United States Patent [19]

Teuber et al.

[11] **3,926,390**

[45] **Dec. 16, 1975**

[54] **CONTROL VALVE LOGIC**

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[73] Assignee: **The United States of America as represented by the Secretary of the Army**, Washington, D.C.

[22] Filed: **June 25, 1974**

[21] Appl. No.: **482,939**

Related U.S. Application Data

[63] Continuation of Ser. No. 308,614, Nov. 21, 1972, abandoned.

[52] **U.S. Cl.** **249/3.22**; 318/561

[51] **Int. Cl.**[2] **F42B 15/18**

[58] **Field of Search** 244/3.22; 318/561, 619

[56] **References Cited**

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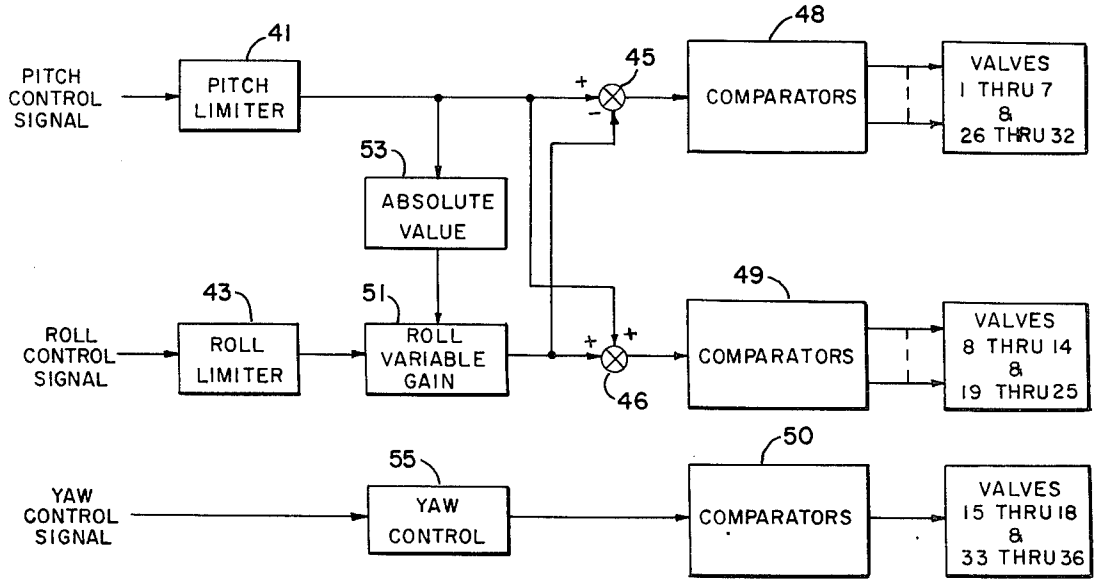
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[57] **ABSTRACT**

The roll and the pitch axes of an elliptical shaped missile are controlled by 28 jets shared by both attitude controllers. The proper jets are selected in accordance to the two error signals which are combined in an additive fashion and sent to one half of the valves and are combined in a subtractive fashion and sent to the other half of the valves. The roll error input signal is controlled in amplitude by a variable gain circuit which in turn is controlled by the amplitude of the pitch error signal—the higher the pitch error signal the more attenuation of the roll error signal.

