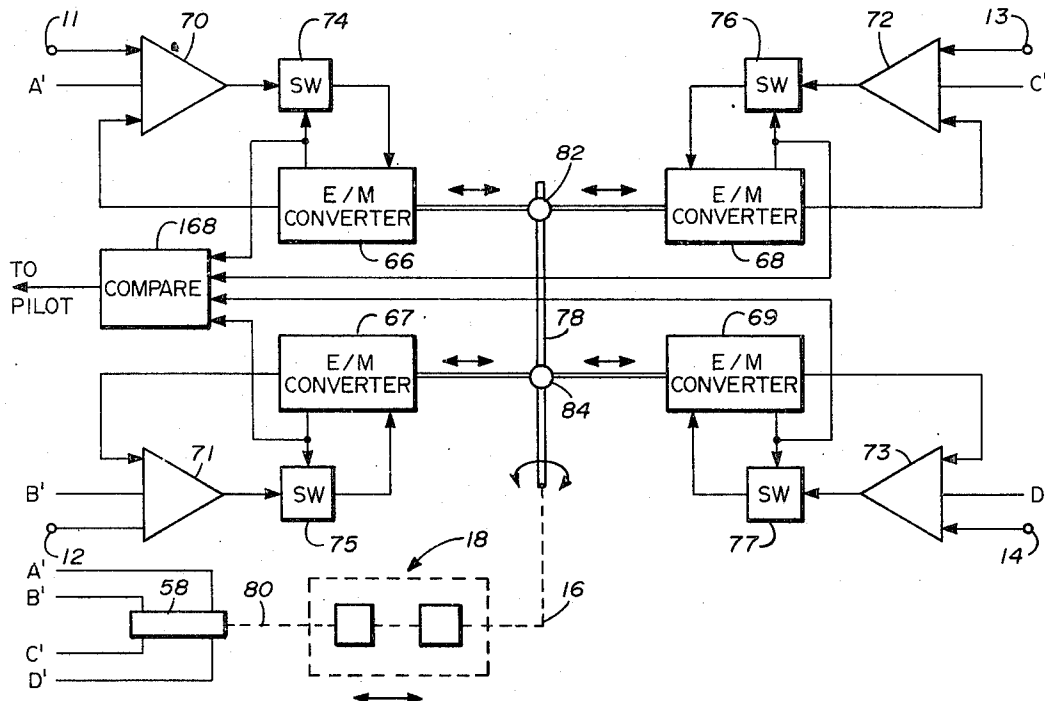


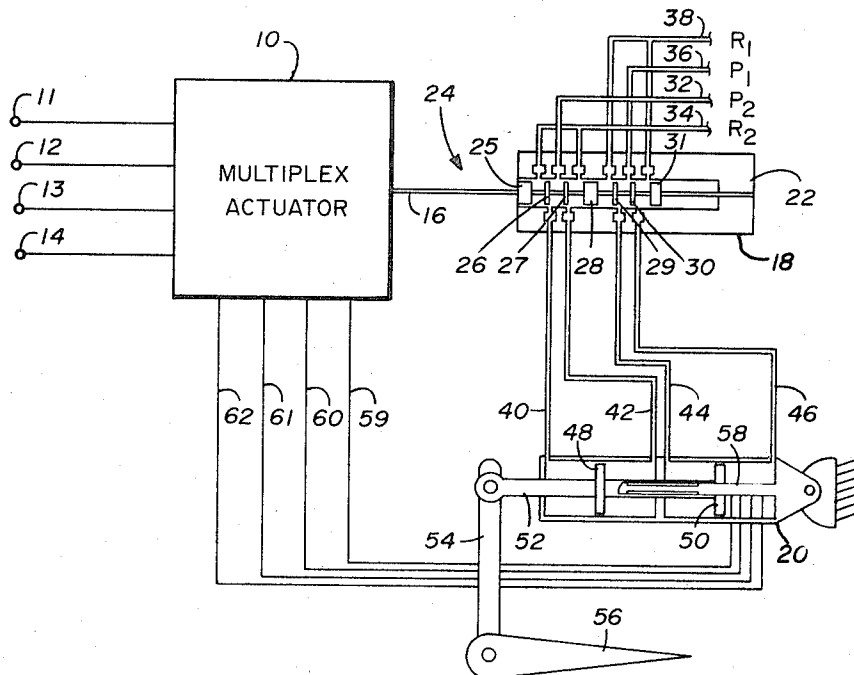
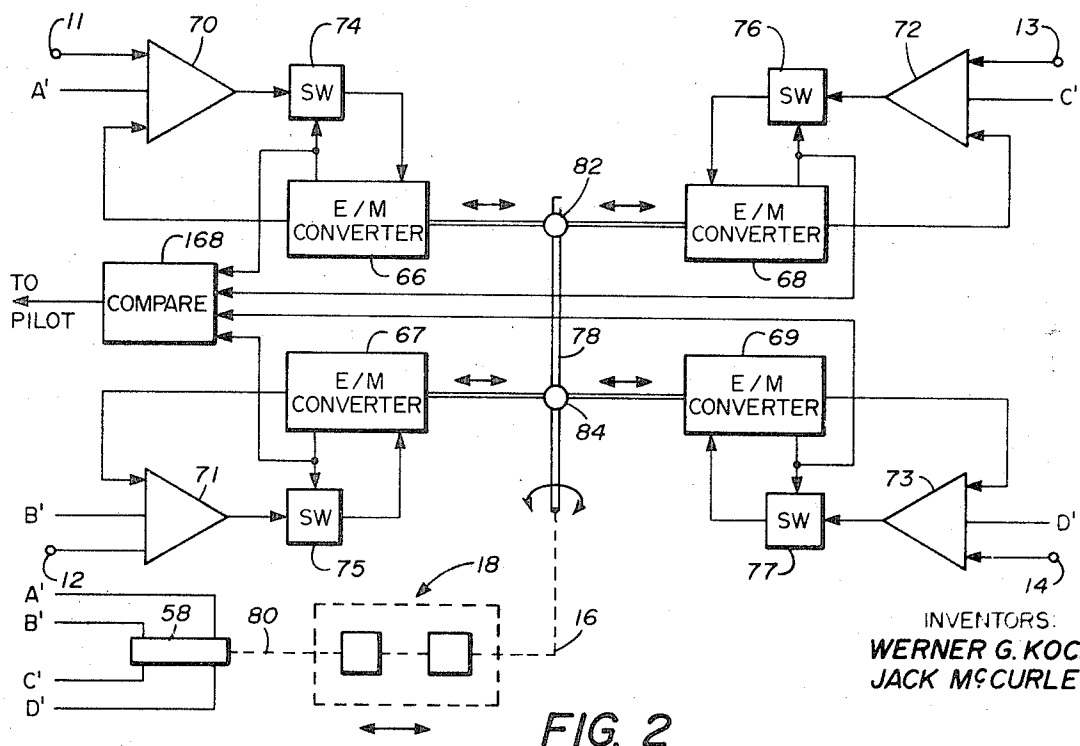
[54] **FORCE SUMMING MULTIPLEX ACTUATOR**[72] Inventors: **Werner G. Koch, Arlington; Jack McCurley, Dallas, both of Tex.**[73] Assignee: **LTV Electrosystems, Inc., Dallas, Tex.**[22] Filed: **Feb. 2, 1970**[21] Appl. No.: **7,673**[52] U.S. Cl. **91/1, 91/361, 74/424.8,****267/179, 91/459**[51] Int. Cl. **F01b 25/26, F01b 31/12**[58] Field of Search **91/361, 459, 1; 267/170, 174,**
267/179; 74/424.8[56] **References Cited****UNITED STATES PATENTS**

