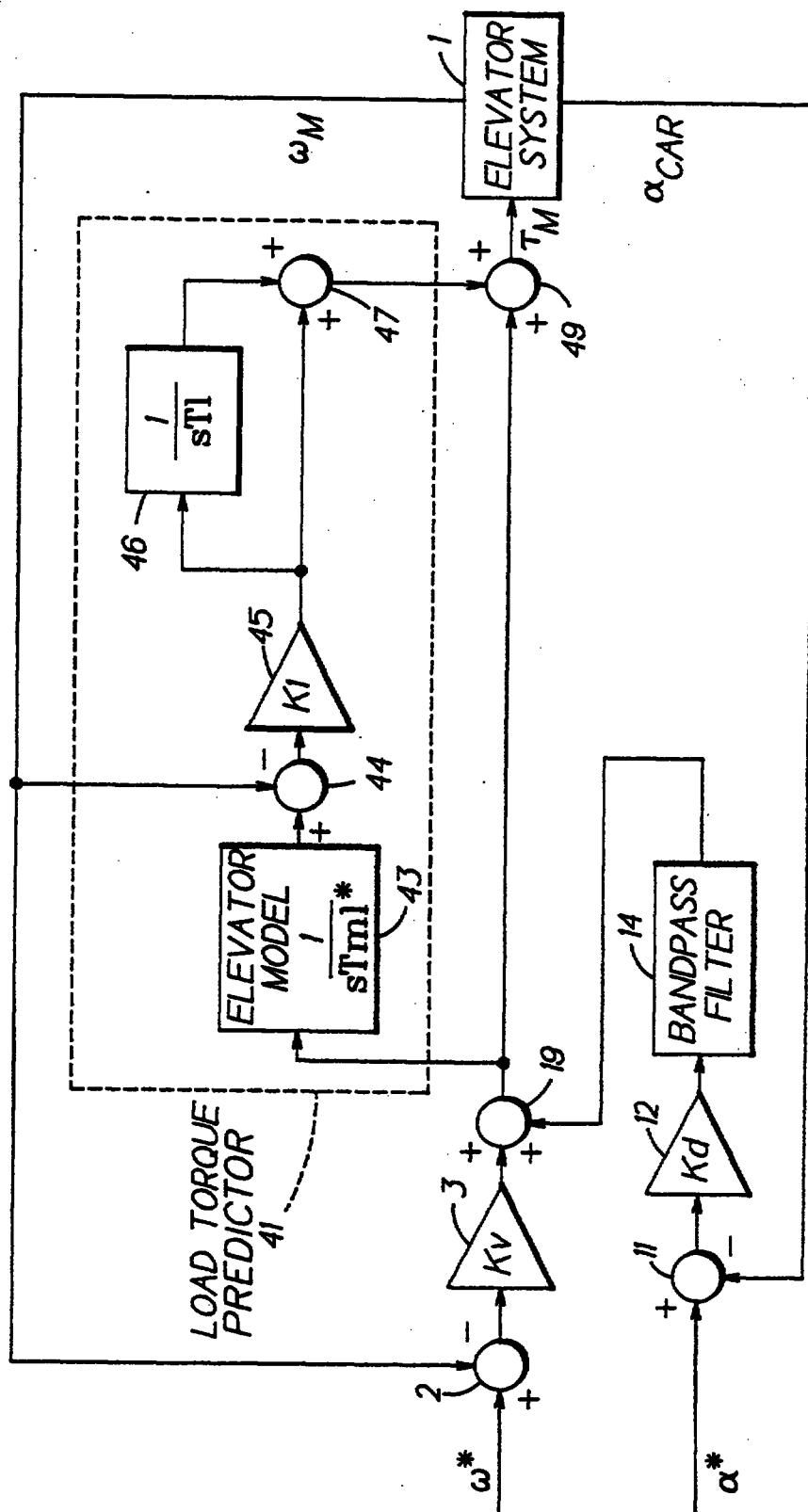
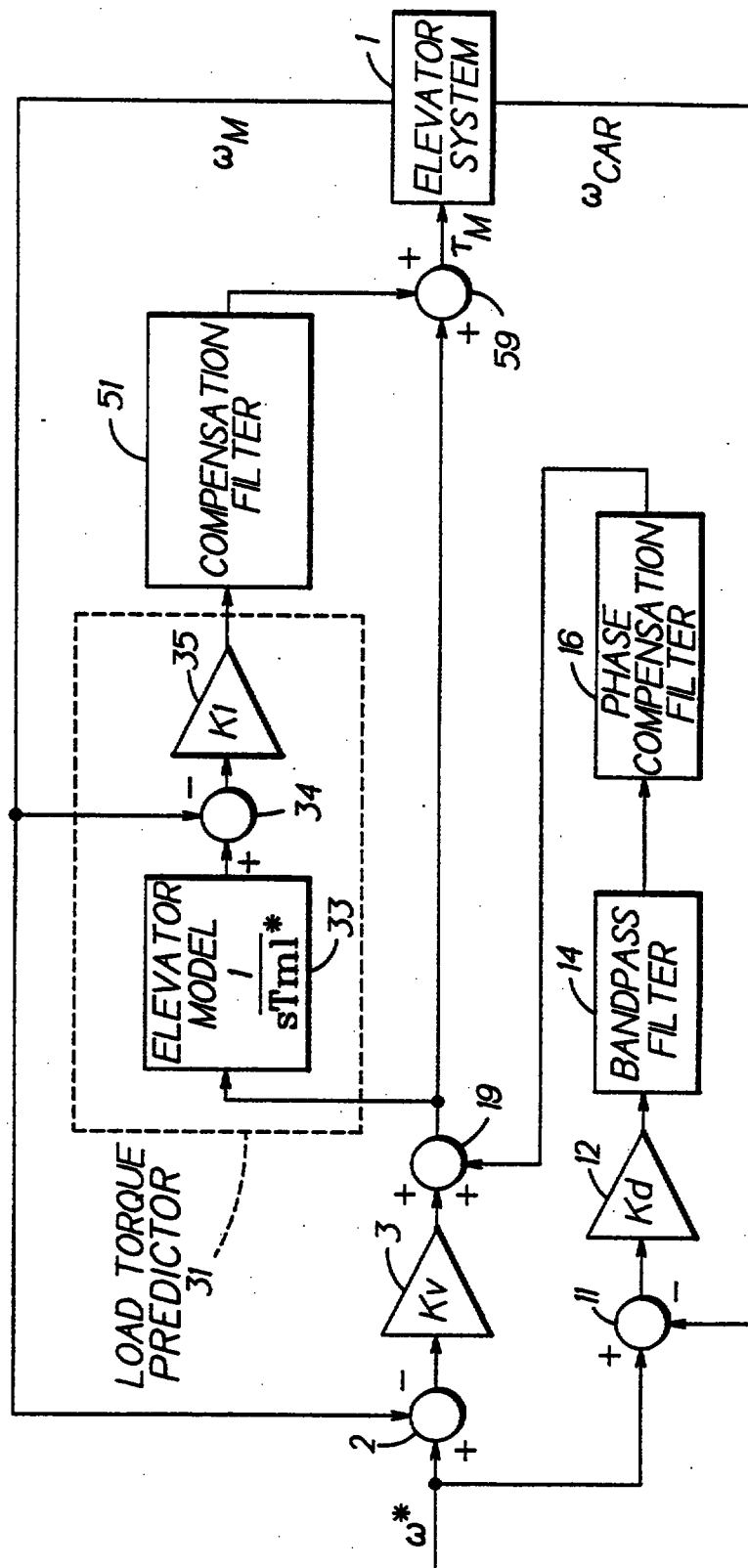