3 Claims, 4 Drawing Figures



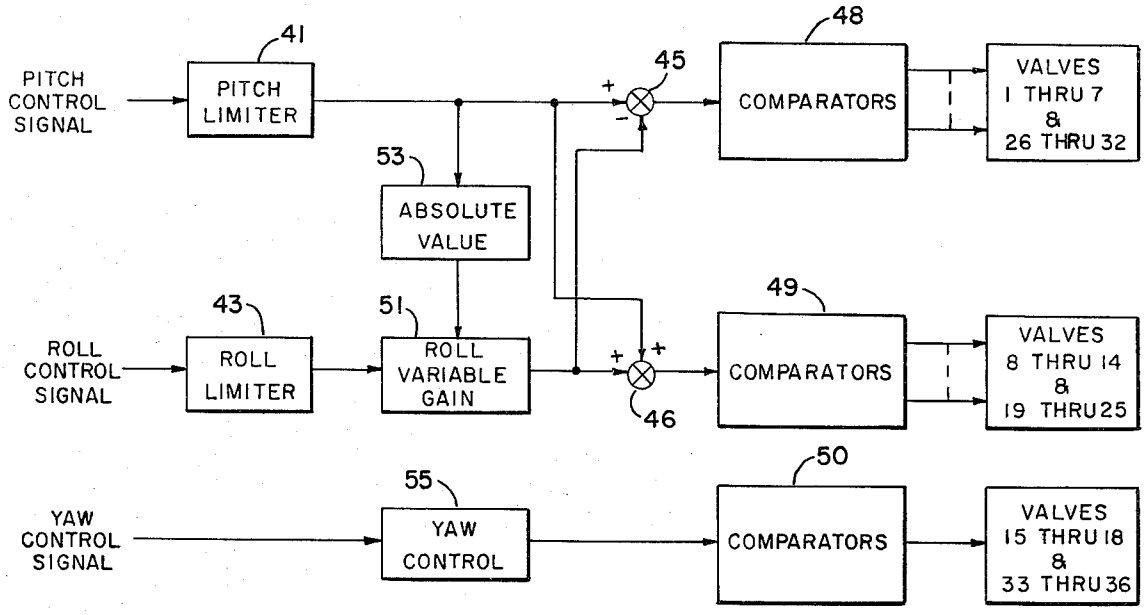


FIG. 1

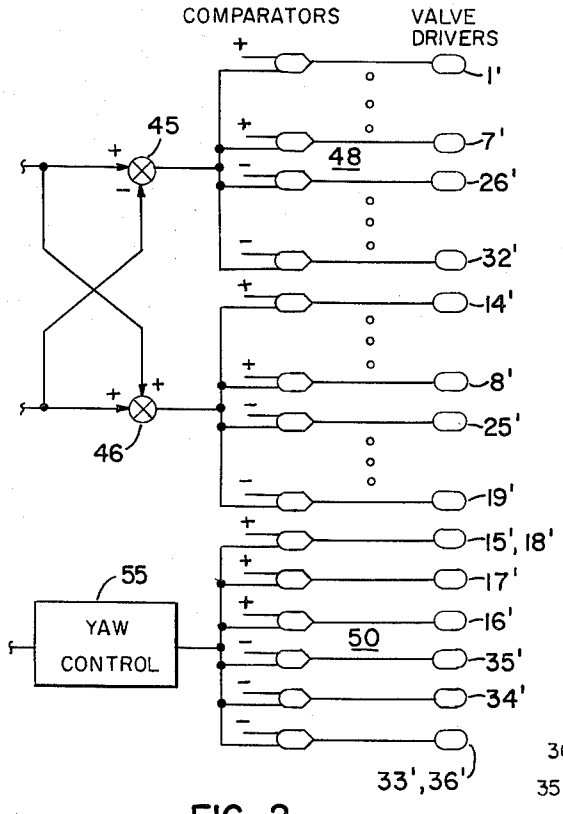


FIG. 2

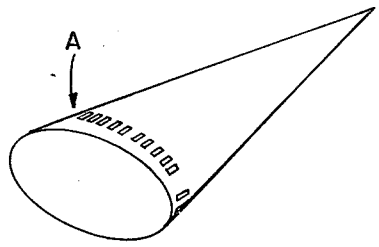


FIG. 3

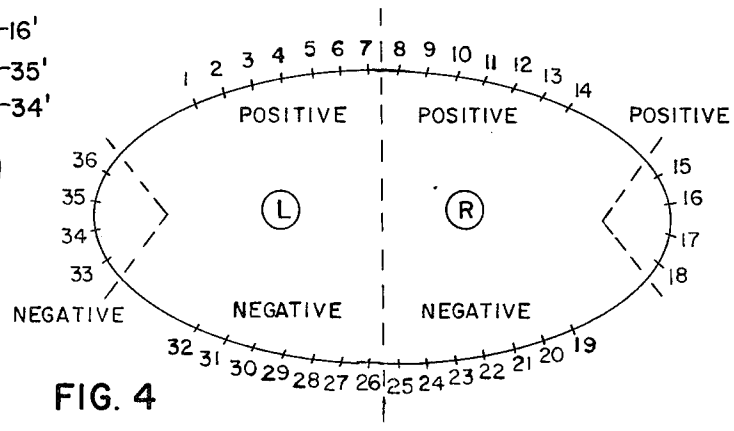


FIG. 4

CONTROL VALVE LOGIC

This is a continuation of application Ser. No. 308,614, filed Nov. 21, 1972 and now abandoned.