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Primary Examiner—Edgar W. Geoghegan*Assistant Examiner*—Clemens Schimikowski*Attorney*—Richards, Harris & Hubbard and James D. Willborn[57] **ABSTRACT**

Four rotary-to-linear motion transducers each responsive to a separate but equal control signal are coupled together in a force summing arrangement to produce a linear motion output. Each of the rotary-to-linear motion transducers is part of a control channel that includes an asymmetrical breakaway force coupler for transmitting the linear motion output of the transducer to an attachment point on a torque tube. The breakaway coupler has a force responsive disconnect that is actuated when the force developed between the attachment point and the rotary-to-linear motion transducer exceeds a preset level. When the force between the attachment point and the transducer output exceeds the preset level, the disconnect actuates a switch to isolate the transducer for that channel from the control signal. Also included in each of the control channels is a position transducer for generating a feedback signal to balance out the generated control signals. At the output of the torque tube a linkage arrangement converts the rotary torque tube motion into a linear displacement that varies in accordance with the control signals.

15 Claims, 6 Drawing Figures



INVENTORS:
WERNER G. KOCH
JACK M^CCURLEY

Richards, Harris & Hubbard
ATTORNEYS

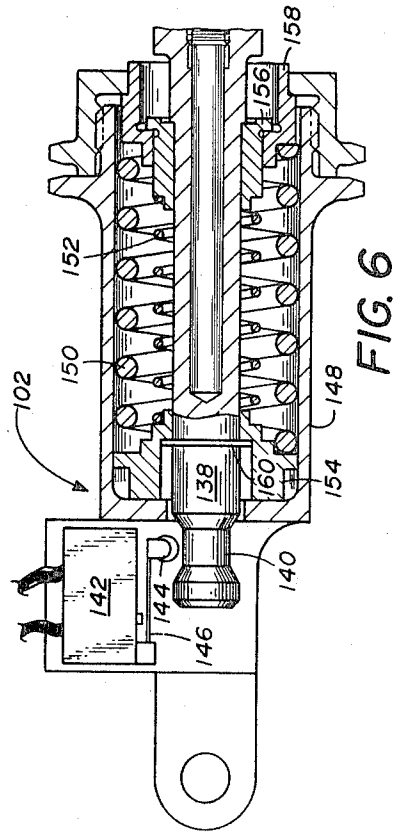


FIG. 6

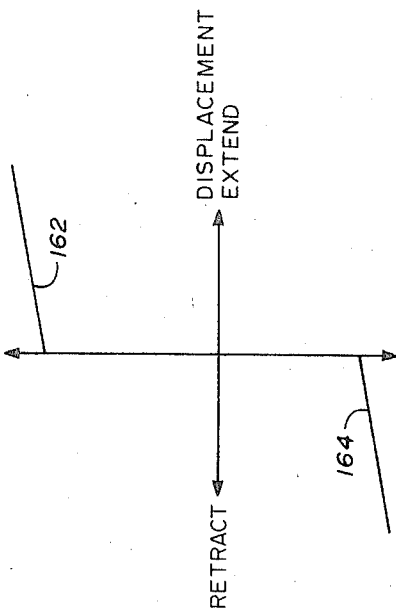


FIG. 5

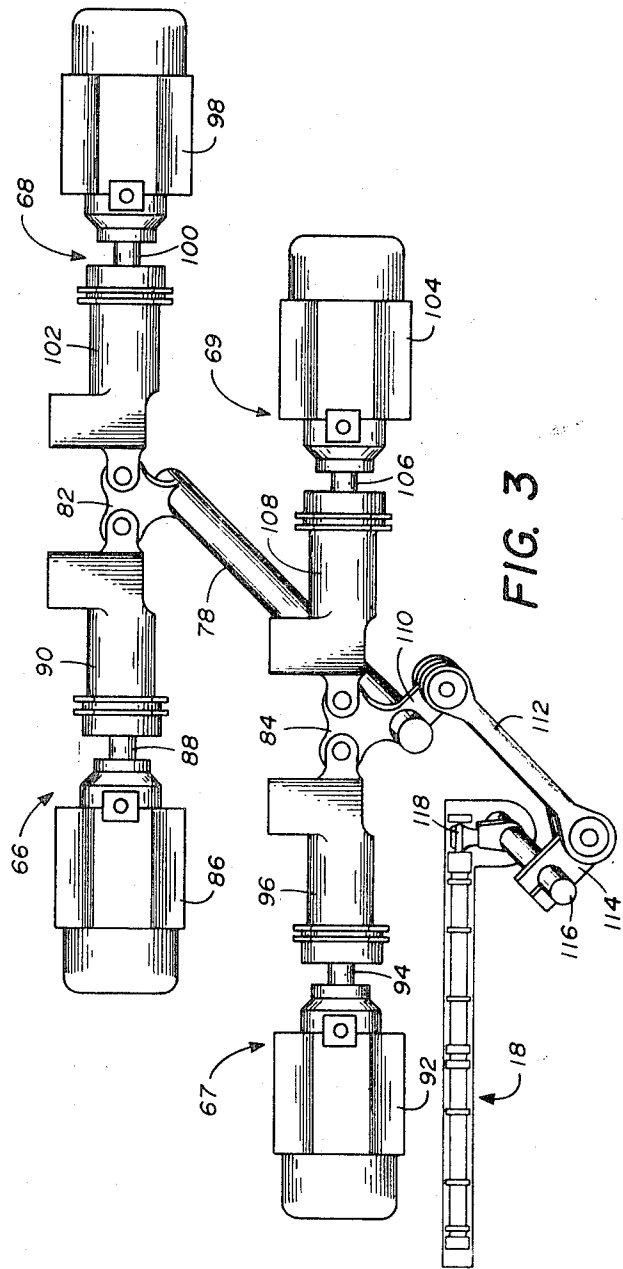


FIG. 3

INVENTORS:
