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(71) Demandeur/Applicant:  
FISHER CONTROLS INTERNATIONAL, LLC, US  
(72) Inventeur/Inventor:  
WINKLER, RICHARD J., US  
(74) Agent: RIDOUT & MAYBEE LLP

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(54) Title: METHOD AND APPARATUS FOR MULTIPLE-INPUT-MULTIPLE-OUTPUT OF A VALVE/ACTUATOR PLANT

(57) **Abrégé/Abstract:**

A method and apparatus for controlling a valve/actuator plant (17) by generating a plurality of independent correcting control signals each (15) responsive to a plurality of respective input signals and at least one of these input signals being the set point signal (54). The plurality of independent correcting control signals includes a pneumatic flow signal. The correcting control signals may be derived from all linear control signals, all non-linear control signals, or a combination of linear control signals and non-linear control signals.



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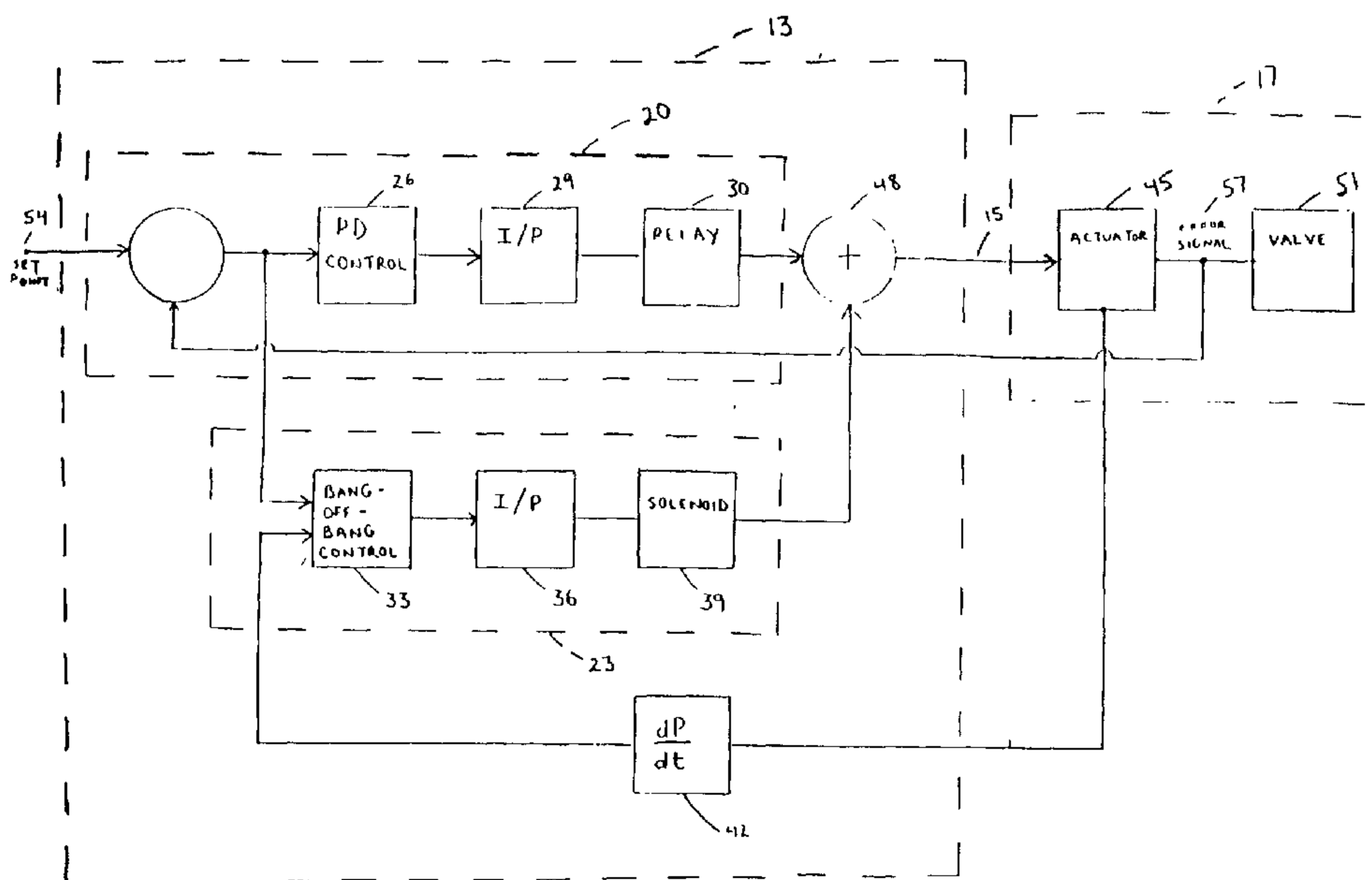
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INC. [US/US]; 8000 Maryland Avenue, Clayton, MO  
63105 (US).(72) Inventor: WINKLER, Richard, J.; 2460A Reed Avenue,  
Marshalltown, IA 50158 (US).(74) Agent: HEPPELMANN, Roger, A.; Marshall, Gerstein  
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METHOD AND APPARATUS FOR MULTIPLE-INPUT-MULTIPLE-OUTPUT  
CONTROL OF A VALVE/ACTUATOR PLANT