FIG. 8

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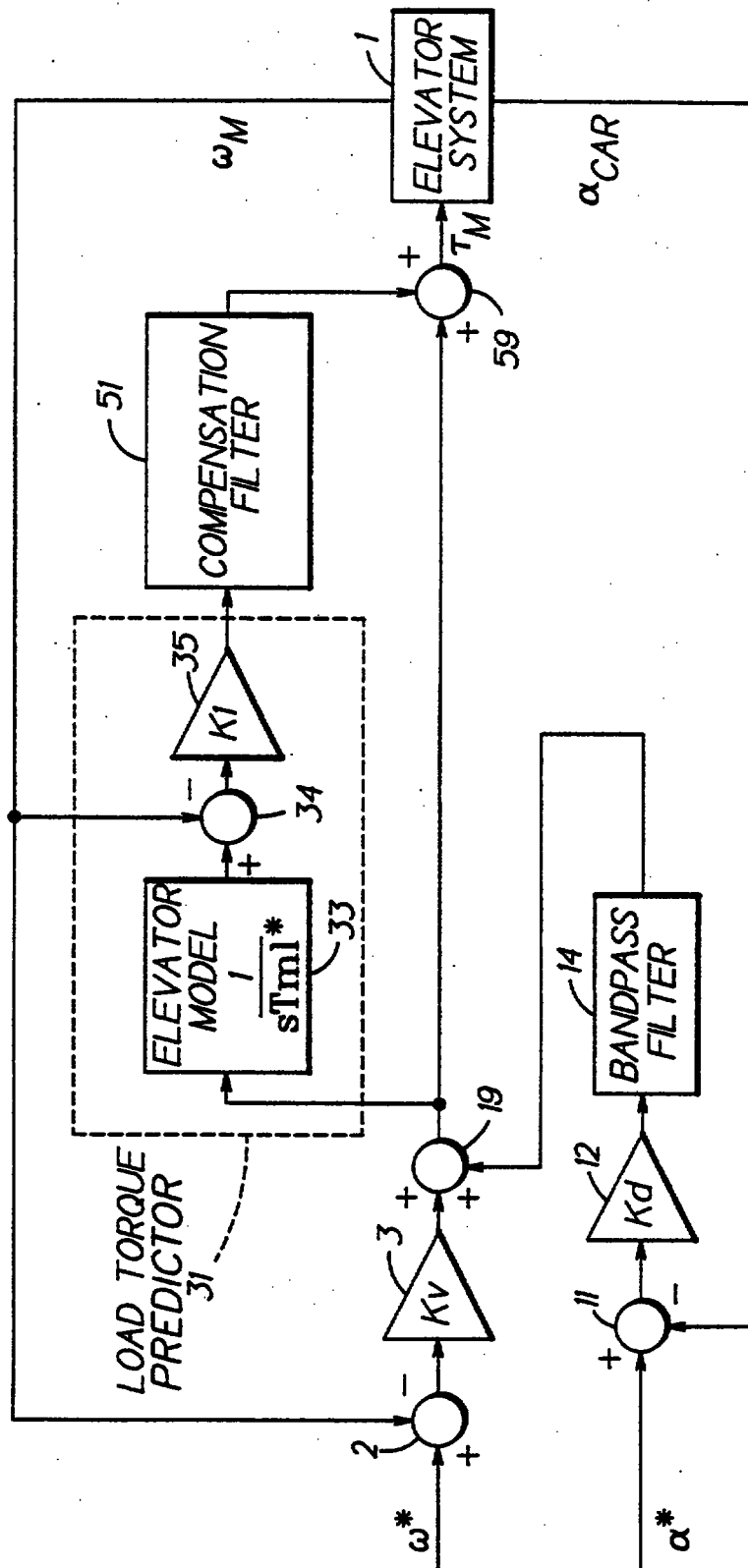


