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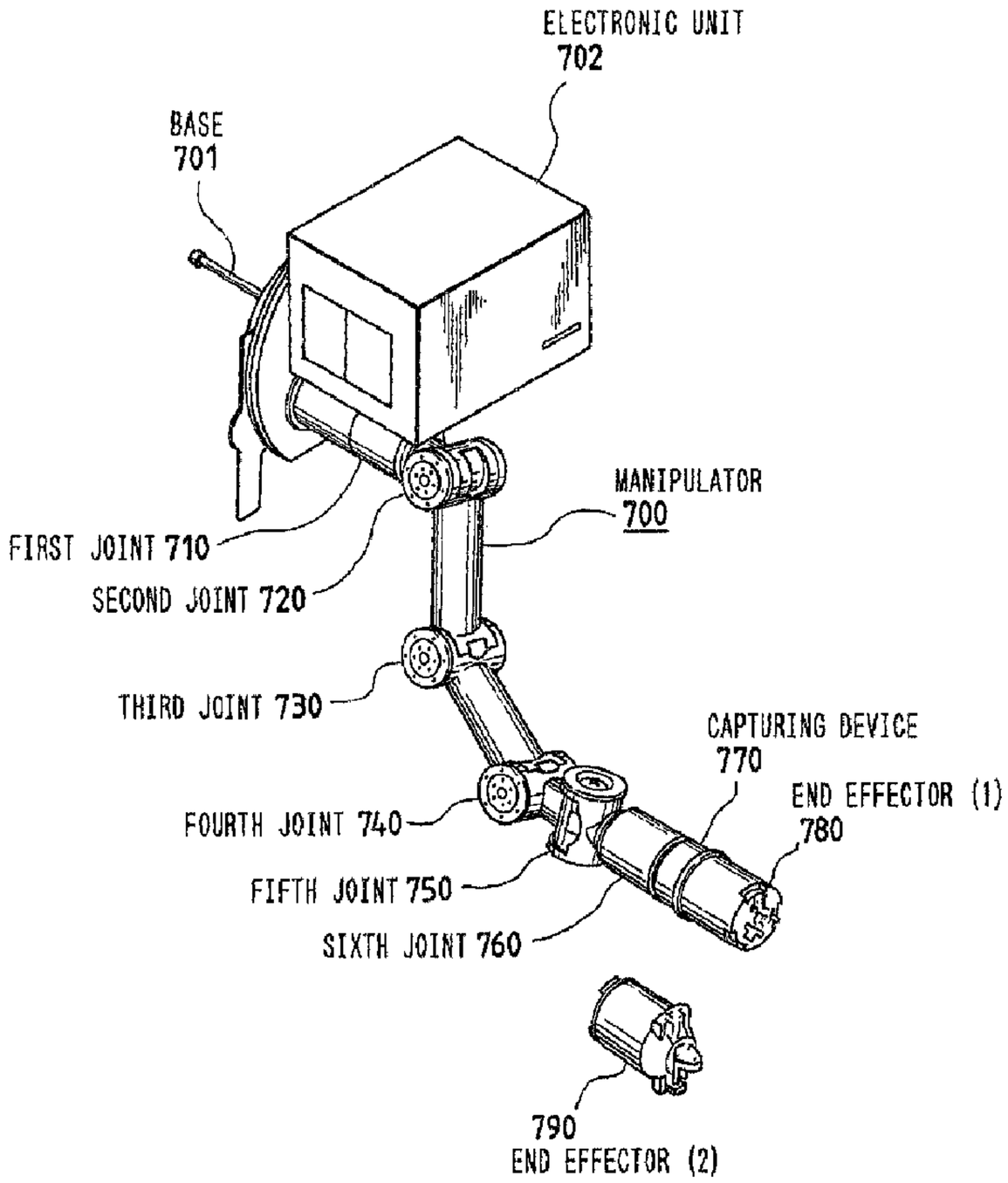


(57) Abrégé/Abstract:
A manipulator has its efficiency and reliability raised by reducing the size and weight of the system by means of a backup by a common specification drive circuit and actuator when a fault occurs. The actuator of an end effector is made so as to have a common structure with the actuators of the multiple joints, their being driven by a common specification drive unit. Two systems which can be switched are provided in the actuator of the end effector and additionally a spare drive unit is provided.

Abstract

A manipulator has its efficiency and reliability raised by reducing the size and weight of the system by means of a backup by a common specification drive circuit and actuator when a fault occurs. The actuator of an end effector is made so as to have a common structure with the actuators of the multiple joints, their being driven by a common specification drive unit. Two systems which can be switched are provided in the actuator of the end effector and additionally a spare drive unit is provided.

# MANIPULATOR

This invention relates to a manipulator that can work in special environments, such as space, with improved reliability.

A conventional space employed manipulator, as mentioned in the Japanese Patent Application Laid-Open No. 64-17102, has been equipped with actuators whose specifications differ between the joints, the mechanism and electronic unit not being made redundant.

Because, in the above mentioned conventional technology, the actuator specification differs between the joints, individual joints need to be produced according to each different specification. This caused the problem that the man-hours for procurement, processing and testing of each part and the associated costs were increased.

Further, because each joint requires individual redundancy, spare joints are not interchangeable, despite a complete (double) redundant composition.

The purpose of the present invention is to avoid the above mentioned disadvantages, reduce the man-hours for design, procurement of parts, processing and testing, while providing a manipulator having a high economic efficiency and improved reliability.

In accordance with one aspect of the present invention there is provided a manipulator, comprising: a plurality of joints each having a joint actuator; said joint actuators having at least one of the same structure and mechanism as one another; an end effector having an end effector actuator coupled to an end of the manipulator, wherein said end effector actuator has one of the same structure and mechanism as said one of said structure and mechanism of said joint actuator; drive units for driving the joint actuators and the end effector actuator; a controller for controlling said drive units; and a spare drive unit that is interchangeable

with the drive units for driving the joint actuators and the end effector actuator, and a redundancy selector for selecting and allocating the drive units to the actuators of said plurality of joints and the actuator of said end effector from among said drive units for driving the joint actuators and said end effector actuator, and said spare drive unit.