Field of the Invention

5           The present invention relates generally to  
valve controllers and more particularly to a method and  
apparatus for controlling a valve/actuator plant with  
multiple independent controller outputs to the  
valve/actuator plant.

10

Background of the Invention

A variety of control algorithms may be used by  
valve controllers to control a valve/actuator plant.  
Typically, valve controllers use an error signal, which  
15 is the difference between the desired set point signal  
and the output feedback signal, to control the  
valve/actuator plant. The valve controller generates a  
correcting control output signal, specifically a  
pneumatic signal proportional to the error signal,  
20 through a control algorithm to drive the valve/actuator  
plant. The control output signal may be the result of  
either a linear or non-linear control algorithm. This  
output signal from the valve controller becomes an input  
signal to the valve/actuator plant and hereinafter will  
25 be referred to as a correcting control signal.

A correcting control signal is generated from a Proportional, a Proportional plus Derivative, or a Proportional plus Derivative plus Integral type linear control algorithm. The Proportional (P) type control  
5 algorithm generates a correcting control signal directly proportional to the error signal. The Proportional plus Derivative (PD) type control algorithm generates a correcting control signal that is the sum of a signal proportional to the error signal and a signal that is  
10 proportional to the rate of change of the error signal. The Proportional plus Derivative plus Integral (PID) type control algorithm generates a correcting control signal that is the sum of a signal proportional to the error signal, a signal that is proportional to the rate of  
15 change of the error signal, and a signal that is proportional to the integral of the error signal.

Non-linear control techniques may compensate for the non-linearities, such as friction, dead band, and hysteresis that are inherent in controlling a  
20 valve/actuator plant. One example of a non-linear control algorithm would be one that uses a pulse width modulation technique. This algorithm would provide an "on-off-on" correcting control signal which has a duty cycle that has some defined relationship to the error  
25 signal. With this "on-off-on" control algorithm there is

a dead-band parameter that defines the values of the error signal for when the correcting control signal is "off" or zero, and when the correcting control signal is "on" or equal to one.

5           The correcting control signals from both the linear and non-linear control algorithms can be converted to pneumatic correcting control signals that would be used to drive a valve/actuator plant to the desired set point position. This pneumatic correcting control signal  
10 consists of, but not limited to, a pneumatic flow.

          All electro-pneumatic valve controllers use either linear or non-linear control algorithms to provide pneumatic correcting control signals to the valve/actuator plant. Typically, a valve controller  
15 provides a single pneumatic correcting control signal to the valve/actuator plant. Accordingly, if the algorithm and/or mechanics used to generate the correcting control signal fails to operate, then the valve controller ceases to function and ceases to provide a pneumatic correcting  
20 control signal to the valve/actuator plant.