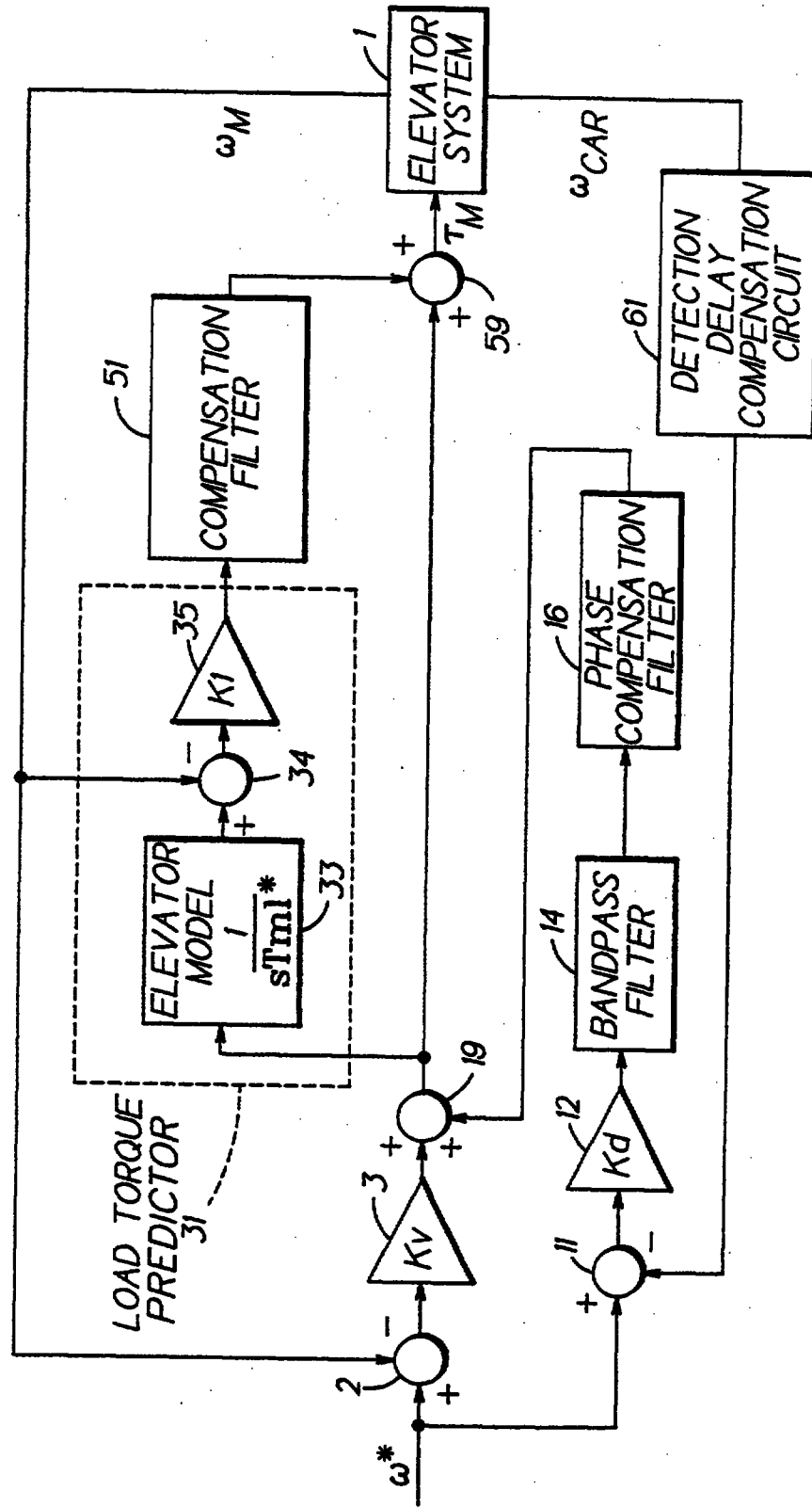
FIG. 10

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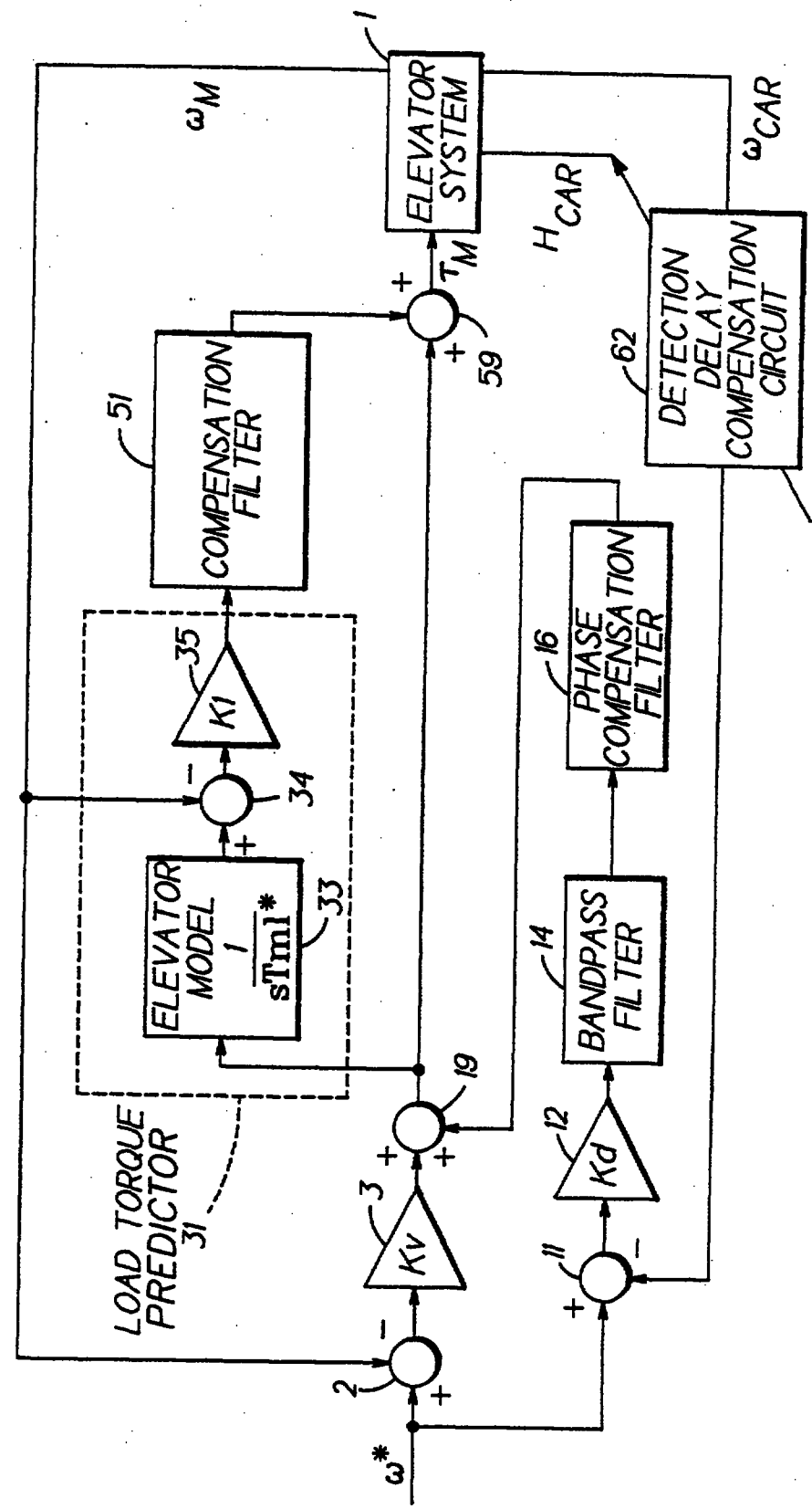
FIG. 11



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FIG. 12



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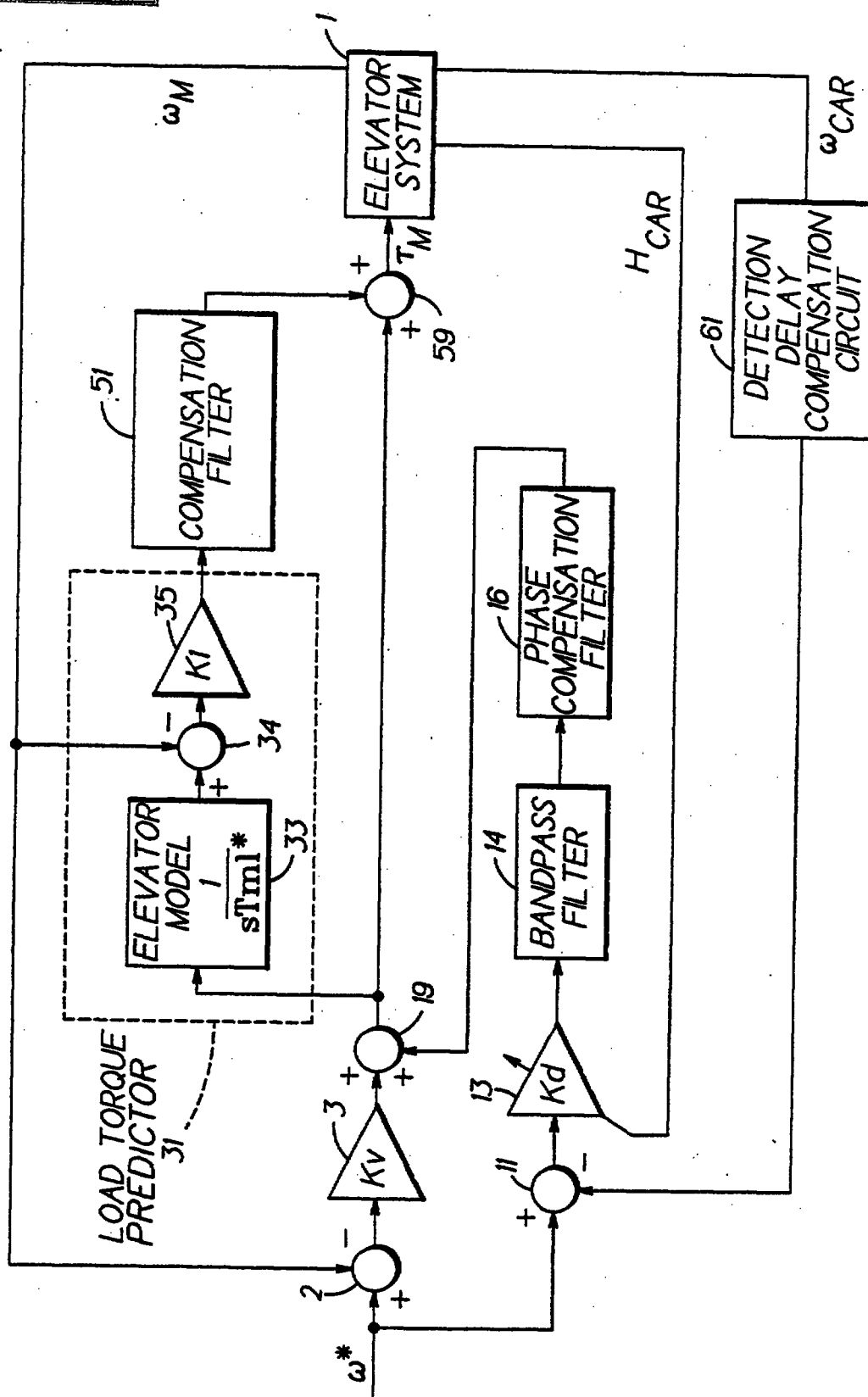