In accordance with another aspect of the present invention there is provided a manipulator, comprising: a first joint having a first actuator; a second joint having a second actuator that is interchangeable with the first actuator, and drive means for driving the first or second actuator, selectively; an end effector incorporating a third actuator having one of at least the same structure and mechanism as the first actuator, and selective means for driving said first or third actuator, selectively; and a spare drive means interchangeable with the respective drive means for driving the first, second and third actuator, and a redundancy selector controller for selecting and allocating any of the respective drive means to the joint and end effector actuators from among the drive means of said joint and end effector actuators, and said spare drive means; wherein the respective drive means for driving the first and second actuators of said first and second joints are interchangeable with the drive means for driving the third actuator of said end effector.

The individual joints and actuator of the end effector of this invention configured as described above have a common structure and/or mechanism, and are driven by a common drive unit, so that when trouble occurs, that drive unit is replaced with a reserve drive unit.

The maximum output current for each drive unit can be changed corresponding to the actuator allocated.

The end effector can be provided with two actuator systems, and when trouble occurs, replaced.

In the drawings:

Fig. 1 is a layout of an embodiment of a manipulator according to the invention;

Fig. 2 illustrates another configuration of this manipulator;

Fig. 3 illustrates a configuration of a joint actuator of this manipulator;

Fig. 4 illustrates yet another configuration of the manipulator;

Fig. 5 shows the physical appearance of the manipulator;

Fig. 6 is a diagram comparing the reliability of the manipulator of this invention with that of a conventional manipulator; and

Fig. 7 illustrates an embodiment of a redundancy selector circuit.

The overall configuration of the manipulator according to the preferred embodiment of this invention is shown in Fig. 5 which shows a manipulator 700 provided with the first to sixth joints 710, 720, 730, 740, 750 and 760, an end effector 780 or 790 mounted on a capturing device 770 at the tip of the manipulator which is fixed to a base 701.

When the end effector 780(1) is replaced by the other end effector 790(2), the end effector (1) is released by the capturing device 770 which is transferred to the end effector (2) position to mount it.

An electronic unit 702 incorporates an actuator drive circuit for the first to sixth joints 710-760 and the end effectors 780, 790.

In Figure 5, the end effectors (1) and (2) have a common configuration and can be driven by a common drive circuit, since the individual joints are common.

Fig. 1 is a block diagram of a first embodiment of the invention and illustrates the individual control elements of the manipulator shown in Fig. 5.

A controller 100 determines an instruction value for the individual joints 710 - 760 and the end effector (1), and outputs to drive units 101 - 107 for the first to sixth joints and the end effector (1) respectively.

The actuator in the first joint 710 incorporates an angular velocity sensor 111, a motor 112 and a reduction gear 113. The signal from the angular velocity sensor 111 is fed into the first joint drive unit 101 and is used for control. The actuators of the second to sixth joints and the end effector are the same as those of the first joint.

Referring to Fig. 1, the individual drive units 101 - 107 are made common and the individual actuators 110 - 170 are made common. Thus the individual drive units 101 - 107 are interchangeable, as are also the individual actuators 110 - 170.

Consequently, when the actuator 170, for example, of the end effector (1) is in trouble, it is replaced with a common spare actuator to continue operation.

If the drive unit 106 is in trouble, the drive unit 107 is used instead, and the manipulator tip is moved to the desired position by means of the sixth joint. The drive unit 107 is then switched to the end effector actuator 170. Hence, since the individual drive units are common, the sixth joint 760 and the end effector actuator 170 can be driven successively by the drive unit 107. As a result, if drive unit 106 is in trouble, such an emergency can be overcome. Subsequently, the drive unit in trouble is replaced with a common spare drive unit.

Fig. 2 is the block diagram of a second embodiment of the invention and illustrates the individual elements of a manipulator 700 that has seven degrees of freedom and is mechanically provided with a redundant system.

A controller 200 determines an instruction value for each joint and for the end effector (1), and outputs to individual drive units 201 to 207 that drive the first to seventh joint actuators 210 to 270.

The first joint actuator incorporates an angular velocity sensor 311 and a motor 312 as the above mentioned redundant system, in addition to an angular velocity sensor 211, a motor 212 and a reduction gear 213. When the angular velocity sensor 211 or the motor 212 is in trouble, a redundancy selector 208 replaces the angular velocity sensor 211 and the motor 212 with the angular velocity sensor 311 and the motor 312. This redundant system operates in the same manner for actuators 220 to 270 of the second to seventh joints, the actuators 210 to 270 of the individual drive units 201 to 207 of the first to seventh joints being made common.

Fig. 3 illustrates another configuration of a redundant system for the individual joints shown in Fig. 2.

In Fig. 3, an angular velocity sensor 411 and a motor 412 for the first system and an angular velocity sensor 511 and a motor 512 for the second system are provided in a single joint, and these first and second systems can be coupled with reduction gear speed reducer 414 by means of clutches 413 and 513.

For example, if the angular velocity sensor 411 and the motor 412 of the first system are coupled with the reduction gear 414 by means of the clutch 413, while the second system is separated from the reduction gear 414 by means of the clutch 513, the clutch 413 is separated from the speed reducer 414 when trouble occurs in the first system, so that the clutch 513 is coupled with the speed reducer 414 to actuate the second system.

The configuration shown in Fig. 3 is effective for achieving a countermeasure against an accident such as when the shaft of the motor 412 sticks due to a lubrication problem.

Fig. 4 illustrates the configuration of another embodiment of this invention having the above mentioned redundant system.

A control system 600 determines a command value for actuators 610 to 670 of the first to seventh joints and actuates the drive units 601 to 608. The drive unit 608 is a spare unit and drive units 601 to 608 and joint actuators 610 to 670 are made common.

Of these drive units, seven are utilized to correspond to the seven joint actuators, and, when one of them is in trouble, it is changed over to the remaining one. 681 and 682 are redundancy switch units or selectors for this switching. Selector 681 selects seven of the eight drive units 601 to 608, connecting a signal from the controller 600, and the selector 682 supplies each output of the selected seven controllers to the joint actuators 610 to 670 of each joint. 680 is a redundancy selector controller for controlling the operation of the selectors 681 and 682.

Because the required current differs depending on the joint, the individual drive units 601 to 608 are equipped with a current limiter 691 to 698, which restricts the output current of each drive unit selected by the redundancy selector controller 680.