#### Summary of the Invention

          In accordance with the principles of the present invention, there is provided a method and  
25 apparatus for controlling a valve/actuator plant with

multiple independent correcting control signals including  
correcting control signals derived from linear control  
signals, non-linear control signals or a combination of  
linear and non-linear control signals. The correcting  
5 control signals may be a pneumatic signal. The multiple  
correcting control signals operate independent of each  
other so if one correcting control signal fails to  
operate, the other correcting control signal or signals  
will continue to function independent of the failed  
10 correcting control signal and still be able to drive the  
valve/actuator plant.

In accordance with the invention, a plurality  
of independent correcting control signals are generated,  
each responsive to a plurality of input signals which  
15 include a set point signal. The correcting control  
signals to the valve/actuator plant are summed together  
by the pneumatic volume of the actuator providing a  
single controlled output from the valve/actuator in  
response to the plurality of independent correcting  
20 control signals. This single controlled output is the  
valve's mechanical travel.

The plurality of independent correcting control  
signals can be generated by only linear control signals,  
only non-linear control signals or a combination of  
25 linear control signals and non-linear control signals.

A significant advantage of the present invention is in being able to incorporate a plurality of independent linear and non-linear pneumatic correcting control signals to a valve/actuator plant and provide a single controlled output from the valve/actuator plant.

#### Brief Description of the Drawings

The features of this invention which are believed to be novel are set forth with particularity in the appended claims. The invention may be best understood by reference to the following description taken in conjunction with the accompanying drawings, in which like reference numerals identify like elements in the several figures and in which:

Figure 1 is a block diagram illustrating a valve controller with multiple-input-single-output control.

Figure 2 is a block diagram illustrating the preferred embodiment of the present invention.

Figure 3 is a block diagram illustrating an alternate embodiment of the present invention.

#### Detailed Description of the Preferred Embodiments

Figure 1 illustrates a plurality of control inputs 10, which include, but are not limited to,



electronic control inputs, coupled to a valve controller  
13 with a plurality of independent correcting control  
signals 15 to control a valve/actuator plant 17. The  
plurality of independent correcting control signals 15,  
5 which may be a pneumatic signal, is derived from either  
all linear control algorithms, all non-linear control  
algorithms, or a combination of linear and non-linear  
control algorithms. For example, correcting control  
signals 15/1 through 15/n may be derived from either all  
10 linear control algorithms or all non-linear control  
algorithms. Moreover, correcting control signal 15/1 may  
be derived from a linear control algorithm and correcting  
control signals 15/2 through 15/n may be derived from  
non-linear control algorithms, or correcting control  
15 signals 15/1 through 15/n may be derived from any other  
combination of linear and non-linear control algorithms.

The plurality of control inputs 10 generate a  
plurality of correcting control signals 15 that are  
coupled to the valve/actuator plant 17. The plurality of  
20 correcting control signals 15 are independent of each  
other so if one correcting control signal fails to  
operate, the other correcting control signal or signals  
will continue to function independent of the failed  
correcting control signal. For example, if correcting  
25 control signal 15/1 failed to operate, correcting control

signals 15/2 through 15/n should continue to function and control the valve/actuator plant 17. The valve controller 13 may be, but is not limited to, an electro-pneumatic controller.

5           As mentioned above, the output of the valve controller 13 may include multiple independent correcting control signals 15 derived from all linear control algorithms, all non-linear control algorithms or a combination of linear and non-linear control algorithms.

10       In one embodiment, as shown in Figure 2, the valve controller 13 generates two independent correcting control signals including one derived from a linear control generator 20 and another from a non-linear control generator 23. The linear control generator 20,

15       which is located in the valve controller 13, includes a PD type controller 26 coupled to a signal amplifier 29, such as a current to pressure (I/P) transducer, and a pneumatic amplifier 30, such as a pressure relay. As described above, a P, PD, or PDI type control generates a

20       linear correcting control signal from the plurality of control inputs 10. The linear control generator 20 may be implemented by, but not limited to, the configuration used in a Type DVC5000 Digital Valve Controller, manufactured by Fisher Controls International, Inc.