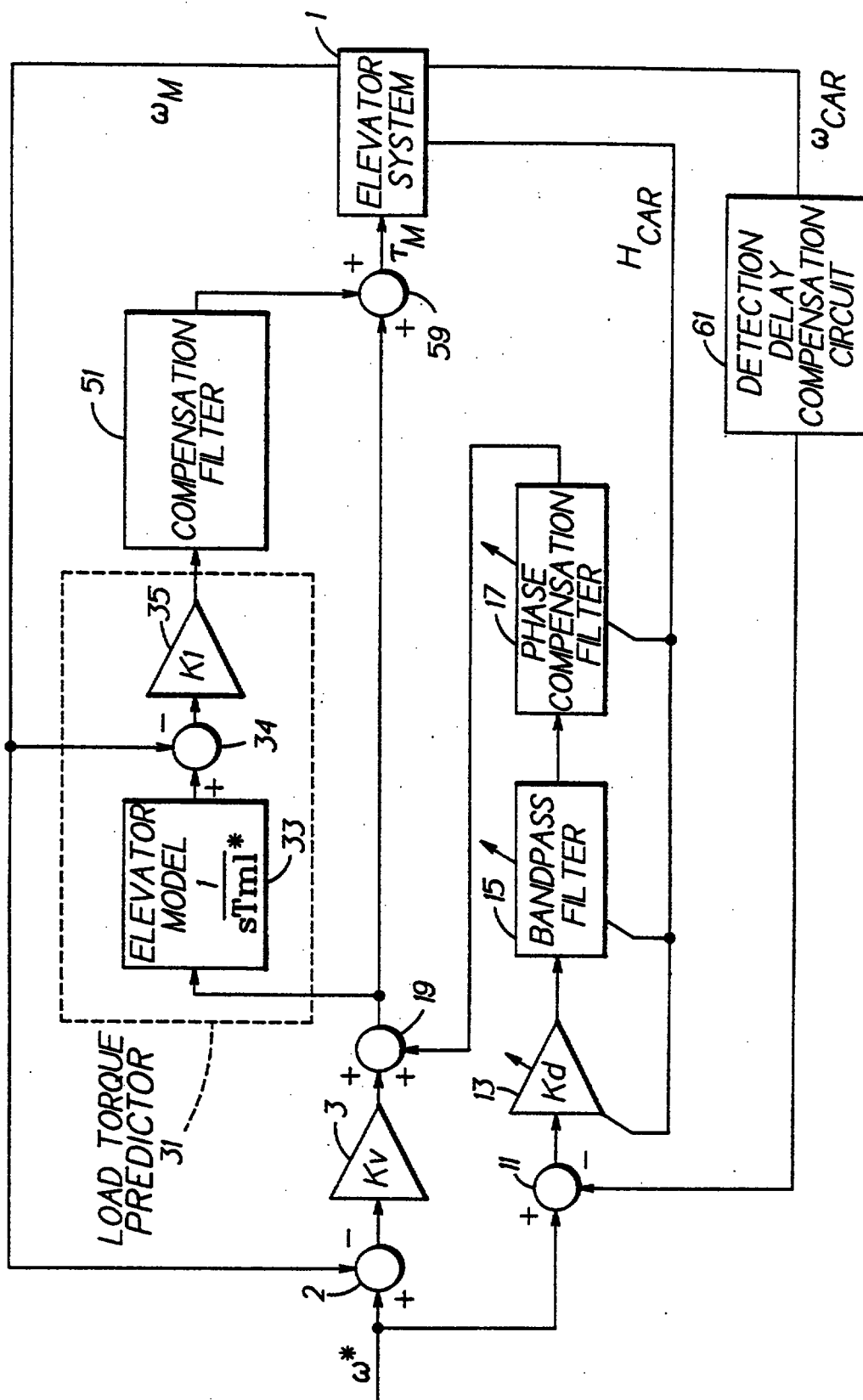
FIG. 13

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FIG. 14



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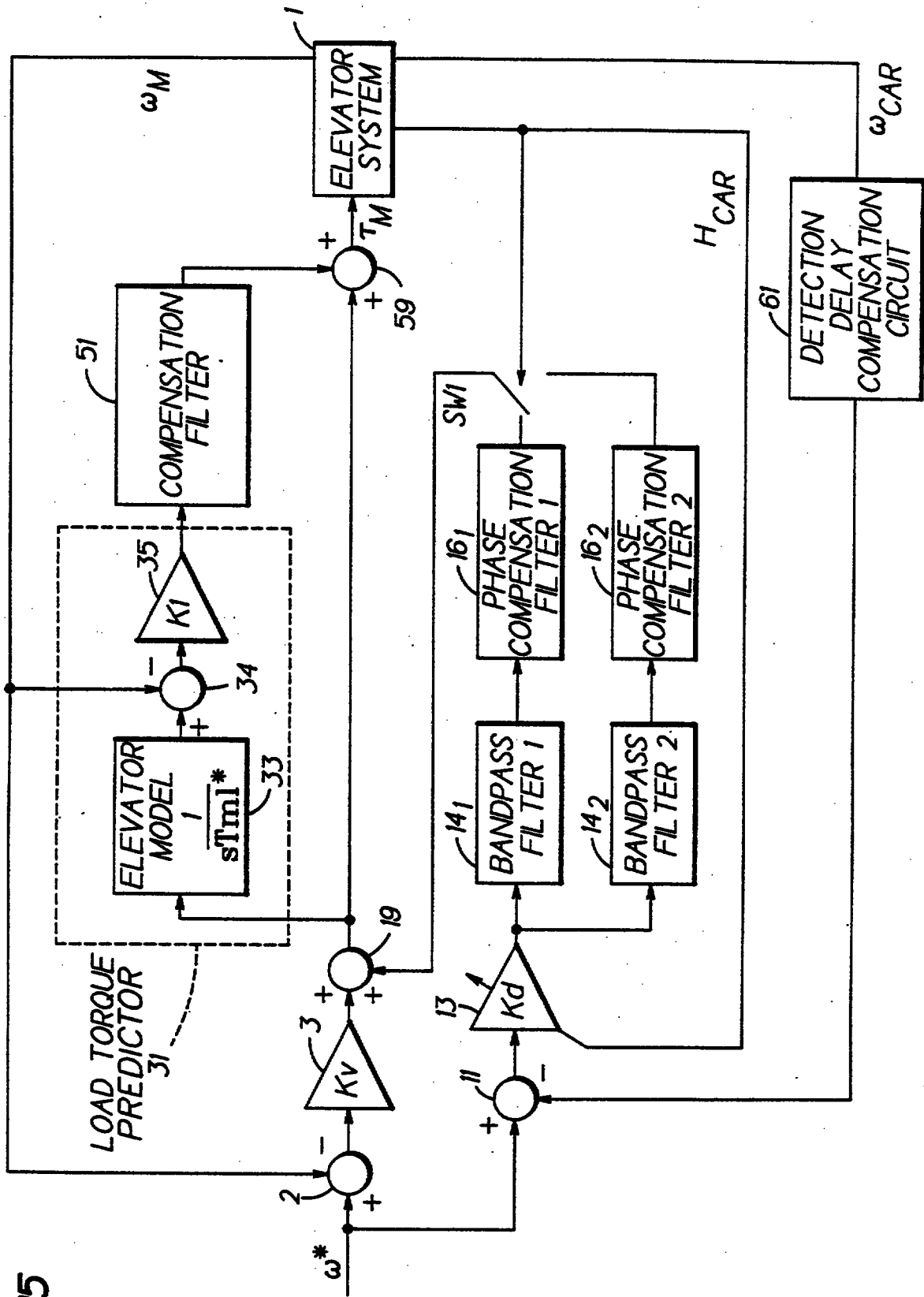