WERNER G. KOCH
JACK M'CURLEY

Richards, Harris & Hubbard
ATTORNEYS

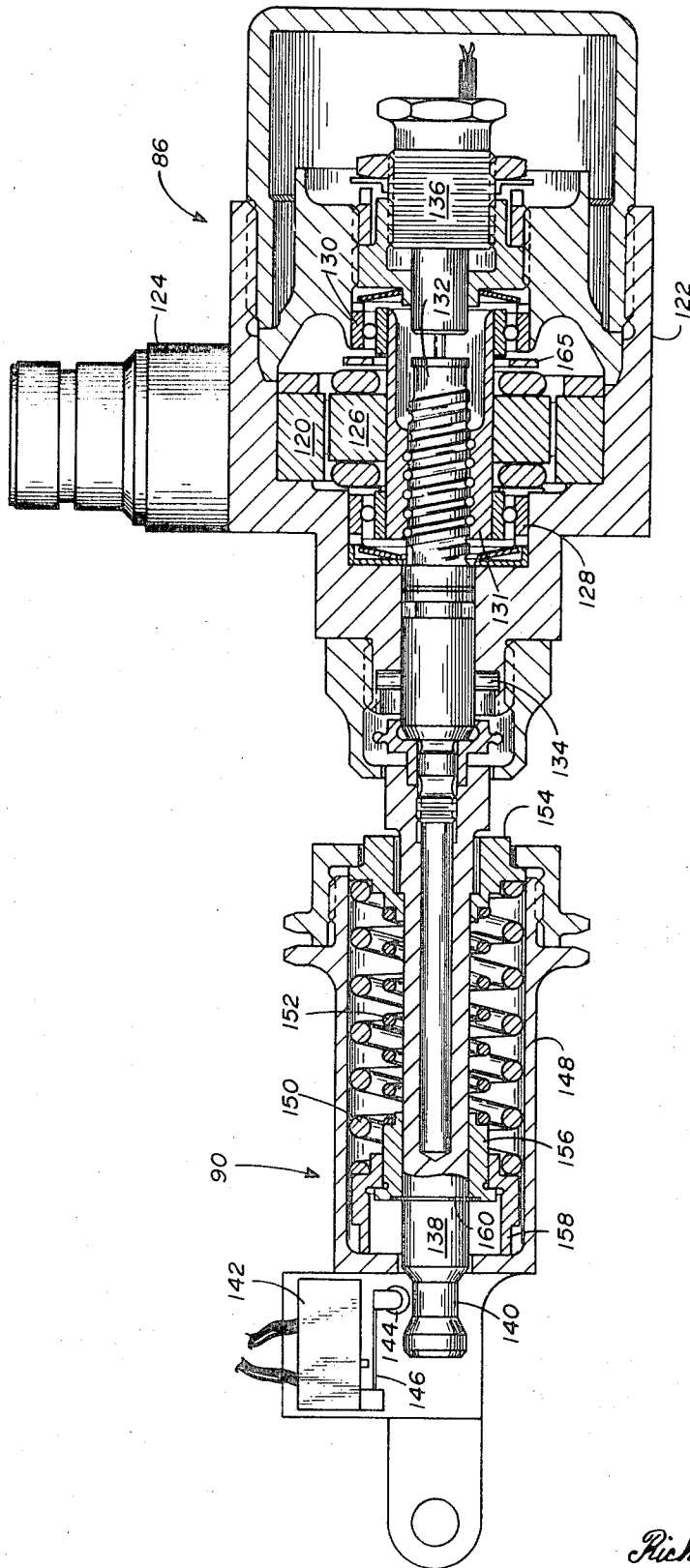


FIG. 4

INVENTORS:
WERNER G. KOCH
JACK M'CURLEY

Richards, Harris & Hubbard
ATTORNEYS

FORCE SUMMING MULTIPLEX ACTUATOR

This invention relates to a multiplex actuator, and more particularly to a force summing redundant channel multiplex actuator.

It was early realized that as aircraft increase in size and speed that conventional cable and mechanical linkage control mechanisms are inadequate and there is a need for electrical flight control systems. There has, however, been some reluctance to accept the electrical flight control system because it is thought that mechanical systems are more reliable. To improve the reliability of electrical control, a system of redundant parallel channels has been implemented.

Heretofore, approaches for providing redundancy have typically resulted in double control chains or channels in which a failure in one channel hopefully would permit the other channels to carry on the necessary command functions. Such a system, depending upon the particular failure suffered, generally experienced at least degradation of control when the failed channel must be "dragged" by the operating channel or channels.

When redundant control channels are employed to improve the system reliability the several channels must eventually terminate at a single master power drive that positions the control surface of the aircraft. The several channels may be brought together at the master power drive either in a "force summing" configuration or a "displacement summing" configuration.