The non-linear control generator 23 includes an "on-off-on" control 33 coupled to a signal amplifier 36 and solenoids 39. The non-linear control generator 23 is implemented by, but not limited to, pulsing two pneumatic solenoids in an "on-off-on" type control 33, which has a duty cycle proportional to an error signal. The signal amplifier 36 includes a current-to-pressure (I/P) transducer that provides a pressure output in response to a current input. The solenoids 39 provide a pneumatic flow in response to the pressure output of the signal amplifier 36. One solenoid provides a pneumatic supply flow and the second solenoid provides an exhaust flow capability.

During a transition from one set point to another, the non-linear control generator 23 attempts to control a pressure rate 42, which builds or decreases in an actuator 45 located in the valve/actuator plant 17. The pressure rate 42, used for the non-linear control generator 23, may be either fixed or user-defined. As mentioned above, the non-linear control technique compensates for non-linearities such as, but not limited to, friction, dead band, and hysteresis, that are inherent in control valve/actuator plants. The non-linear control generator 23 may be implemented a modified

version of the Type DVC5000 Digital Valve Controller referred to above.

The correcting control signals 15 from the linear control generator 20 and the non-linear control generator 23 are pneumatically summed and integrated to pressure by the load volume of the actuator 45. The pressure rate 42 from the actuator 45 is fed back to the non-linear control algorithm 23 on line 43. An error signal 57 is fed back on line 47 from the valve/actuator plant 17 that adjusts both the linear and non-linear control generators 20, 23, respectively.

In Figure 2, the two correcting control signals, which are generated by the linear control generator 20 and the non-linear control generator 23, are pneumatically summed and integrated to pressure which, in turn, provides the driving force for the valve/actuator plant 17. The valve/actuator plant 17 includes the actuator 45 coupled to a valve 51. A desired set point signal 54 enters the valve controller 13 to operate the control generators 20, 23. In the linear control generators 20, the PD controller 26 provides an electrical drive signal, which may be, but is not limited to, a current signal. The signal amplifier 29 includes a current-to-pressure (I/P) transducer that provides a pressure output in response to a current input from the

PD controller 26. The pneumatic amplifier 30 includes a pressure relay that provides a pneumatic flow to the actuator 45 in response to the pressure output from the signal amplifier 29.

5           The non-linear control generator 23 is active only when the feedback output signal, which may be the error signal 57 from the actuator 45, is outside a predetermined percent of a set point signal 54. If the output signal is within the predetermined percentage of  
10 the set point signal 54, then the non-linear control generator 23 shuts off and the linear control generator 20 continues to bring the output signal of the actuator 45 to within the desired set point signal 54.

          Figure 3 illustrates an alternate embodiment of  
15 the present invention, which includes a plurality of independent correcting control signals that may be a combination of linear correcting control signals and non-linear correcting control signals. For example, the valve controller 13 includes, but is not limited to, a  
20 combination of linear control generators 20 with correcting control output signals 15/1 through 15/n and non-linear correcting control generators 23 with output signals 15/1' through 15/n'. The correcting control signals consist of, but are not limited to, pneumatic

flows and are summed and integrated to pressure by the valve/actuator plant 17.

The foregoing detailed description has been given for clearance of understanding only, and no  
5 unnecessary limitations would be understood therefrom, as modifications will be obvious to those skilled in the art.

What is claimed:

1. A method for controlling a valve/actuator plant comprising the steps of:

5           generating a plurality of independent correcting control signals each responsive to a plurality of input signals having a set point signal; and

          generating a single controlled output from the valve/actuator plant based on the plurality of  
10 independent correcting control signals.

2. The method of claim 1, wherein the plurality of independent correcting control signals include a pneumatic control signal.

15           3. The method of claim 1, wherein the plurality of independent correcting control signals are each derived from respective linear control signals.

20           4. The method of claim 1, wherein the plurality of independent correcting control signals are each derived from respective non-linear control signals.