Assuming that the reliability of the drive units 601 to 608 shown in Fig. 4 is "r" and that of the section including the redundancy selector controller 680, and redundancy selectors 681 and 682, is also "r", the entire reliability $\lambda_1$ of Fig. 4 is given by the expression (1).

$$\lambda_1 = r^8 + {}_8C_1 \times (1 - r) \times r^7 \qquad (1)$$

Because of the individual drive units of the conventional system are not common, a spare drive unit must be installed on each drive unit. Thus the number of spare drive units increases to 7, compared with the one spare drive unit shown in Fig. 4.

The entire reliability $\lambda_2$ of this conventional system is given by the expression (2).

$$\lambda_2 = \left\{1 - (1 - r)^2\right\}^7 \qquad (2)$$

In case no redundant system is provided, the reliability $\lambda_3$ is given by the expression (3).

$$\lambda_3 = r^7 \qquad (3)$$

Fig. 6 shows a comparison of the above equations (1) and (2). Assuming "r" to be 0.9, the system reliability $\lambda_1$ of the embodiment shown in Fig. 4 is improved to 0.81, while the system reliability when no spare is provided is $\lambda_3 = 0.47$, and the system reliability $\lambda_2$ of the conventional system equipped with seven spare units is about 0.93.

If, assuming r = 0.9, the number of spare units shown in Fig. 4 is increased to 2, $\lambda_1$ becomes 0.96, exceeding the above mentioned $\lambda_2$ value. Namely, this invention makes it possible to secure a system reliability equal to or higher than the conventional double redundancy system using a smaller number of spare units.

Fig. 7 illustrates an embodiment of a redundancy selector for realizing the redundant system, in which two drive units and two joint actuators are provided together with a spare drive unit. The following description relates to the case shown in Fig. 4.

A redundancy selector controller 680 obtains the number of the drive unit to be switched, the numbers preliminarily allocated to the drive units 601 to 602, together with a switch action permission signal 820 from the controller 600, and sets an instruction value to redundancy selectors 681 and 682, and the limit level of the current limiter of the drive units 601 and 602, and controls the operation sequence. The current limit level can be selected by a preliminarily allocated number corresponding to the current limit value of

each drive unit, and entering this limit number in the drive unit enables the current limit level to be switched. The limit number is set in the redundancy selector controller 680 corresponding to the number of drive units 601 and 602.

According to the number of the drive unit to be switched on line 823 from the redundancy selector controller 680, the redundancy selector 681 selects an instruction value from the controller 600 for the drive unit to be switched, and inputs it into the spare drive unit 608 by means of a selector unit 803.

A redundancy selector controller 682 consists of selector units 801 and 802, and according to the switch object number on line 822 from the redundancy selector controller 680, a selector unit 802 connects the output signal of the angular velocity sensors 810 to 811 of the joint to be switched to the spare drive unit 608. Also the selector unit 801 switches the output of the spare drive unit 608 electrically for the drive signal for an actuator corresponding to the drive unit to be switched.

A redundancy selector controller 680 controls the states of the redundancy selectors 681 and 682 in the following order. First, to avoid run-away of a joint upon switching due to a failure of a drive unit output stop instruction from the controller 600, it generates an output stop instruction 821 for the drive unit to be switched and stops driving of the corresponding joint actuator. Next, to avoid an unstable condition of an input signal, its sets a value such to keep down any joint actuator to a spare drive unit. After that, the signal of the angular velocity sensor of the actuator corresponding to the drive unit to be switched is electrically connected to the spare drive unit 608 by means of the selector unit 802, and then the output of the spare drive unit 608 is electrically connected to the drive signal path by means of the selector unit 801, whereupon it outputs a redundancy

selection completion signal to the controller 600. Finally, an instruction value of the drive unit to be switched is input to the spare drive unit by means of the redundancy selector 681. This switch action sequence enables switching of a drive unit to a spare drive unit.

According to this invention, by making common the actuator of each joint and its drive circuit of the manipulator, the individual actuators can share the spare drive circuit, providing backup against a system fault. As a result, the number of spare drive units can be reduced, so as to reduce the size and weight of the system and simultaneously to improve the economic efficiency and reliability.

Further, each actuator and its drive circuit can be designed and produced according to a common specification, so that the design can be completed in a short term, thus reducing the man-hours for design, manufacturing and testing, and also the parts procurement man-hours and associated costs.

Claims:

1. A manipulator, comprising:

a plurality of joints each having a joint actuator;

said joint actuators having at least one of the same structure and mechanism as one another;

an end effector having an end effector actuator coupled to an end of the manipulator, wherein said end effector actuator has one of the same structure and mechanism as said one of said structure and mechanism of said joint actuator;

drive units for driving the joint actuators and the end effector actuator;

a controller for controlling said drive units; and

a spare drive unit that is interchangeable with the drive units for driving the joint actuators and the end effector actuator, and a redundancy selector for selecting and allocating the drive units to the actuators of said plurality of joints and the actuator of said end effector from among said drive units for driving the joint actuators and said end effector actuator, and said spare drive unit.

2. A manipulator according to claim 1, wherein at least one of the drive units for driving the joint actuators of said plurality of joints is interchangeable with the drive units for driving the end effector actuator of said end effector.

3. A manipulator according to claim 1, wherein said end effector actuator includes at least two actuator systems and a switch unit.

4. A manipulator according to claim 1, further including current limiters for changing a current limit value of the drive unit for the joint and end effector actuators.

5. A manipulator, comprising:

a first joint having a first actuator;

a second joint having a second actuator that is interchangeable with the first actuator, and drive means for driving the first or second actuator, selectively;

an end effector incorporating a third actuator having one of at least the same structure and mechanism as the first actuator, and selective means for driving said first or third actuator, selectively; and

a spare drive means interchangeable with the respective drive means for driving the first, second and third actuator, and a redundancy selector controller for selecting and allocating any of the respective drive means to the joint and end effector actuators from among the drive means of said joint and end effector actuators, and said spare drive means;

wherein the respective drive means for driving the first and second actuators of said first and second joints are interchangeable with the drive means for driving the third actuator of said end effector.

6. A manipulator according to claim 5, wherein the third actuator of said end effector has the same structure as the first and second actuators.

7. A manipulator according to claim 5, wherein said end third actuator includes at least two systems and a switch unit.

8. A manipulator according to claim 5, further comprising:

a capturing device at one end of the end effector, wherein one of said joints is coupled to said end effector through said capturing device.

FIG. 1

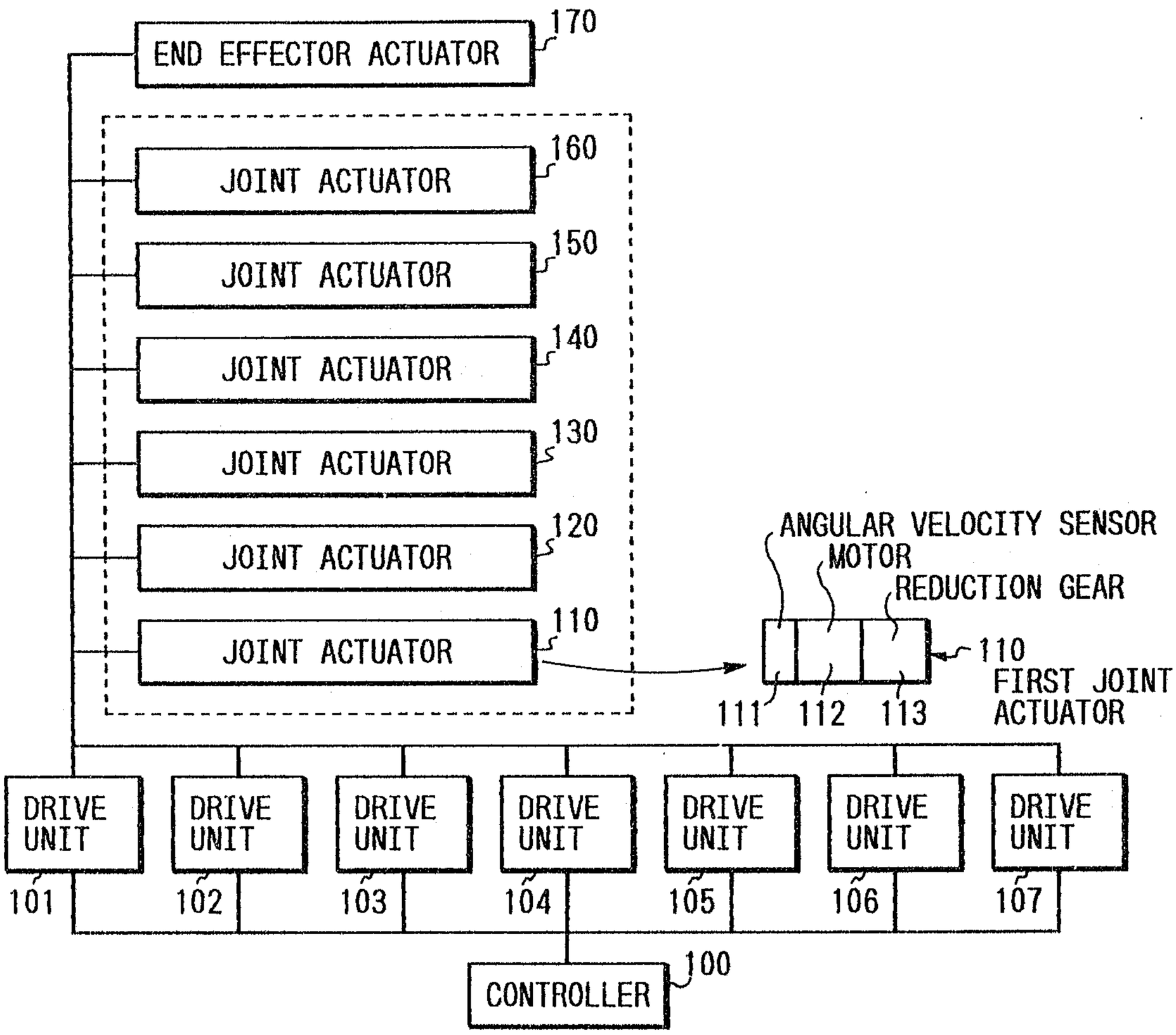
END EFFECTOR ACTUATOR
170
JOINT ACTUATOR
160
JOINT ACTUATOR
150
JOINT ACTUATOR
140
JOINT ACTUATOR
130
JOINT ACTUATOR
120
JOINT ACTUATOR
110
ANGULAR VELOCITY SENSOR
MOTOR
REDUCTION GEAR
110
FIRST JOINT ACTUATOR
111
112
113
DRIVE UNIT
101
DRIVE UNIT
102
DRIVE UNIT
103
DRIVE UNIT
104
DRIVE UNIT
105
DRIVE UNIT
106
DRIVE UNIT
107
CONTROLLER
100

FIG. 2

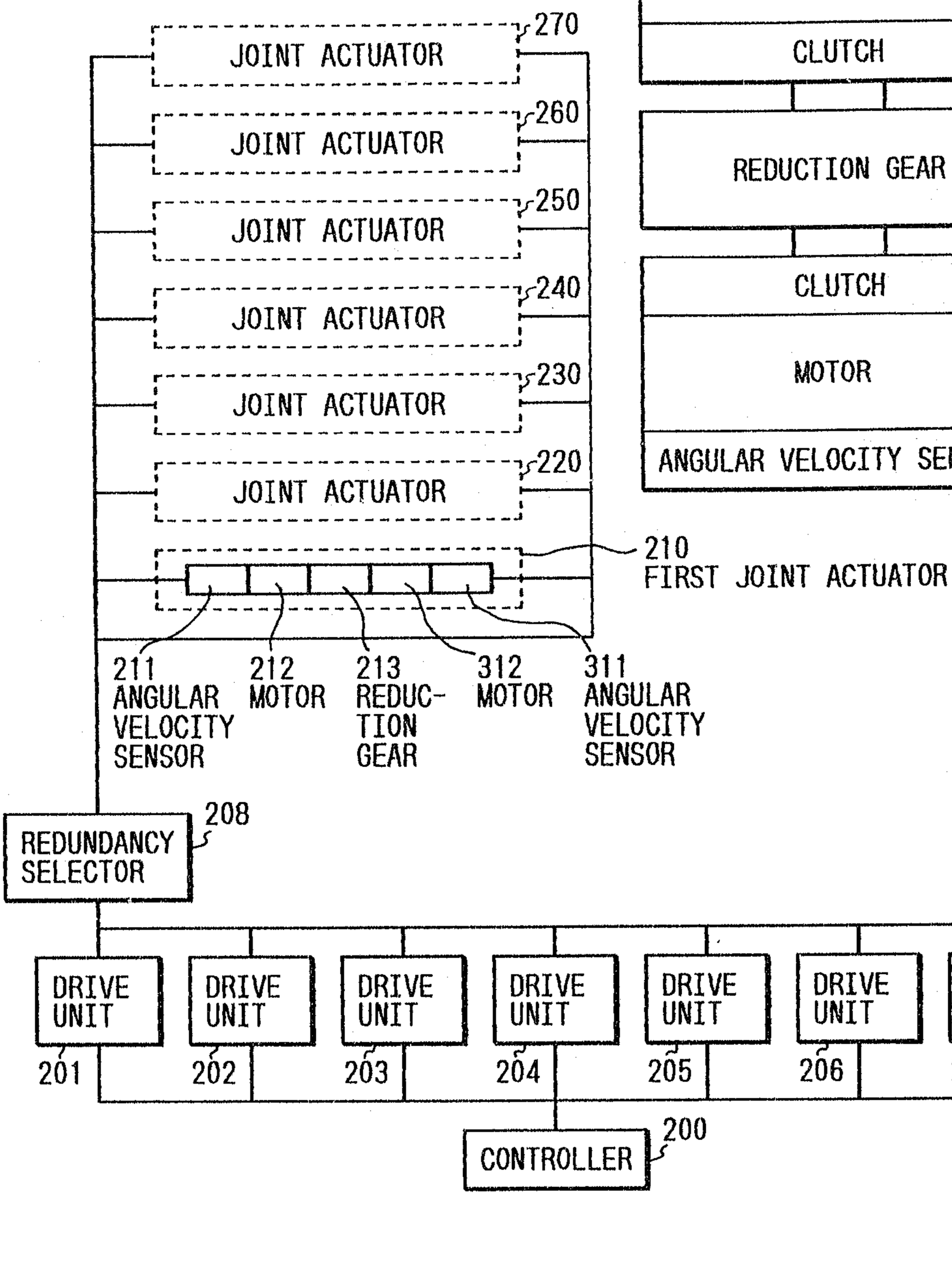


FIG. 3

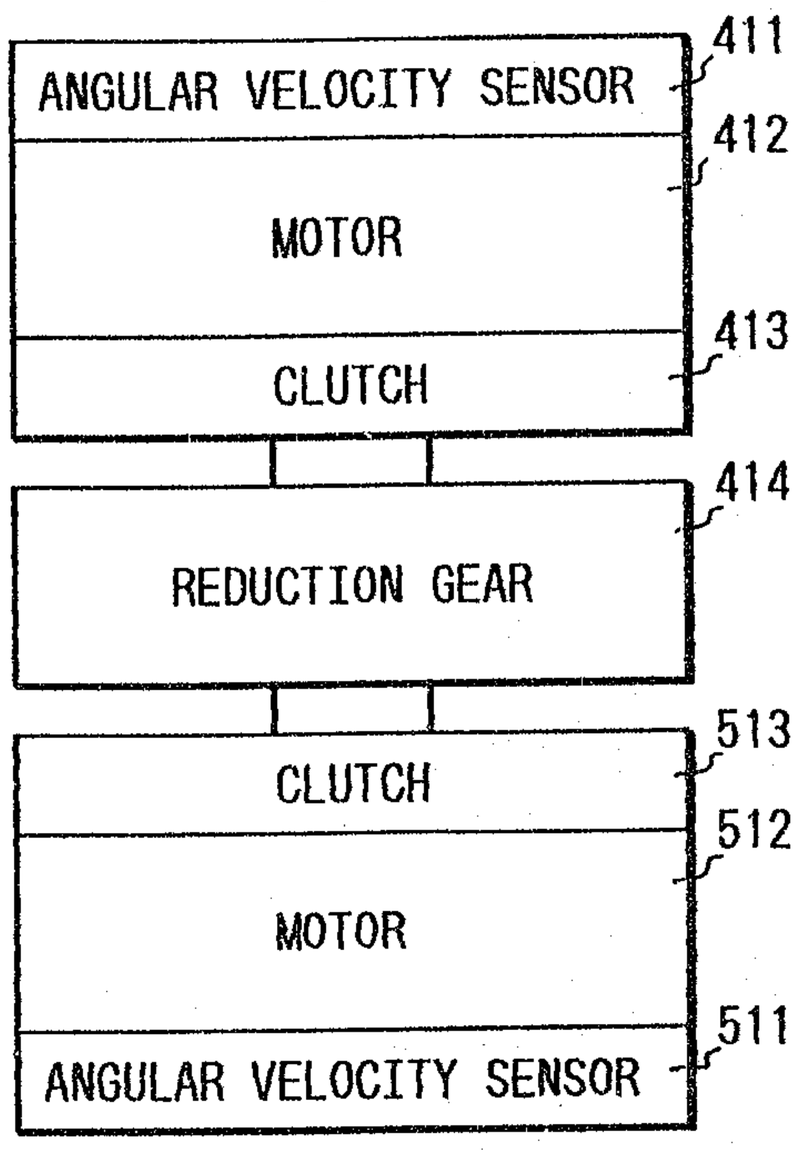


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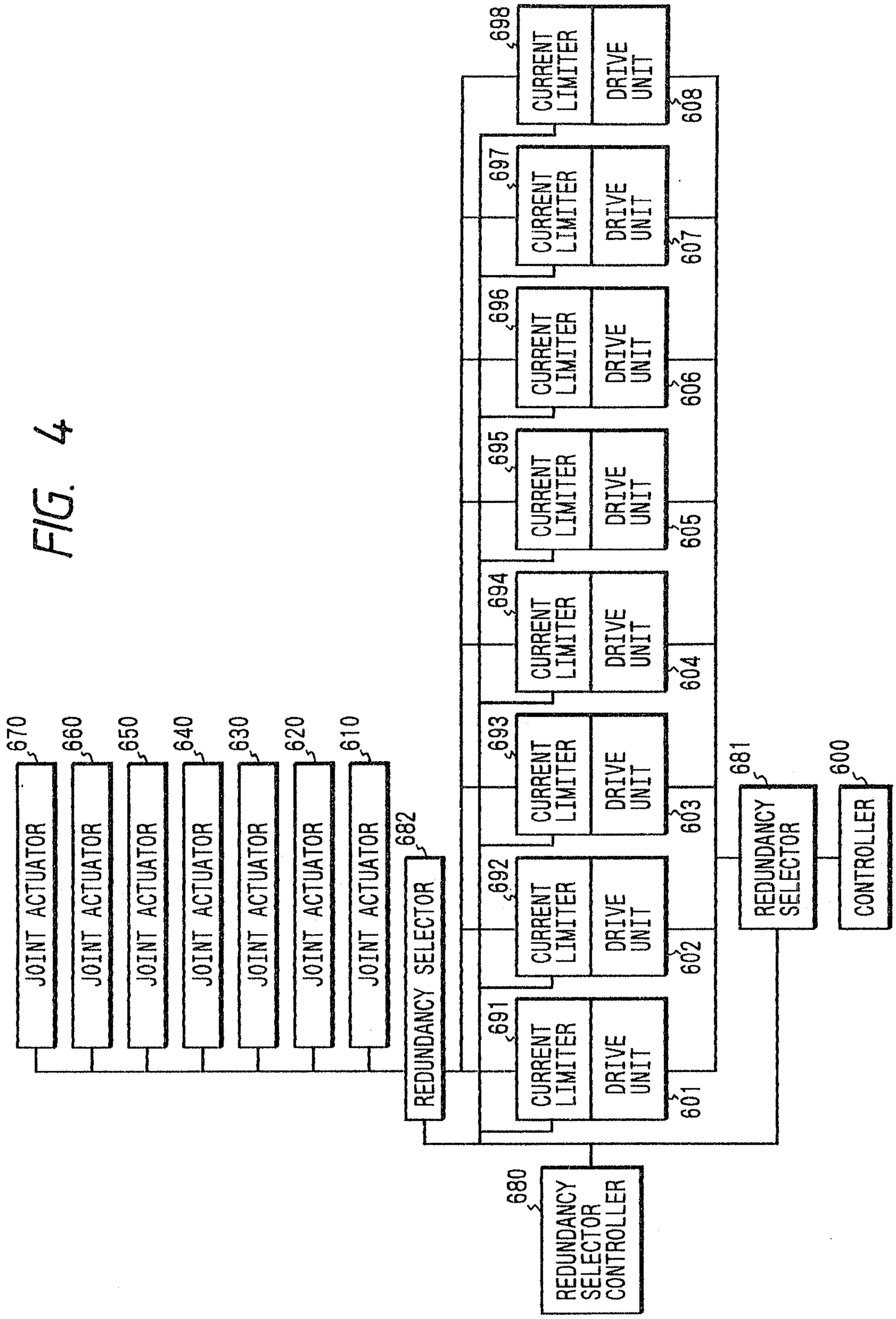
FIG. 4

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Baker & Potvin