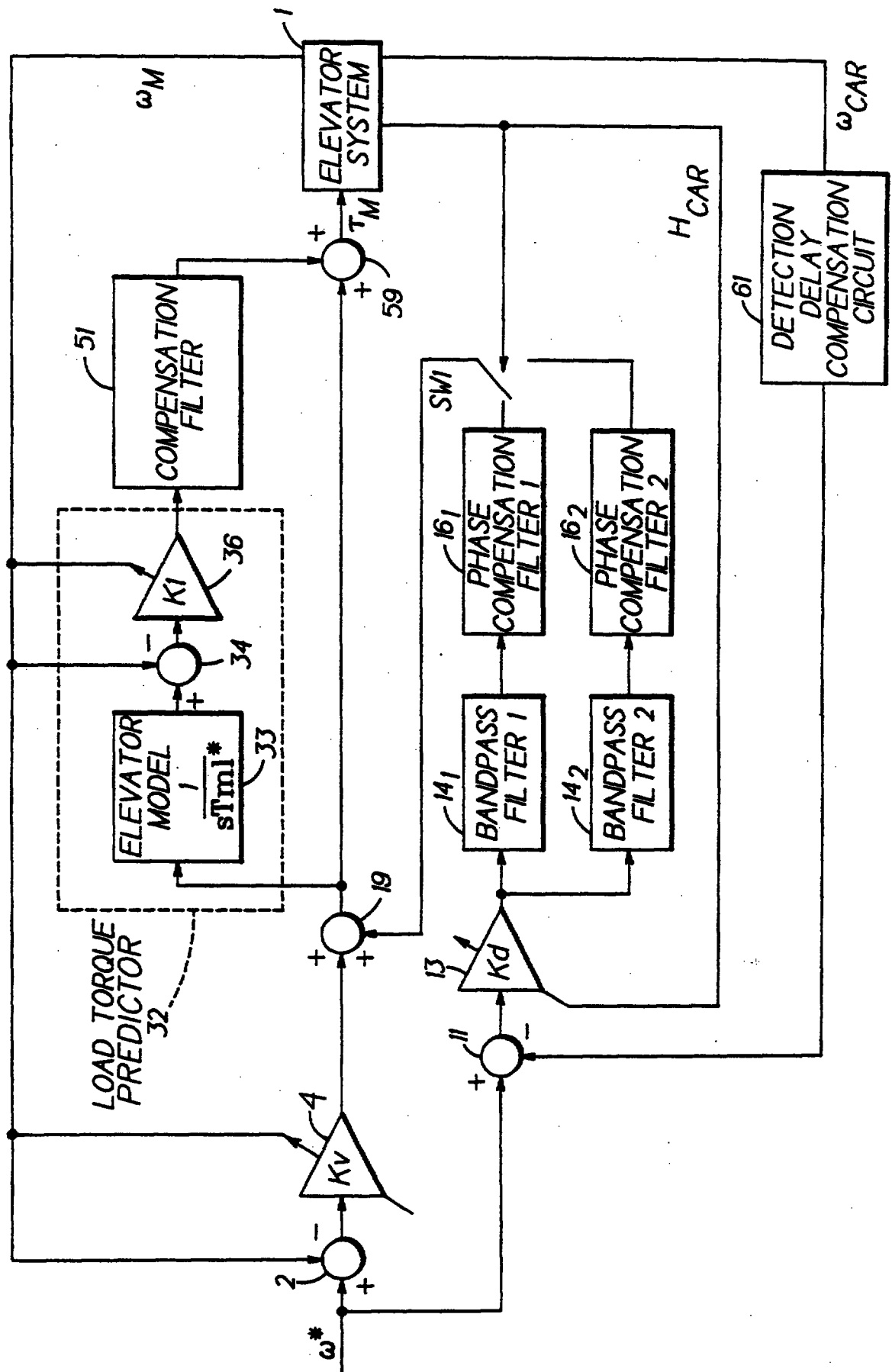
FIG. 15

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FIG. 16



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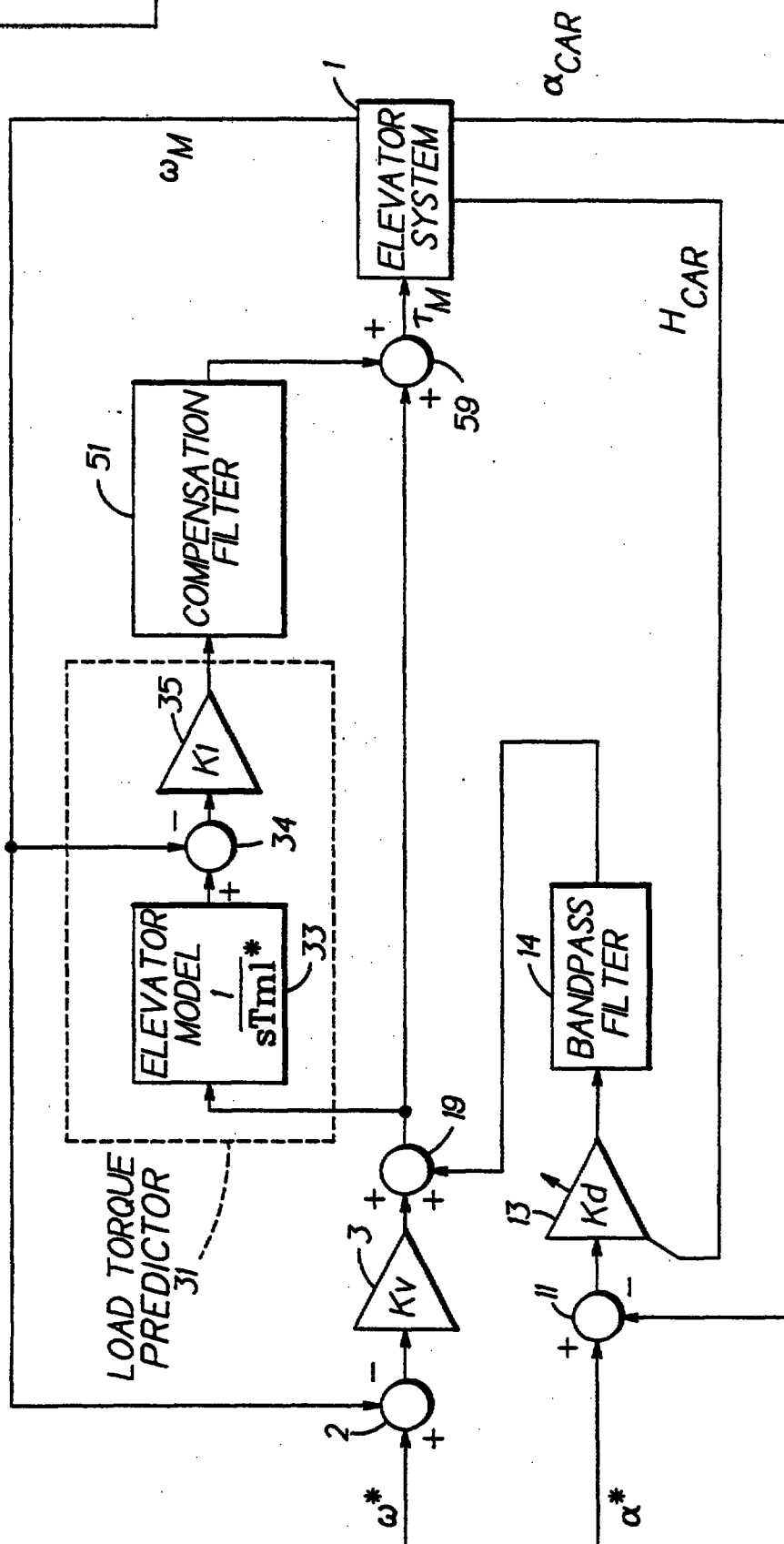