5. The method of claim 1, wherein the plurality of independent correcting control signals are derived from a combination of linear control signals and non-linear control signals.

5

6. The method of claim 3, wherein the linear correcting control signals are directly proportional to an error signal.

10

7. The method of claim 3, wherein the linear correcting control signals include a correcting control signal that is proportional to an error signal and a correcting control signal proportional to the rate of change of the error signal.

15

8. The method of claim 3, wherein the linear correcting control signals include a correcting control signal proportional to an error signal, a correcting control signal proportional to the rate of change of the error signal, and a correcting control signal proportional to the integral of the error signal.

20



9. The method of claim 4, wherein the non-linear correcting control signal includes a correcting control signal having a duty cycle proportional to an error signal.

5

10. An apparatus for controlling a valve/actuator plant comprising:

a plurality of control generators generating respective independent control signals, each control generator responsive to a respective set point to provide said respective control signals; and

an actuator having a plurality of inputs respectively coupled to each of the respective independent control signals for providing a combined control output in response to one or more of the plurality of independent control signals.

11. The apparatus of claim 10, wherein the plurality of control generators include a plurality of linear control generators.

12. The apparatus of claim 10, wherein the plurality of control generators include a plurality of non-linear control generators.

13. The apparatus of claim 10, wherein the plurality of independent control generators include a combination of linear control generators and non-linear control generators.