When the several channels of a redundant control system are "displacement summed," the output of each channel is combined in a series arrangement. Displacement summing (series summing) has the advantage that the remaining active channels do not have to drag the failed channel. In the conventional displacement summing system, the several redundant channels are combined to produce the total desired range of movement for the aircraft control surface. Upon a failure of one of these channels, some loss of stroke of the master power drive results with the attendant loss in the range of movement of the control surface.

In the "forcing summing" configuration, the outputs of the several channels are connected to a common summing point. The forces developed by each of the channels are summed at this common point into a single force motion. Upon a failure of any one of the several channels, the remaining channels will continue to position the aircraft control surfaces through the full range of operation. Heretofore, in the force summing arrangements, the failed channel created a drag on the remaining active channels. Another of the disadvantages of previous force summing systems is that a "jam" in any one of the several channels may result in a catastrophic failure.

An object of this invention is to provide a multiplex actuator in a redundant control system wherein the actuator has full stroke output capabilities upon a failure of all but two of the redundant channels. Another object of this invention is to provide a multiplex actuator in a redundant control system wherein the several control channels are force summed. A further object of this invention is to provide a multiplex actuator in a redundant control system wherein the failure of one of the several channels does not produce a drag on the remaining active channels. Still another object of this invention is to provide a multiplex actuator in a redundant control system wherein malfunctioning channels are disconnected from the control signals.

In accordance with this invention, a multiplex actuator having an output motion that varies in accordance with generated control signals includes a plurality of control channels with each channel having rotary-to-linear motion transducer responsive to a separate one of the generated control signals. The linear motion output of the transducer for each channel is transmitted to an attachment point when a force applied to a breakaway force coupler is below a breakout value. If the force between the attachment point and the output of the motion transducer exceed the breakout value by a given amount, a switch carried by the coupler is actuated, thereby disconnecting the transducer from the generated control signal.

Each of the several control channels connects to a force bar at the attachment point to produce an output motion that varies in accordance with the generated signal energizing each of the control channels.

In accordance with a more specific embodiment of the invention, a multiplex actuator for positioning an aircraft control surface by means of a power ram in accordance with pilot generated control signals includes a first control channel pair coupled together in a force summing arrangement to a common attachment point. Each of the control channels includes: a rotary-to-linear motion transducer responsive to a separate one of the pilot generated control signals; a breakaway force coupler engaging the output of the transducer for transferring the linear motion thereof to the common attachment point when the force applied between the attachment point and the transducer is below a breakout value; and a switch carried by the coupler and actuated when the force applied thereto exceeds by a given amount the breakout value to disconnect the transducer from the generated control signal. A second control channel pair is also force summed at a common attachment point. Each of the control channels of the second pair is similar to those of the first pair. The common attachment points of the two control channel pairs are connected to a torque tube that produces an output motion in accordance with the pilot generated signals to the various control channels. A rotary-to-linear motion transducer converts the rotary output of the torque tube into a linear motion for controlling the power ram.

A more complete understanding of the invention and its advantages will be apparent from the specification and claims and from the accompanying drawings illustrative of the invention.

Referring to the drawings:

FIG. 1 is a schematic of a redundant control system including a force summing multiplex actuator having a linear output coupled to a servo-valve for controlling a power ram connected to an aircraft control surface;

FIG. 2 is a block diagram of a quadruplex input force summing actuator producing a linear output for coupling to a servo-valve;

FIG. 3 is a schematic of a quadruplex input force summing actuator employing rotary-to-linear motion transducers and breakaway force couplers;

FIG. 4 is a cross section of the transducer and breakaway force coupler of one channel of the actuator of FIG. 3;

FIG. 5 is a plot of force as a function of displacement for a breakaway force coupler of the system of FIG. 3; and

FIG. 6 is a cross section of a breakaway force coupler having complimentary release characteristics from the coupler of FIG. 4.

Referring to FIG. 1, there is shown a multiplex actuator 10 having four electrical signals applied to terminals 11 through 14. These control signals may be generated in a conventional manner by a stick transducer that converts a mechanical input from a pilot's control stick into electrical signals. The pilot's control input, converted into electrical signals by the stick transducer, is transmitted to the terminals 11 through 14 by a parallel arrangement of wires which may be located at different paths in the air frame to minimize the possibility of a disruption of all the pilot generated control signals to the actuator 10. In addition to pilot generated signals, the electrical signals on terminals 11 through 14 may be received from autopilot sensors, a stability augmentation system, or from other systems, such as a navigation control.

The multiplex actuator 10 produces a linear motion output on a connecting rod 16; the linear motion varies in accordance with the pilot generated control signals on the terminals 11 through 14 in a manner to be described. Coupled to the output of the actuator 10 is a dual tandem servo-valve 18 providing fluid pressure signals to a dual tandem power ram 20. The servo-valve 18 includes a cylinder 22 having a spool valve 24 slidably disposed therein and including interconnected lands 25 through 31. Conduits 32 and 34 interconnect the first sec-

tion of the servo-valve 18 to a pressure supply and reservoir (neither shown), respectively. Similarly, conduits 36 and 38 connect the second section of the valve 18 to a source of fluid pressure and a fluid reservoir (neither shown), respectively. Conduits 40 and 42 interconnect the first section of the valve 18 to the first stage of the power ram 20 on opposite sides of a piston 48. Conduits 44 and 46 similarly interconnect the second stage of the valve 18 to the second stage of the power ram 20 on opposite sides of a piston 50.

Pistons 48 and 50 of the power ram 20 are interconnected on a piston rod 52 that has an external coupling to a link 54. Link 54 is intended to represent the mechanical linkage between a power ram and one of the control surfaces 56 of an aircraft. The piston rod 52 is in the form of a hollow shaft and is positionable over a linear voltage differential transformer 58 that generates four separate but equal position feedback signals on lines 59 through 62. Feedback signals on the line 59 through 62 are applied to the multiplex actuator 10 to balance the pilot generated signals on the terminals 11 through 14 to stop the motion of the connecting rod 16 at a new desired position.