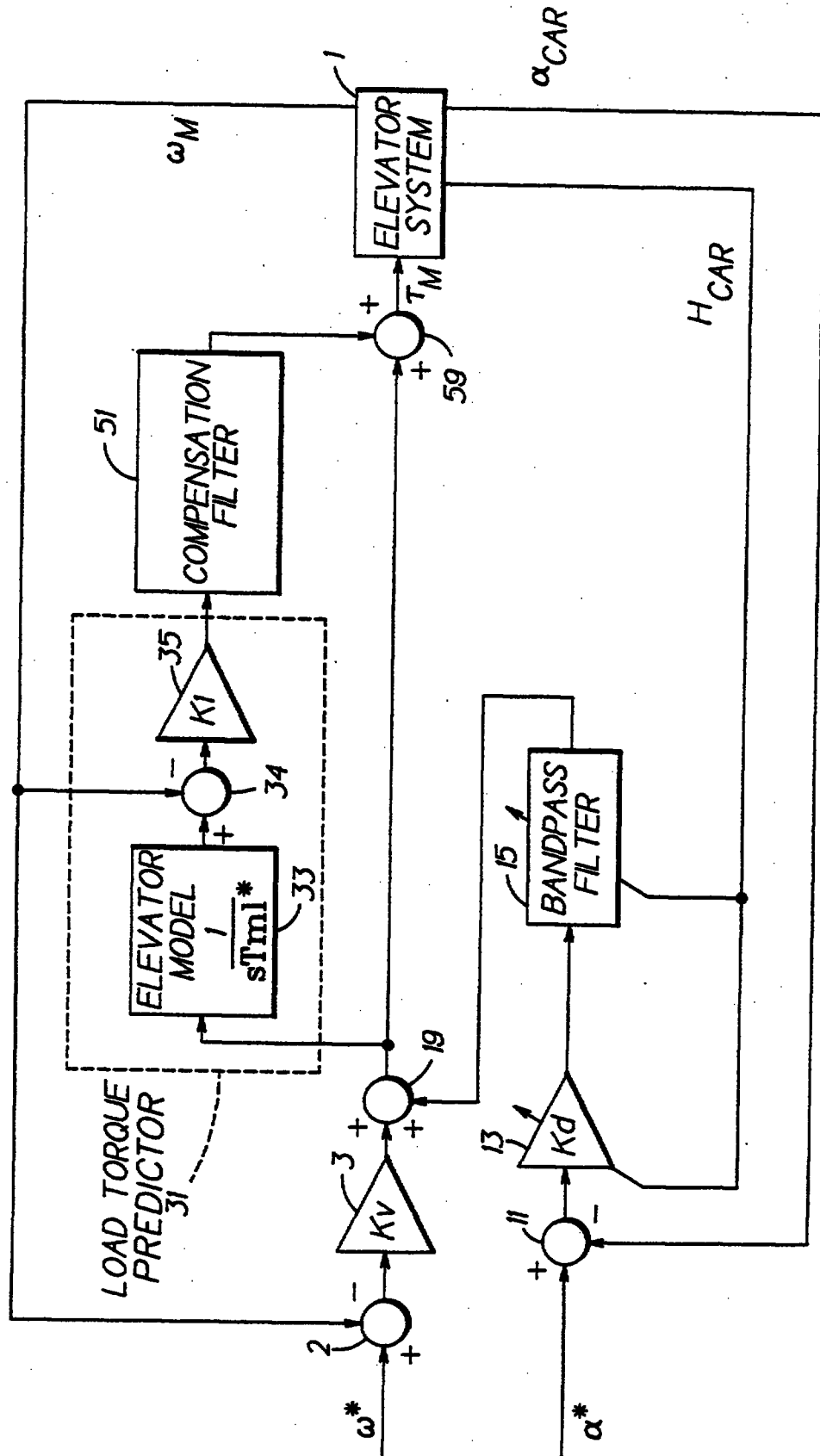
FIG. 17

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FIG. 18



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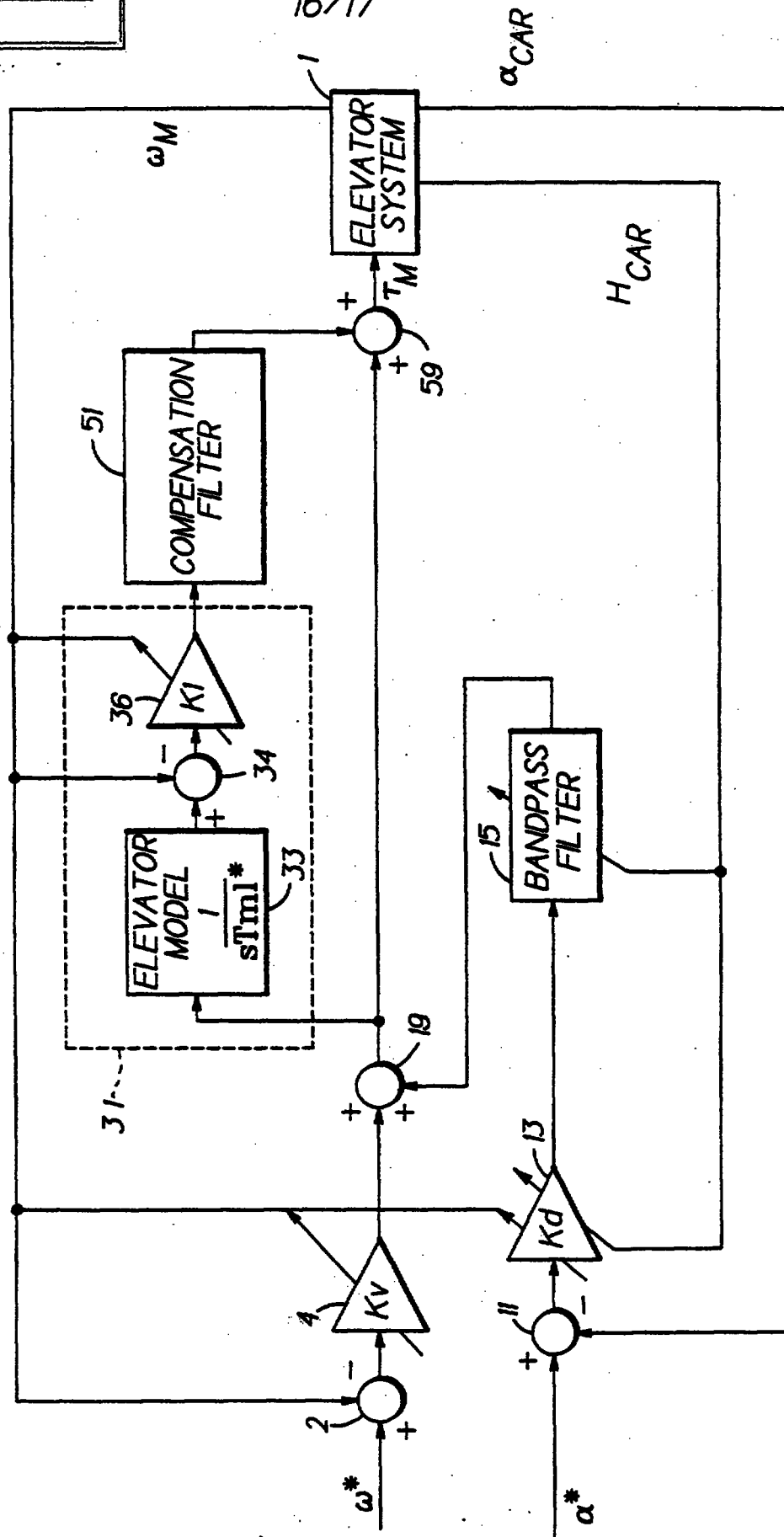


FIG. 19

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FIG. 20
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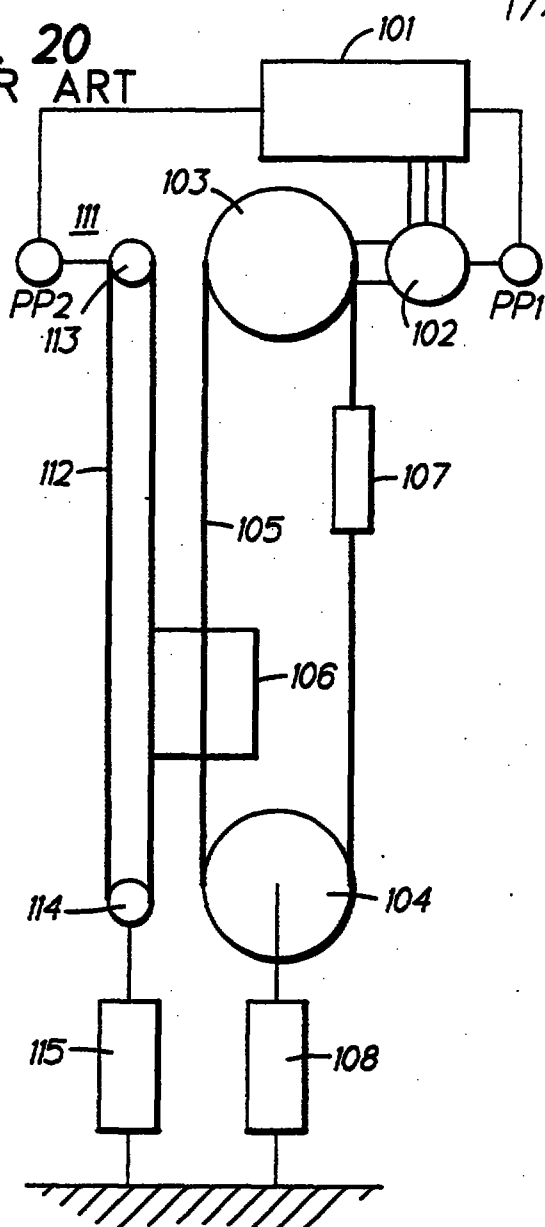


FIG. 21
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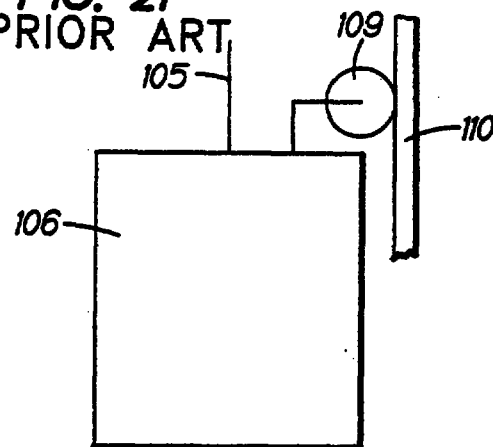


FIG. 22
PRIOR ART
BALANCING WEIGHT