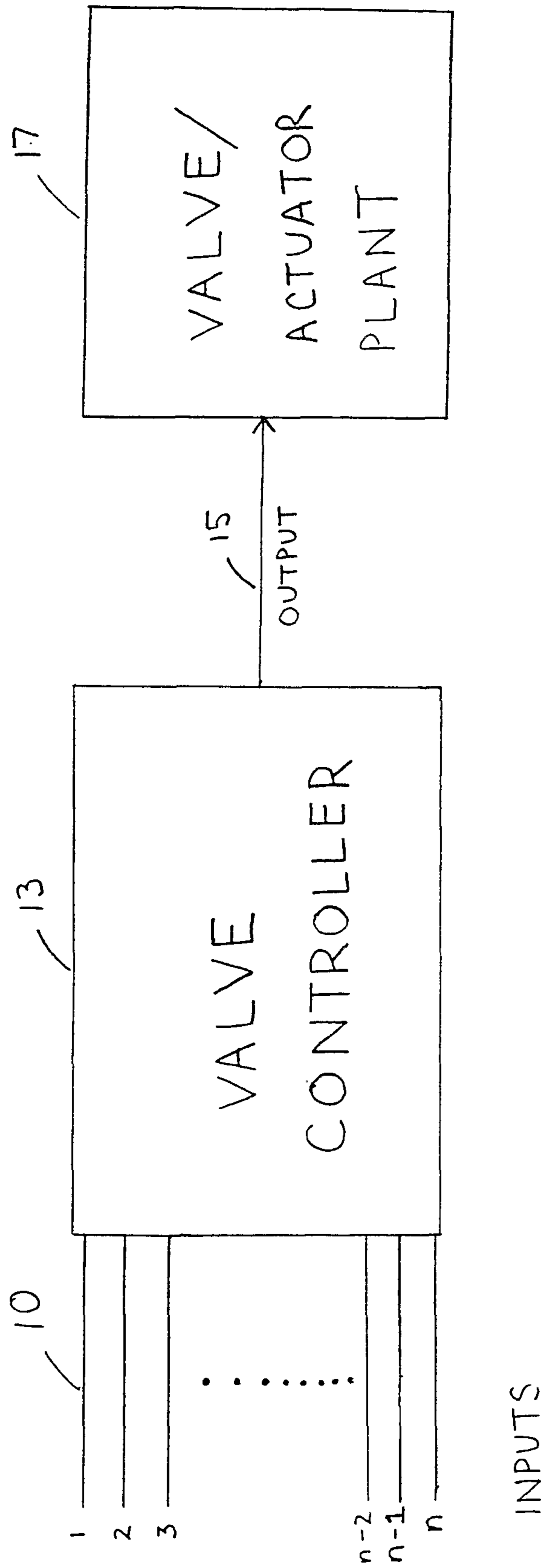


FIG. 1

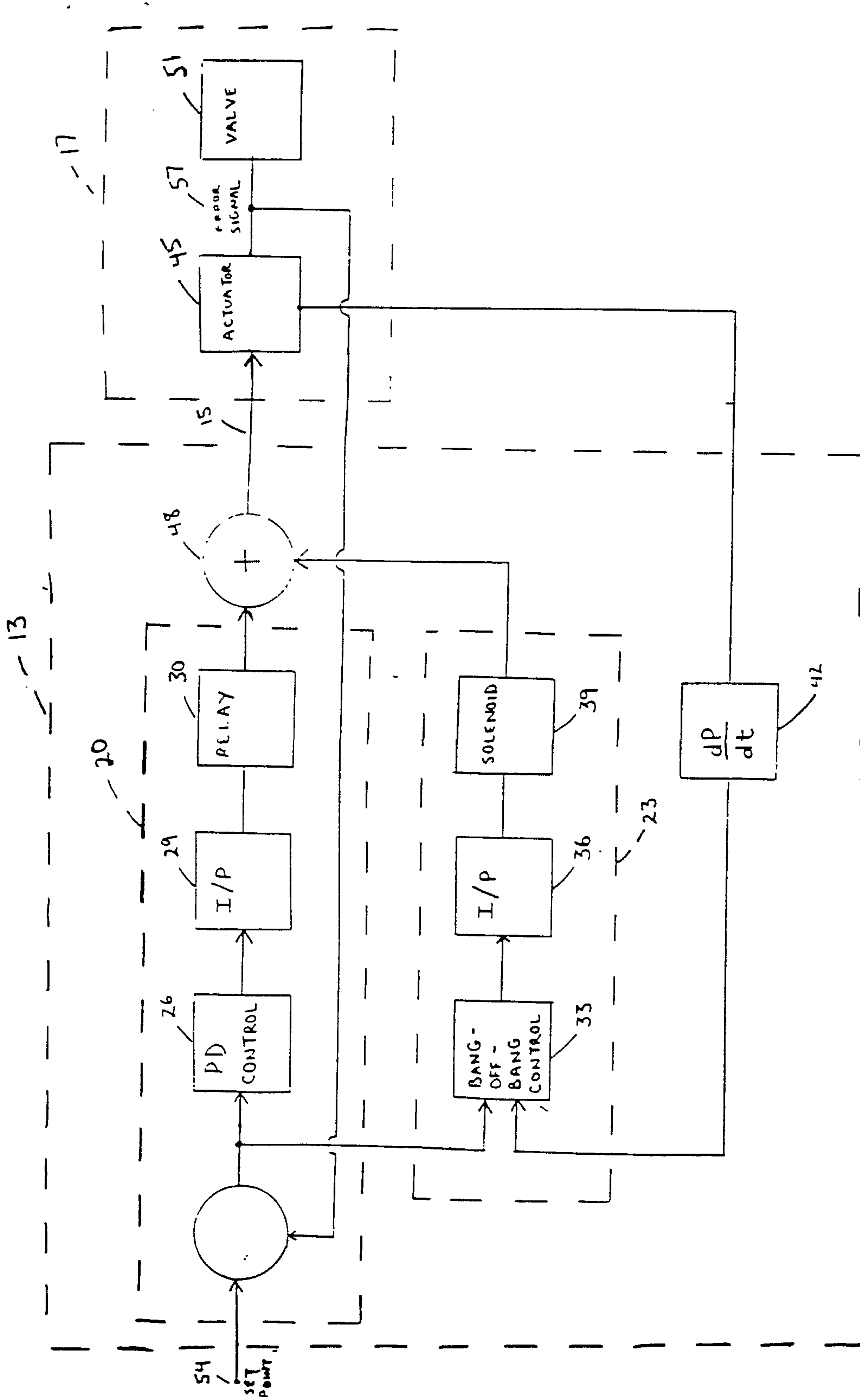