Referring to FIG. 2, there is shown a quadruplex force summing actuator wherein the pilot generated signals are applied to the terminals 11 through 14. At present, quadruplex actuators provide the most favorable degree of redundancy for many actuator applications, but any degree of redundancy may be used with the force summing system of the present invention.

The system of FIG. 2 consists of four control channels and includes electromechanical converters 66 through 69, summing amplifiers 70 through 73 responsive to the pilot control signals and feedback signals, and disconnect switches 74 through 77. Output connecting rods of the converters 66 through 69 are coupled to a torque tube 78 which sums the converter outputs into an oscillating motion. This oscillating motion is then converted into a linear displacement for driving the dual tandem servo-valve 18 through the connecting rod 16. The four-channel linear voltage differential transformer (LVDT) 58 is illustrated responsive to movement of the servo-valve 18 through a linkage 80 that is intended to represent the operation of the power ram 20 in response to signals from the servo-valve 18. The four-unit LVD transformer 58 is used to provide electrical signals which are proportional to the position of the control surface 56 for the system followup or feedback loop. Typically, a four-unit LVDT is a cluster of four separate transducers in a common housing.

Referring to FIG. 3, there is shown the four electromechanical converters 66 through 69 coupled to the torque tube 78. Converters 66 and 68 are coupled together in a force summing arrangement at a common attachment point 82 connected to the tube 78. Similarly, converters 67 and 69 are coupled in a force summing arrangement at a common attachment point 84, also connected to the tube 78.

Converter 66 includes a rotary-to-linear motion transducer 86 having an output shaft 88 engaging a breakaway coupler 90. The breakaway coupler 90 transmits the motion of the output shaft 88 to the attachment point 82 as a rigid link when the force developed across the coupler is below an established breakout level. In a similar arrangement, the converter 67 comprises a rotary-to-linear motion transducer 92 having an output shaft 94 engaging a breakaway coupler 96. Coupler 96 transmits motion at the output shaft 94 to the common attachment point 84. The converter 68 includes a rotary-to-linear motion transducer 98 having an output shaft 100 engaging a breakaway coupler 102 that connects to the attachment point 82. The fourth channel of the system illustrated includes the converter 69 which comprises a rotary-to-linear motion transducer 104 having an output shaft 106 engaging a breakaway coupler 108. Coupler 108 transmits the motion of the output shaft 106 to the attachment point 84 when the force developed across the coupler is below the breakout level.

Rotary oscillating motion produced on the torque tube 78 by force summing the output motion of the rotary-to-linear transducers of the converters 66 through 69 is converted into a linear displacement for positioning the servo-valve 18 through a mechanical linkage. The mechanical linkage includes an arm 110 attached to the torque tube 78 and having a pivotal connection to a connecting link 112. Link 112 also has a pivotal connection to an arm 114 secured to a stub shaft 116. The stub shaft 116 includes a sliding member 118 engaging the spool valve 24 of the servo-valve 18. It should be understood, that the illustration of a torque tube 78 and the mechanical linkage arrangement connected to the servo-valve 18 is intended as showing only one embodiment of force summing mechanism for the four control channels.

Referring to FIG. 4, there is shown in cross section the electromechanical converter 66 for the control channel of the actuator system of FIG. 2. The other converters of the actuator are similarly constructed. The rotary-to-linear motion transducer 86 has a permanent magnet stator 120 mounted in a housing 122. The pilot generated signal is applied through a connector 124 to a brush ring 165 and then to an armature 126. The armature 126 rotates, by the interaction between its electrical field and the magnetic field of the stator 120. It is mounted to rotate in the housing 122 by means of bearings 128 and 130. A ball nut 131 is fixed to the armature 126 and engages a lead screw 132 that extends through the housing 122 as part of the output shaft 88. Linear motion results from the operation of the lead screw 132 and the ball nut 131. This ball-screw arrangement provides a high-efficiency gearing and allows the individual converters to be back driven in the event of a failure. To produce this linear motion, the lead screw 132 is restrained from rotating by means of a dowel pin 134.

Also included as part of the transducer 86 is a linear voltage differential transformer 136 threaded into the housing 122 and engaging the lead screw 132 for generating a position feedback signal. This feedback signal is transmitted through the connector 124 to the summing amplifier 70, as explained. The transducer position feedback signal plus the feedback signal from the power ram are thus both summed in the amplifier 70 to balance the pilot generated control signal at terminal 11.

An output motion from the transducer as evidenced by movement of the lead screw 132 is transmitted to the attachment point 82 through the breakaway force coupler 90. As illustrated in FIG. 4, the breakaway coupler includes a connecting rod 138 coupled to the output shaft 88 of the rotary-to-linear motion transducer. A detent 140 at the extreme end of the rod 138 is provided to control the actuation of a microswitch 142. During the normal operation of the converter 66, a roller 144 at the end of an actuating arm 146 for the switch 142 fits into the detent 140. When the rod 138 moves either to the left or right of the position shown, the roller 144 engages the rod thereby actuating the switch 142. Switch 142 has lead wires (not shown) connected to the disconnect 74. When the switch 142 is actuated, it energizes the disconnect 74 to isolate the rotary-to-linear motion transducer 86 from the amplifier 70. By properly sizing the detent 140, some movement of the rod 138 may occur without actuating the switch 142.

In normal operation, the rod 138 is held in a fixed position thereby forming a rigid coupling between the output shaft of the transducer 86 and the attachment point of the breakaway coupler 90. To maintain the rod 138 in a fixed position relative to the housing 148 of the coupler 90, two springs 150 and 152 are preloaded into the housing between collets 154, 156 and 158. In the position shown, the collet 154 engages a shoulder on the rod 138 and one end of the housing 148. The collet 156 is restrained on the rod 138 by means of a retaining ring 160. The spring 152 is preloaded between the collets 154 and 156. Collet 158 is movable with respect to the collet 156 and the housing 148; in the position shown, it is at rest against the housing 148 and a shoulder of the collet 156. The spring 150 is preloaded between the collet 154 and the collet 158.