SUMMARY OF THE INVENTION

An elliptical missile has **36** control jets around its periphery for controlling yaw, pitch and roll. Fourteen of the jets are located at the top of the missile while **14** of the control jets are located at the bottom of the missile. The other eight are divided four and four on either side of the periphery of the missile. The **14** at the top and the **14** at the bottom are utilized jointly by the pitch and roll control circuits. The controls for the valves of the top **14** jets will cause these jets to fire in a predetermined sequence upon receiving a positive input voltage. The control for the bottom **14** jets will cause these jets to fire in a predetermined sequence when they receive a negative control voltage. The control circuits at the left hand side top and the left hand side bottom jets are grouped together and fed error signals from both the pitch and roll error generating circuits. The roll signal is combined in a negative fashion with the pitch signal being sent to the control units of the valves. Similarly the control units of the right hand top valves and the control units of the right hand bottom jets are connected to receive the additive combined signals of the pitch and roll error signals.

The control valves each have a comparator which allows the control valve to operate only upon receiving a signal (of the proper polarity) of an amplitude above a predetermined level. In this way the valves will be operated in sequence as the combined signal increases in magnitude. The sequence of firing is that those closest to top or bottom center are fired first and those furthest from the top or bottom center are fired last. The rest are fired in the order of their position with respect to top or bottom center. In this way both the pitch and roll of the missile can be controlled by a combined circuit and shared jets.

Because the controllers of the jets are shared, pitch and roll command limits determine which command is dominant for large combined errors. If roll is dominant, large pitch errors may occur during a roll maneuver. Conversely, dominant pitch commands may cause a slowing of roll maneuvers. To counter this, a pitch limiter and a roll limiter are inserted in series with their respective error signals. Conversely, because of the order in which the jets are fired, a roll command in the presence of a low pitch control signal will fire jets with very small roll moment arms. These small moment arms degrade roll response.

To counter this undesirable effect a variable gain circuit is inserted in series with the roll control error signal. This variable gain circuit is controlled in accordance with the inversed amplitude of the pitch control signal. In other words when pitch command is high the roll gain is lowered, allowing pitch usage to take precedence.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram showing the basic embodiment of the present invention;

FIG. **2** is a schematic diagram showing the invention in greater detail;

FIG. **3** is a pictorial showing of the missile; and

FIG. **4** is a representation of the position of the jets on the missile.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIGS. **1** and **2** show control valve logic system. Error signals from circuitry not shown in the missile generate pitch control signals and roll control signal. Also yaw control signals are generated. These signals are limited by pitch limiter **41** and roll limiter **43.** Limits imposed on the pitch and roll force commands are chosen by design to determine which command is dominant for large combine errors.

Before proceeding with the control logic, the overall construction of the missile should be considered. FIG. **3** shows that the periphery of the missile is elliptical and the body is a lifting body shape with two side symmetry. Jets A are distributed about the periphery for controlling the attitude of the missile. FIG. **4** shows the positions of the jets **1–36** in greater detail. As can be seen jets **1–14** are at the top part of the missile and jets **19–32** are located at the bottom portion of the missile. The yaw control jets **15–18** and **33–36** are also shown. Jets **1–7** and **26–36** are on the left hand side of the missile while jets **8–25** are on the right hand side of the missile.