FIG. 2

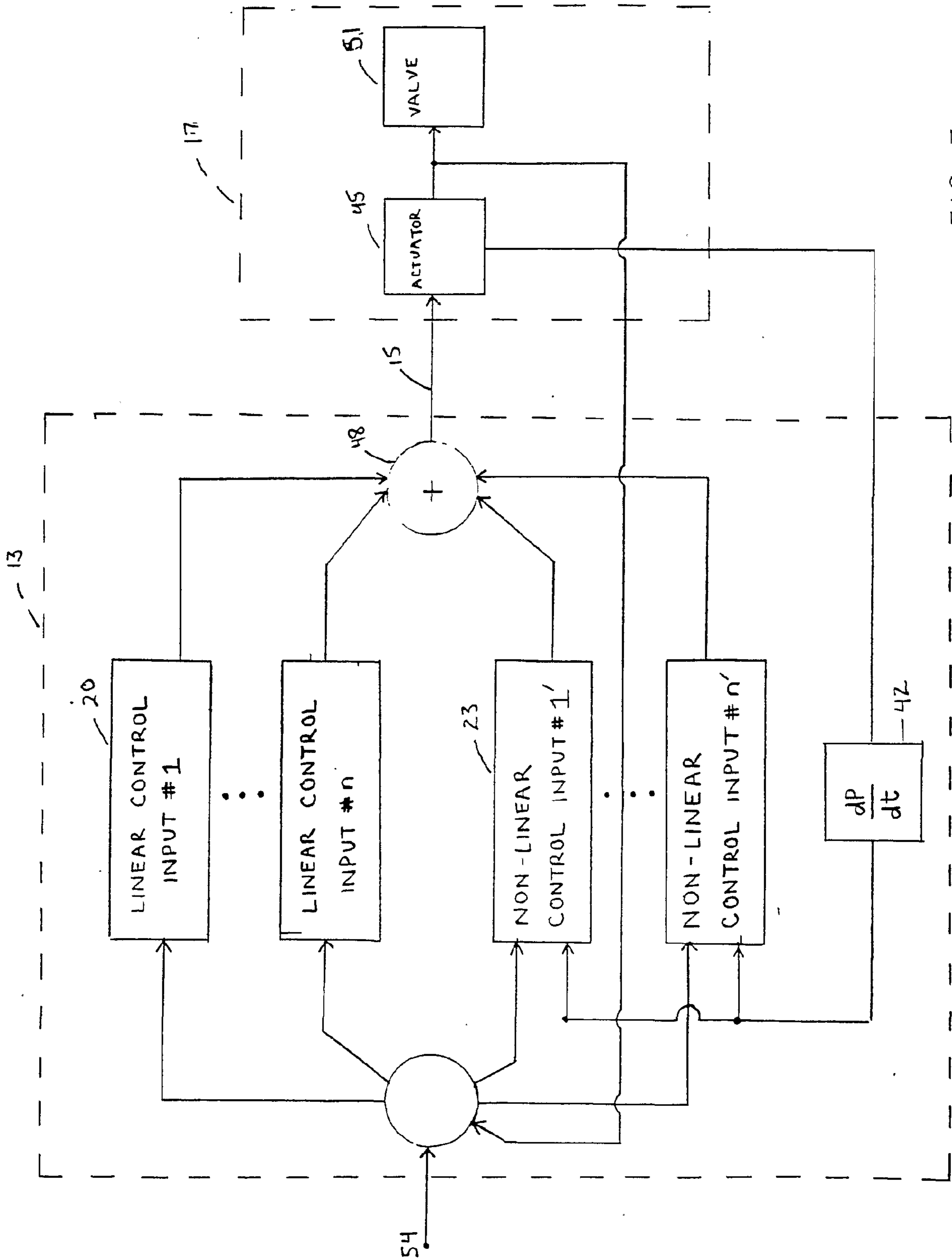


FIG. 3