An important feature of the actuator of the present invention is the asymmetrical breakout of the coupler 90. That is, the force required to move the rod 138 with respect to the housing 148 in one direction is different than the force required to move the rod in the opposite direction. Consider that the output shaft of the transducer 86 is held stationary and the housing 148 has a force exerted thereon tending to move it toward the left. The force required to move the rod 138 relative to the housing 148 in this case must be sufficient to overcome the preload of the springs 150 and 152. A force tending to move the housing 148 toward the left will cause the collet 154 to follow the housing and become disengaged from the shoulder on the rod 138. The collets 156 and 158, however, will remain in the position illustrated relative to the rod 138 by means of the retaining ring 160. Thus, the preload of both springs must be overcome to displace the rod 138 relative to the housing 148. Now if it is assumed that a force is exerted on the housing 148 tending to move it toward the right, then collet 158 will move toward the right with respect to the collet 156. The collets 154 and 156, however, will be held in the spaced relationship shown by means of the shoulder on the rod 138 and the retaining ring 160, respectively. Thus, to displace the housing 148 toward the right with respect to the rod 138, requires only a force sufficient to overcome the preload of the spring 150. In this case, the spring 152 is bypassed. Accordingly, the breakout of the coupler 90 is asymmetrical between the extend and retract displacement of the transducer 86.

Referring to FIG. 5, there is shown a plot of force versus displacement for the extend and retracted directions. Before displacement takes place between the rod 138 and the housing 148 in the extend direction, that is, movement of the lead screw 132 toward the left, a force must be developed as indicated by the intersection of the vertical axis and the line 162. After the initial breakaway force has been exceeded, additional displacement between the rod 138 and the housing 148 takes place as the force increases as along the line 162. In the retract direction, that is, movement of the lead screw 132 toward the right, a displacement between the rod 138 and the housing 148 will take place when a force is developed that exceeds that indicated by the intersection of the line 164 and the vertical axis. Again, additional displacement will be developed as the force increases as along the line 164.

By providing asymmetrical breakout in the coupler 90, a positive positioning of the torque tube 78 is assured. Because of manufacturing tolerances, the displacement developed by two converters, such as converters 66 and 68, will not be equal even though both converters are controlled from identical signals. One or the other of the two converters will produce a greater displacement than the other for the same control signal. When this occurs, one of the couplers 90 will "breakaway" thereby displacing the rod 138 from the housing 148. The remaining coupler, however, will remain rigid thereby fixing the position of the torque tube 78.

To couple two converters to a common attachment point in an opposing force summing configuration the breakout of the two opposing couplers must be in the same direction. That is, between the couplers 90 and 102, if the extend breakout of the coupler 90 is less than the retract breakout, than for the coupler 102 to retract breakout must be less than the extend breakout.

Referring to FIG. 6, there is shown a cross section of the coupler 102 providing asymmetrical breakout in the reverse direction from the coupler 90. The same reference numerals will be used to show the similarity and differences between the couplers 90 and 102. Connecting rod 138 of the coupler 102 is maintained in a fixed spaced relationship with respect to the housing 148 by means of the preloaded springs 150 and 152. Collets 154, 156 and 158 maintain the springs 150 and 152 in the preloaded condition. Collet 154 is positioned on the rod 138 against the retaining ring 160 and engages the housing 148. Collets 156 and 158 are shown positioned against the shoulder of the rod 138 and the housing 148, respectively.

Assume the output shaft 100 of the transducer 98 is held in a fixed position, then to displace the rod 138 of the coupler 102 with respect to the housing 148 a force must be exerted on the coupler housing toward the right which is sufficient to overcome the preload of both springs 150 and 152. With the collet arrangement as illustrated in FIG. 6, movement of the housing 148 toward the right carries with it the collet 154 which then moves away from the retaining ring 160. Both springs 150 and 152 must thus be compressed before a displacement between the rod 138 and the housing 148 takes place. A force exerted on the housing 148 of the coupler 102 toward the left which is sufficient to overcome the preload of the spring 150 causes the collet 158 to move with respect to the collet 156. The spring 152 in this case moves with the rod 138 and thus does not effect the total force required to cause a displacement between the coupler rod and coupler housing. This operation is the reverse of that described previously with respect to the coupler 90 of FIG. 4.

By arranging the couplers 90 and 102 as illustrated, the breakaway force will always be greater in one direction (toward the right) than the other (toward the left). A similar arrangement is provided between the couplers 96 and 108. Coupler 96 being similar to coupler 90 and coupler 108 being similar to coupler 102.

In operation, a pilot generated signal at the terminal 11 appears as an output voltage from the summing amplifier 70 to drive the electromechanical converter 66 through the disconnect 74. The output shaft of the converter 66 either extends or retracts depending on the magnitude and polarity of the pilot generated signal. A position feedback signal from a feedback transducer in the converter 66 is applied to one input of the summing amplifier 70 to balance the pilot generated signal. A separate but equal pilot generated signal at the terminal 13 is processed through the summing amplifier 72 to drive the electromechanical converter 68 through the disconnect 76. By properly polarizing the signals to the converters 66 and 68, the same pilot control signals will cause one of the converters to extend the output shaft while the other retracts thus producing a combined movement in one direction at the attachment point 82. If the displacement of the output shaft of the converters 66 and 68 are exactly equal, the breakaway coupler in each of these units will remain a rigid link between the attachment point 82 and the respective rotary-to-linear motion transducer. If, however, the output of one of the converters is displaced more than the other, one of the breakaway couplers will breakout, thereby disconnecting the respective transducer from a rigid link to the attachment point. Note that so long as this breakout movement is such that the switch 142 is not actuated, the transducer of the affected channel will be coupled to the summing amplifier output.

A similar control channel pair is attached to the attachment point 84. A pilot generated signal at the input terminal 12 appears at the output terminal of the summing amplifier 71 to drive the electromechanical converter 67 through the disconnect 75. A feedback signal from the position transducer of the converter 67 appears at a second input to the amplifier 71 to balance out the pilot generated signal. The fourth pilot generated signal appearing at the input terminal 14 is applied to the summing amplifier 73 that generates an output for driving the electromechanical converter 69 through the disconnect 77. Converter 69 also includes a position transducer for generating a feedback signal connected to a second input of the summing amplifier 73 to balance out the pilot generated signal. Converters 67 and 69 are coupled to the attachment point 84 in a force summing arrangement. These two converters are polarized in a manner such that when the output shaft of one is extending, the output shaft of the opposite is retracting to produce a net movement in one direction at the attachment point 84.

As oscillating motion imparted to the torque tube 78 by operation of the converters 66 through 69 is converted into a linear displacement of the connecting rod 16 to position the servo-valve 18. The power ram 20 responds to signals

generated by the servo-valve 18 and moves the control surface 56 in accordance with the pilot generated signals. The linear voltage differential transformer 58 of the power ram generates four position feedback signals each coupled to one of the summing amplifiers 70 through 73. These position feedback signals are a final adjustment to balance out the pilot generated signals and produce the desired output from the converters 66 through 69.

Should a malfunction occur such that the converter unit of one channel no longer provides the correct force to the torque tube 78, the breakaway coupler of that channel will break out. When the breakout displacement of the coupler exceeds a given amount, the disconnect in that channel will be actuated by the coupler carried switch, thereby isolating the converter from the pilot generated signal. With the signal to a converter cut off through the disconnect, the breakaway coupler of that converter will return to a nonbreakout state. In such a situation, the converter will be back driven by the remaining active channels with little, if any, performance degradation. Such operation is possible because of the highly efficient ball-screw unit. The active channels are able to back drive the failed channel and still provide a nearly normal output performance.

After one channel has failed due to a malfunction, it can be reactivated by the pilot through a reset circuit in the disconnect. Such a feature is desirable since the original malfunction may be temporary and self-correct after a short time. By providing a reset in the disconnect, the system can be checked out. A simulated failure is injected into each channel in sequence. After the check out the channels are reactivated through the reset circuit.

If a failure in one channel is the result of a jam in the armature or motor, the breakaway coupler enables the remaining unit to continue to provide a control function. When a jam occurs in a converter, the breakaway coupler in that channel continues to break out as the remaining active channels continue to position the torque tube 78.

Each of the channels of the actuator is also continuously monitored by a comparator circuit 168 that determines the number of channels that have malfunctioned. When any two of the four channels malfunction, leaving only two remaining active channels, the comparator circuit 168 will generate an alarm signal to the pilot. With only two active channels, there is the possibility that if one of the remaining channels malfunctions it will overpower the other active channel. This may cause the control surface 56 to be positioned hard-over resulting in a catastrophic failure. When the pilot is signaled that only two of the four channels are still active, he may make proper corrective action to minimize the possibility of a hard-over positioning of the control surface.

While only one embodiment of the invention, together with modifications thereof, has been described in detail herein and shown in the accompanying drawings, it will be evident that various further modifications are possible with departing from the scope of the invention.

What is claimed is:

1. A multiple actuator having an output motion that varies in accordance with generated control signals, comprising:

- a plurality of control channels each including a rotary-to-linear motion transducer responsive to a separate one of the generated control signals, motion transmitting means for transferring the linear motion produced by the transducer to an attachment point, said motion transmitting means having:
 - a. first and second members movable relative to each other, one member coupled to the output of the transducer and the second member coupled to the attachment point,
 - b. first means for restraining the movement of the first and second members relative to each other in a first direction below a first breakout value, and
 - c. second means for restraining the movement of the first and second members relative to each other in a second direction below a second breakout value greater than the first breakout value,

and switching means carried by said motion transmitting means and actuated thereby when the force applied thereto exceeds the breakout values to disconnect the transducer from the generated control signal, and

a forcing bar having the attachment point of each of the plurality of control channels connected thereto and producing an output motion varying in accordance with the generated signal energizing each of the control channels.

2. A multiplex actuator having an output motion that varies in accordance with generated control signals, comprising:

a plurality of control channels each including a rotary-to-linear motion transducer responsive to a separate one of the generated control signals, and motion transmitting means coupled to the output of the transducer for transferring the linear motion produced thereby to an attachment point, said motion transmitting means including:

- a. first and second members movable relative to each other, one member coupled to the output of the transducer and the second member coupled to the attachment point,
- b. first means for restraining the movement of the first and second members relative to each other in a first direction below a first breakout value, and
- c. second means for restraining the movement of the first and second members relative to each other in a second direction below a second breakout value greater than the first breakout value, and

a force bar having the attachment point of each of the plurality of control channels connected thereto and producing an output motion varying in accordance with the generated signals energizing each of the control channels.

3. A multiplex actuator having an output motion that varies in accordance with generated control signals as set forth in claim 2 including a position transducer in each of the control channels coupled to said rotary-to-linear motion transducer for generating a position feedback signal from the motion transducer to balance out the generated control signal applied thereto.

4. A multiplex actuator having an output motion that varies in accordance with generated control signals as set forth in claim 2 wherein said force bar is a torque tube having a pivotal connection to each of said plurality of control channels and producing a rotary output from said actuator.

5. A multiplex actuator having an output motion that varies in accordance with generated control signals, comprising:

a plurality of control channels each including a rotary-to-linear motion transducer responsive to a separate one of the generated control signals, and motion transmitting means coupled to the output of the transducer for transferring the linear motion produced thereby to an attachment point, said motion transmitting means including:

- a. a housing pivotally connected to the attachment point,
- b. a connecting rod slidably positioned in said housing and coupled to the output of said motion transducer,
- c. a first collet fitted over said rod and engaging a stop thereon and said housing,
- d. a second collet also fitted over said rod and engaging a stop thereon,
- e. a first spring positioned between said first and second collets in a preloaded condition,
- f. a third collet concentrically mounted with said second collet and movable with respect thereto and engaging said housing, and
- g. a second spring positioned between said first and third collets in a preloaded condition, said first and second springs establishing an asymmetrical breakout force for movement of the connecting rod with respect to the housing, and

a force bar having the attachment point of each of the plurality of control channels connected thereto and producing an output motion varying in accordance with the generated signals energizing each of the control channels.

6. A multiplex actuator for positioning an aircraft control surface in accordance with pilot generated control signals, comprising:

- a plurality of control channels each including a rotary-to-linear motion transducer responsive to a separate one of the generated control signals, a breakaway force coupler coupled to the output of the transducer for transferring the output motion to an attachment point, said breakaway force coupler including:
 - a. first and second members movable relative to each other, one member coupled to the output of the transducer and the second member coupled to the attachment point,
 - b. first means for restraining the movement of the first and second members relative to each other in a first direction below a first breakout value, and
 - c. second means for restraining the movement of the first and second members relative to each other in a second direction below a second breakout value greater than the first breakout value, and

switching means carried by the breakaway coupler and actuated thereby when the force applied thereto exceeds by a given amount the breakout values to disconnect the transducer from the generated control signal,

a position transducer in each of the control channels coupled to said rotary-to-linear motion transducer for generating a position feedback signal connected to the respective amplifier for that channel, and

a force bar having the attachment point of each of the plurality of control channels connected thereto and producing an output motion for controlling a power ram connected to said aircraft surface for varying the position of said surface in accordance with the pilot generated control signals.

7. A multiplex actuator for positioning an aircraft control surface as set forth in claim 6 including means for monitoring the output of all of said plurality of control channels and generating an alarm signal when the switching means carried by all but two of said channels is actuated.

8. A multiplex actuator for positioning an aircraft control surface as set forth in claim 6 wherein said force bar is a torque tube having a pivotal connection to each of said plurality of control channels and producing a rotary output, and including a rotary-to-linear motion transducer for generating the control signals to said power ram.

9. A multiplex actuator for positioning an aircraft control surface as set forth in claim 6 wherein said rotary-to-linear motion transducer includes a lead screw connected to said breakaway coupler and a ball-nut assembly as part of a motor armature, said lead screw and ball-nut assembly may be back driven by a force applied to the output of said transducer.

10. A multiplex actuator for positioning an aircraft control surface in accordance with pilot generated control signals, comprising:

- a plurality of control channels each including a rotary-to-linear motion transducer responsive to a separate one of the generated control signals, a breakaway force coupler coupled to the output of the transducer for transferring the output motion to an attachment point, said breakaway force coupler including:
 - a. a housing pivotally connected to the attachment point,
 - b. a connecting rod slidably positioned in said housing and coupled to the output of said motion transducer,
 - c. a first collet fitted over said rod and engaging a stop thereon and said housing,
 - d. a second collet also fitted over said rod and engaging a stop thereon,
 - e. a first spring positioned between said first and second collets in a preloaded condition,
 - f. a third collet concentrically mounted with said second collet and movable with respect thereto and engaging said housing, and

g. a second spring positioned between said first and third collets in a preloaded condition, said first and second springs establishing an asymmetrical breakout force for movement of the connecting rod with respect to the housing, and

switching means carried by the breakaway coupler and actuated thereby when the force applied thereto exceeds by a given amount the breakout values to disconnect the transducer from the generated signal,

a position transducer in each of the control channels coupled to said rotary-to-linear motion transducer for generating a position feedback signal connected to the respective amplifier for that channel, and

a force bar having the attachment point of each of the plurality of control channels connected thereto and producing an output motion for controlling a power ram connected to said aircraft surface for varying the position of said surface in accordance with the pilot generated control signals.

11. A multiplex actuator for positioning an aircraft control surface by means of a power ram in accordance with pilot generated control signals, comprising:

a first control channel pair coupled together in a force summing arrangement to a common attachment point, each of said control channels including a rotary-to-linear motion transducer responsive to a separate one of the generated control signals, a breakaway force coupler engaging the output of the transducer for transferring the linear motion output thereof to the common attachment point, said breakaway force coupler including:

- a. first and second members movable relative to each other, one member coupled to the output of the transducer and the second member coupled to the attachment point,

- b. first means for restraining the movement of the first and second members relative to each other in a first direction below a first breakout value, and

- c. second means for restraining the movement of the first and second members relative to each other in a second direction below a second breakout value greater than the first breakout value, and

switching means carried by the coupler and actuated thereby when the force applied thereto exceeds by a given amount the established breakout values to disconnect the transducer from the generated control signal,

a second control channel pair coupled together in a force summing arrangement to a common attachment point, each of the control channels including a rotary-to-linear motion transducer responsive to a separate one of the generated control signals, a breakaway force coupler engaging the output of the transducer for transferring the linear motion output thereof to the common attachment point, said breakaway force coupler including:

- a. first and second members movable relative to each other, one member coupled to the output of the transducer and the second member coupled to the attachment point,

- b. first means for restraining the movement of the first and second members relative to each other in a first direction below a first breakout value, and

- c. second means for restraining the movement of the first and second members relative to each other in a second direction below a second breakout value greater than the first breakout value, and

switching means carried by the coupler and actuated thereby when the force applied thereto exceeds by a given amount the established breakout values to disconnect the transducer from the generated control signal,

a position transducer in each of the control channels connected to the rotary-to-linear motion transducer for generating a position feedback signal from the motion transducer to balance out the pilot generated signal connected thereto,

11

a torque tube having the common attachment points for the said first and second control pairs connected thereto and producing an output motion varying in accordance with the pilot generated signal, and means for converting the rotary motion at said torque tube into a linear motion for controlling the power ram connected to an aircraft control surface.

12. A multiplex actuator for positioning an aircraft control surface as set forth in claim 11 wherein the rotary-to-linear motion transducer in each control channel comprises a ball-nut and lead-screw assembly which may be back driven by the other control channels coupled to said torque tube.

13. A multiplex actuator for positioning an aircraft control surface as set forth in claim 12 wherein the position transducer in each of the control channels comprises a linear volt-

12

age differential transformer.

14. A multiplex actuator for positioning an aircraft control surface as set forth in claim 11 including means for monitoring each of the breakaway couplers for generating a pilot alarm signal when the switching means of all but two of the four channels has been actuated by an excessive breakout force.

15. A multiplex actuator for positioning an aircraft control surface as set forth in claim 14 including a plurality of summing amplifiers each having an output connected to one of the rotary-to-linear motion transducers of the control channel through a switch actuated disconnect and a first input connected to one of the pilot generated control signals and a second input connected to the respective feedback signal from the position transducer.

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