In the basic operation of the system (FIG. **1**) signals from the pitch limiter **41** will flow to mixers **45** and **46** and be combined with a roll signal from roll limiter **43.** The two signals are additively combined by mixer **46** and are subtractively combined by mixer **45.** The output from mixer **45** is sent through a first section of comparators, **48.** The output of mixer **46** is fed through a second section of comparators, **49.**

FIG. **2** shows the specific connections of the comparators **48** and **49** and also shows comparators **50** for the yaw control. The comparators are associated with the valve drivers **1′–36′** of the jets **1–36.** Comparators associated with valve drivers **1′–7′** will have an output only if the output of mixer **45** is positive and of a magnitude greater than the set value of the comparators. The set value of these comparators is provided by the plus input and each said input is spaced a voltage difference one from the other in a step relationship downward from **1′–7′.** In this way valve drivers **1′–7′** will be energized in sequence with valve driver **7′** energized first with the lowest positive output of mixer **45,** and valve driver **1′** with the highest permissible output of mixer **45.** In a like manner the comparators associated with valve drivers **26′–32′** are set by their negative input voltages so that the valve drivers will be energized in a positive numerical step sequence.

The values set for comparators **48** are set so that the jet firing sequence for the left side of the missile shall be **7, 6, 5, 4, 3, 2,** and **1,** for positive outputs and **26, 27, 28, 29, 30, 31,** and **32** for negative outputs. For the right hand side of the missile via comparators **49** the firing order shall be **8, 9, 10, 11, 12, 13,** and **14,** for the positive output and **25, 24, 23, 22, 21, 20,** and **19** for the negative output. The yaw firing order shall be **16** and then **17** then the pair **15** and **18** for the positive right hand section and for the negative left hand section the order is **35** and then **34** and then the pair **33** and **36** for negative signals.

It can now be seen that for a pitch correction in the absence of any roll correction signal, depending upon the magnitude of the pitch error signal, a number of pairs of jets will be fired. Assuming a low negative magnitude of output, then the output from mixer **45** will be a negative signal sent to the comparator associated with

valve driver 26'. Valve driver 26' will be turned on whereas valve driver 27' will not be turned on because the comparator associated with it would not be energized with this low output from mixer 45. Likewise valve driver 25' will be energized due to the negative signal sensed through its associated comparator, and valve driver 24' will not be energized in that the negative output from mixer 46 is not sufficient to cause the comparator associated with valve driver 24' to have an output. From this it can be seen as the error signal from the pitch limiter 41 increases additional pairs of jets 24 27, 23 28, 22 29, etc. are energized. In this way no roll moment is created as the roll moment of each pair is zero.

Roll control error signals will cause pairs of jets 8, 26; 9, 27; etc. and 7, 25; 6, 24; etc. to be energized so as to have a zero moment of pitch. As an example the smallest unit output of positive error signal from roll limiter 43 will pass through mixer 46 to the comparators 49. The comparator associated with valve driver 8 will have an output and cause the opening of valve driver 8 which in turn causes the jet 8 to create a thrust. The output from roll limiter 43 will also pass through mixer 45 where it changes polarity to a negative signal which is sent to comparators 48. The comparator associated with valve driver 26' will now have an output to cause valve driver to energize jet 26. Therefore, jets 8 and 26 are energized which gives the missile a moment of roll but gives a zero moment of pitch and yaw.

Limiters 41 and 43 ideally limit the error signal from becoming greater than the amount to turn on the highest value comparator 48 or 49. This is done to prevent an error signal from one attitude becoming so great as to prevent an error signal from the other attitude having any effect upon the comparators 48 and 49. Limiters 41 and 43 can take the shape of any of the well known limiters in the art.

Because of the firing order in which the jets are fired, a roll command in the presence of a low pitch control signal will fire jets with very small moment arms. The jets 6–9 and 24–27 will be fired first in the absence of a pitch control signal. However, in the presence of a large pitch control signal a roll control signal error will cause jets of large moment arms to be fired for roll correction. For example if a pitch control signal error output of pitch limiter 41 is of a positive value such that the valve drivers 3'–12' will be turned to an on condition at the presence of the pitch signal from 41 only; then roll error signal for left correction of a two comparator value will cause jets 2 and 1 to be further energized and jets 12 and 11 to be cut off. This causes a large moment of roll correction.