FIG. 5

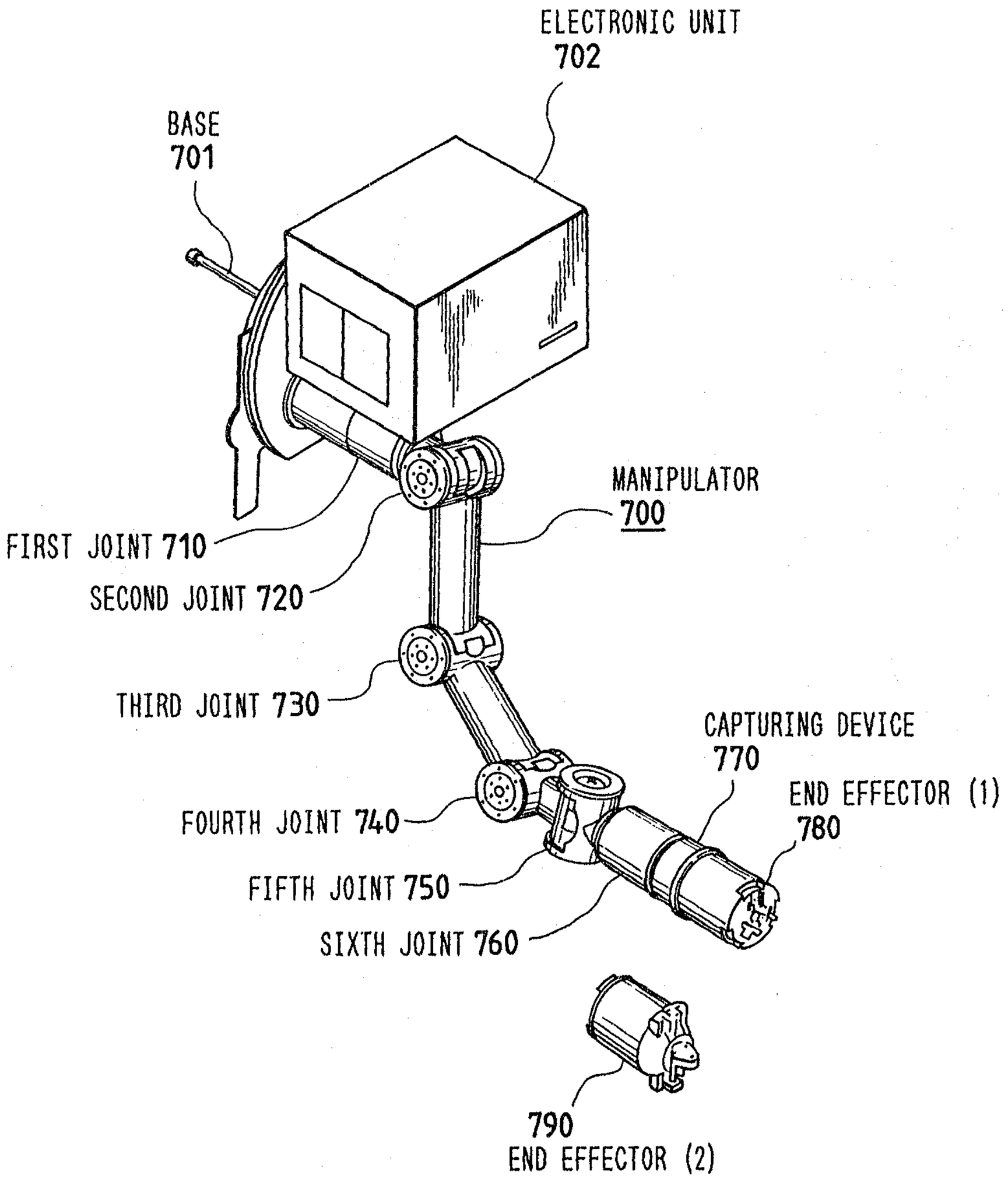

ELECTRONIC UNIT
702
BASE
701
MANIPULATOR
700
FIRST JOINT 710
SECOND JOINT 720
THIRD JOINT 730
CAPTURING DEVICE
770
END EFFECTOR (1)
780
FOURTH JOINT 740
FIFTH JOINT 750
SIXTH JOINT 760
790
END EFFECTOR (2)

FIG. 6

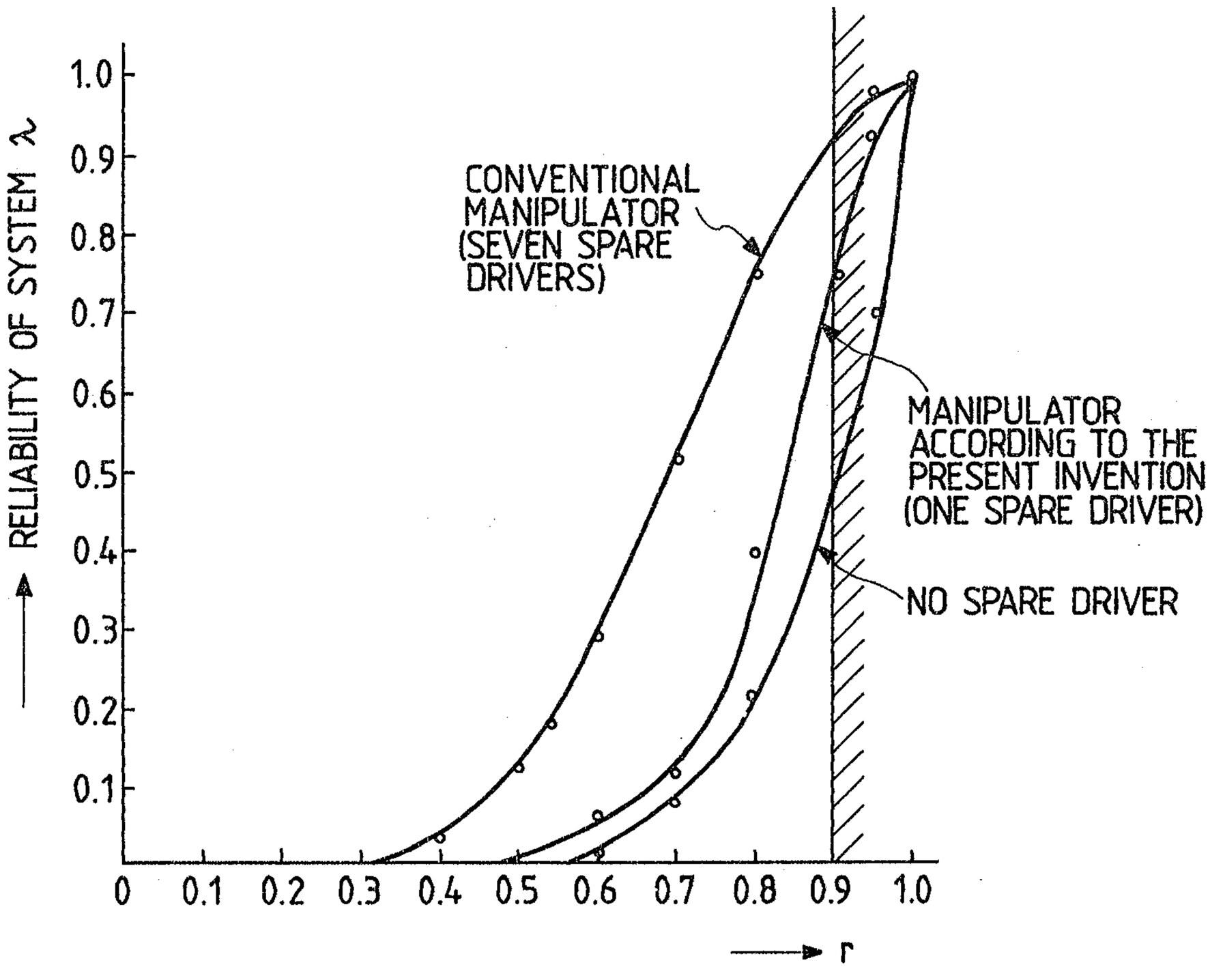
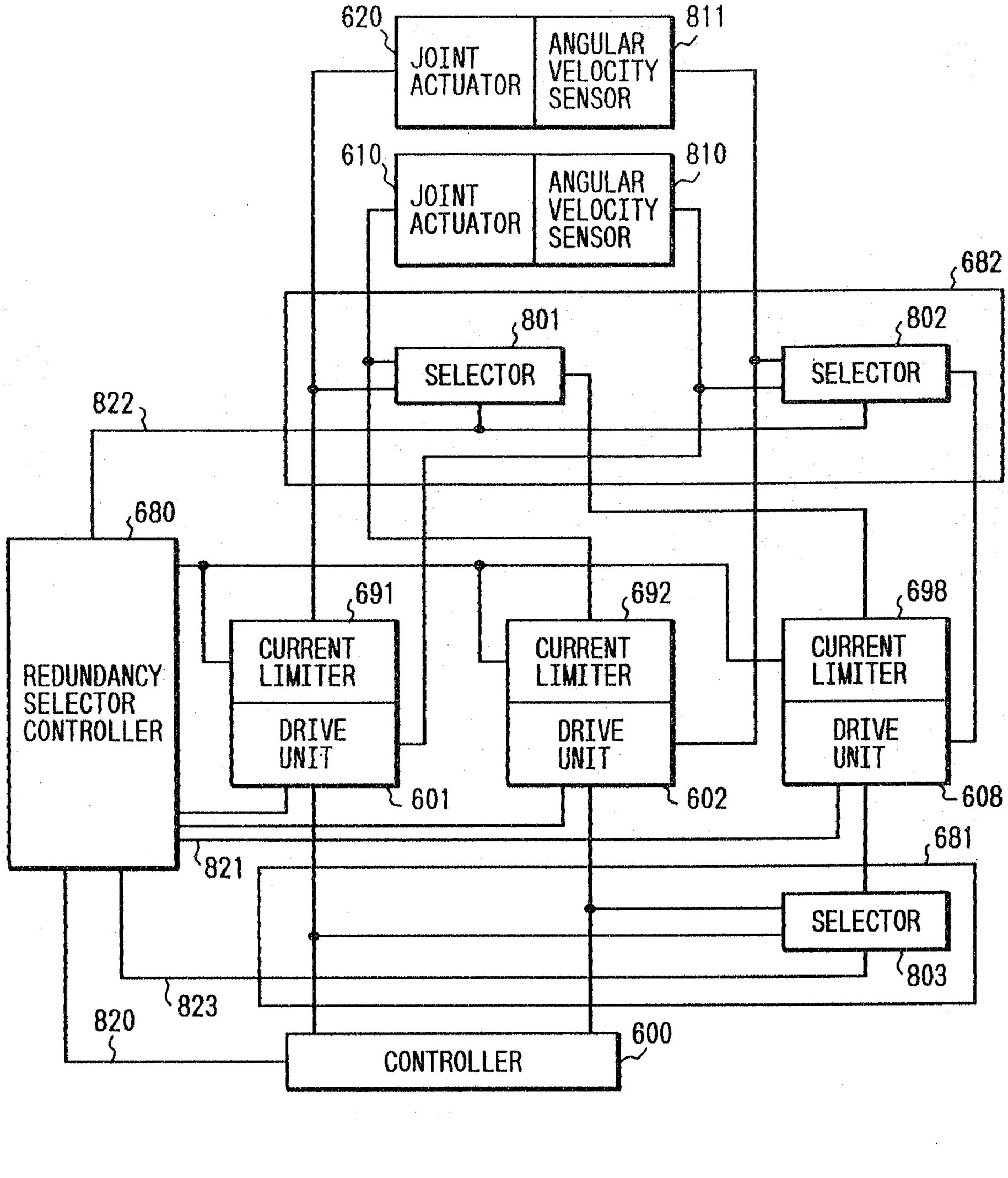

RELIABILITY OF SYSTEM λ
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
r
CONVENTIONAL MANIPULATOR (SEVEN SPARE DRIVERS)
MANIPULATOR ACCORDING TO THE PRESENT INVENTION (ONE SPARE DRIVER)
NO SPARE DRIVER

FIG. 7

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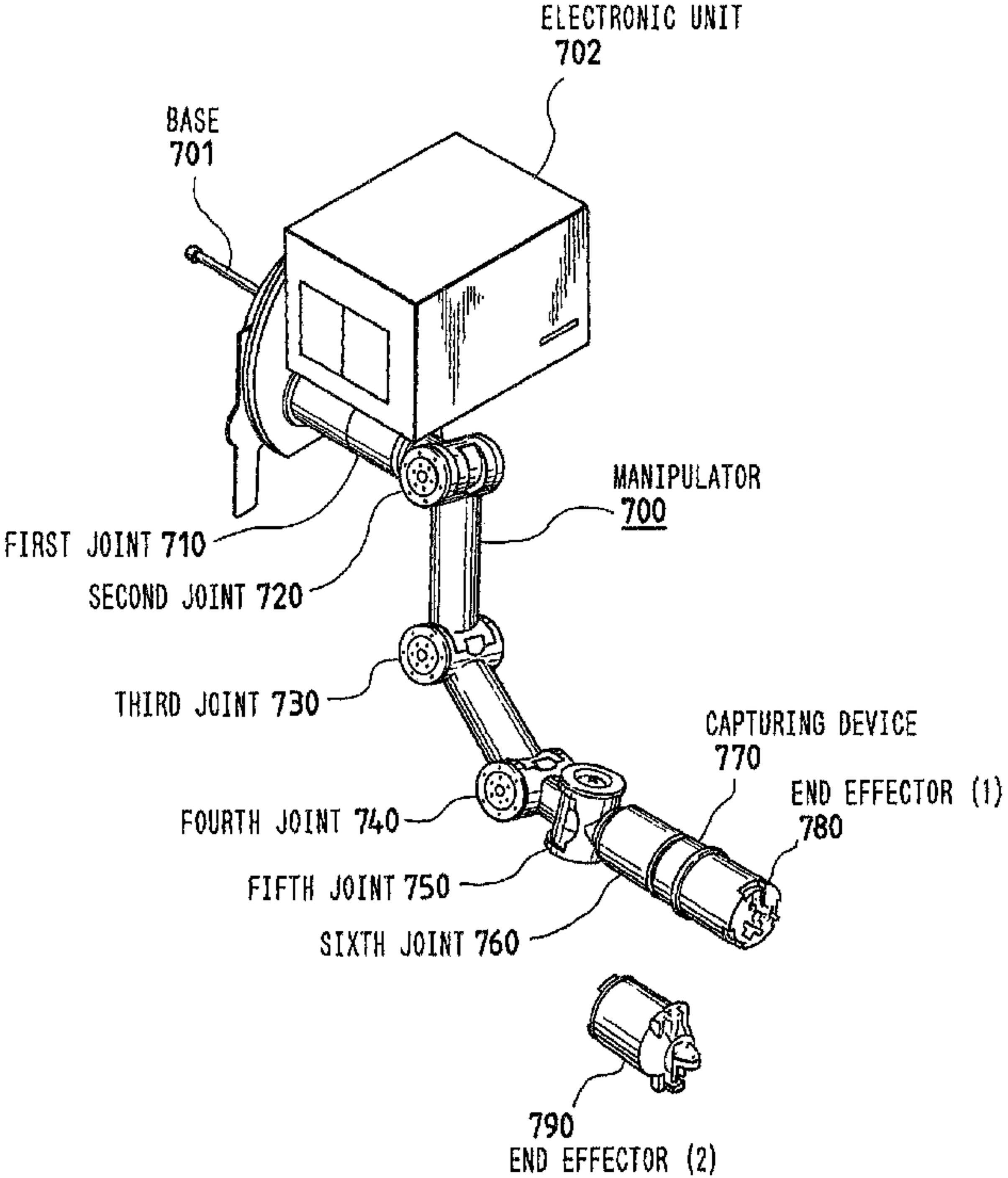
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MANIPULATOR
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FIRST JOINT 710
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CAPTURING DEVICE
770
END EFFECTOR (1)
780
FOURTH JOINT 740
FIFTH JOINT 750
SIXTH JOINT 760
790
END EFFECTOR (2)