From the above it can be seen that the signal from the roll circuits needs to be larger when the signal from the pitch limiter 41 is small and needs to be smaller when the signal from the pitch limiter 41 is large. To accomplish this, a roll variable gain circuit 51 is inserted in series between roll limiter 43 and mixers 45 and 46. Roll variable gain circuit 51 may be a variable gain amplifier whose gain is controlled by a connection to the output of its limiter 41 through an isolator 53. As the output of limiter 41 increases the gain of roll variable gain circuit 51 decreases. In this way the amount of roll moment caused by a given roll control error signal will be the same (within step limits) regardless of the value the pitch control error signal.

The yaw control signals 55 operates independent of the pitch and roll control signals.

We claim:

1. A control system for use in controlling fluid flow regulating means comprising:

a. first and second signal means;

b. variable gain means having an input, control, and output, with said first signal means being connected to said control of said variable gain means to control the gain thereof inversely in accordance with the value of said first signal means, and said second signal means being connected to said input of said variable gain means;

c. a first mixer having first and second inputs and an output, said first mixer combining its inputs in an additive fashion, with said output of said variable gain means connected to said first input of said first mixer and said first signal means being connected to said second input of said first mixer;

d. a second mixer having first and second inputs and an output, said second mixer combining its inputs in a subtractive fashion, with said output of said variable gain means being connected to said first input of said second mixer and said first signal means being connected to said second input of said second mixer;

e. first and second sets of comparators with said first set of comparators being connected to said output of said first mixer, and said second set of comparators being connected to said output of said second mixer;

f. said first and second sets of comparators having a plurality of at least four units making up each of said sets of comparators, each said comparator unit having an input and an output, said input of each of said comparator units connected to said output of said associated mixer, with each said comparator unit being set such that it will not have an output until the voltage on its input exceeds a predetermined set value, and with half of said individual comparator units of each of said set of comparators being set such that they will have predetermined set values in stepped sequence as the output of the associated mixer increases positively in voltage and the other half of said individual comparator units of said set of comparators having predetermined set values in stepped sequence as the output of the associated mixer increases negatively in voltage; and

g. fluid flow regulating means each having an input connected to said output of said individual comparator units whereby each said fluid flow regulating means is activated only when said first and second signal means results in said input of said comparator unit to which said fluid flow regulating means is connected, receiving the proper amount and polarity of voltage thereby allowing multiple selective activation of said fluid flow regulating means by the variation of only said first and second signal means.

2. A control system as set forth in claim 1 further comprising a missile; a plurality of control jets on said missile equal in number to the number of control devices; each of said control devices being individually connected to said jets to control the operation thereof; one fourth of said control jets being located on the upper left of said missile; another fourth of said control jets being located on the upper right of said missile; a further fourth of said jets being located on the lower left of said missile; the final fourth of said control jets being located on the lower right of said missile; said first set of comparators being connected to control de-

vices which are controlling the upper left and lower left jets; said second comparator being connected to control devices which control the upper right and lower right jets; the control devices controlling the upper jets of the missile being connected to comparator units which are set to respond to a positive voltage; control devices controlling the lower jets being connected to control units which are set to respond to negative voltages; and said second mixer means subtracting the output of the variable gain means from the second signal means.

3. A control system as set forth in claim **2** further comprising first and second limiter means each having an input and an output: said first limiter means having its input connected to said first signal means and an output connected to said control of said variable gain means; and said second limiter means having an input connected to said second signal means and an output connected to the second input of said first and second mixer means.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,926,390

DATED : December 16, 1975

INVENTOR(S) : Roland F. Teuber, John L. Pearson and Charles D. Brown

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the heading "[75] Inventors: Roland E. Teuber, Huntington Beach; John L. Pearson, Culver City; Charles D. Brown, Pacific Palisades, all of Calif." should read --[75] Inventors: Roland F. Teuber, Huntington Beach; John L. Pearson, Culver City; Charles D. Brown, Pacific Palisades, all of Calif.--.

Signed and Sealed this

second Day of *March 1976*

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks

UNITED STATES PATENT OFFICE

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Signed and Sealed this

second Day of *March 1976*

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks