May 14, 1968 J. W. RAIDER 3,382,769

DIGITAL HYDRAULIC ACTUATOR

Filed April 4, 1966 2 Sheets-Sheet 1

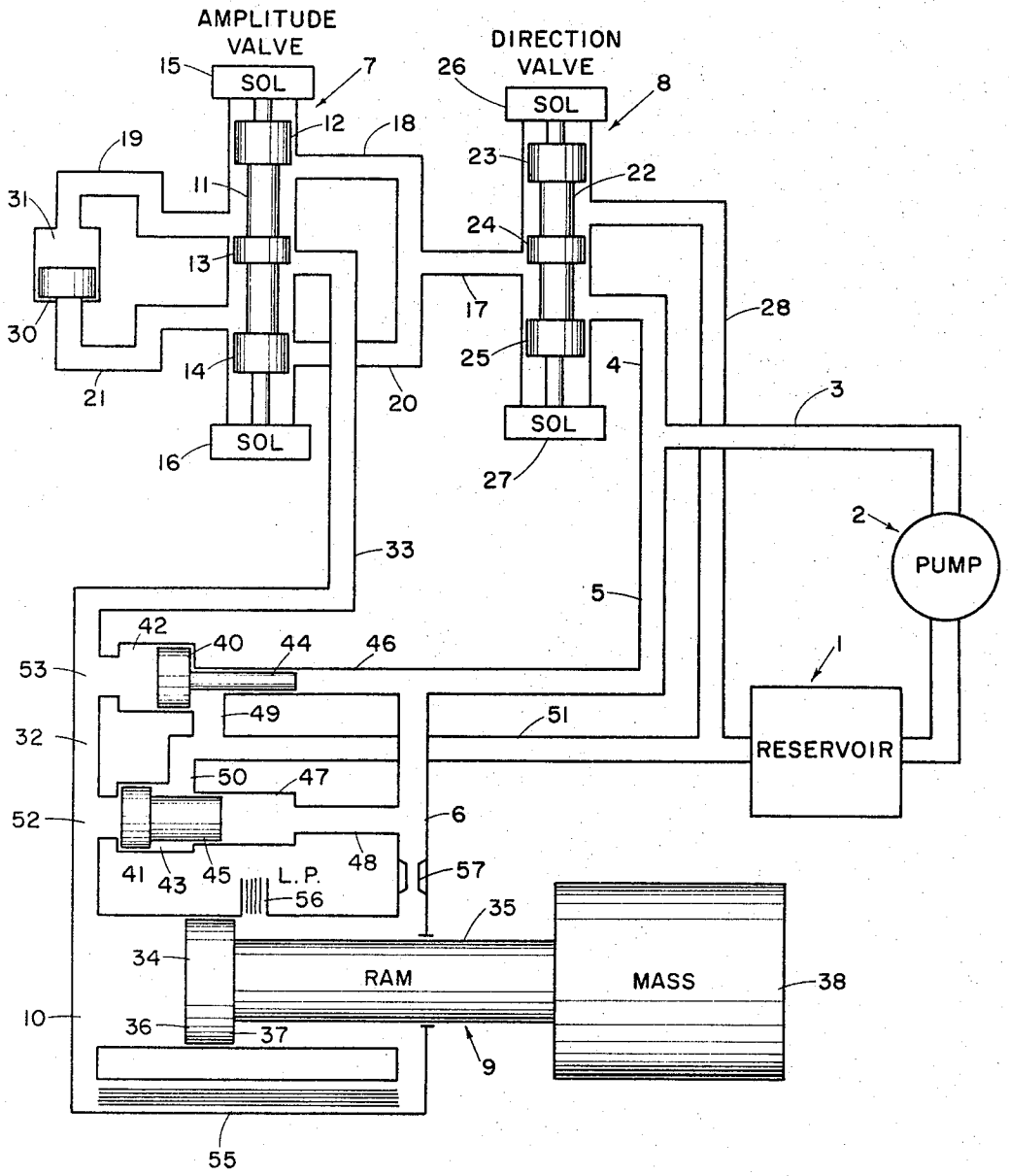

Fig. 1

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Filed April 4, 1966 2 Sheets-Sheet 2

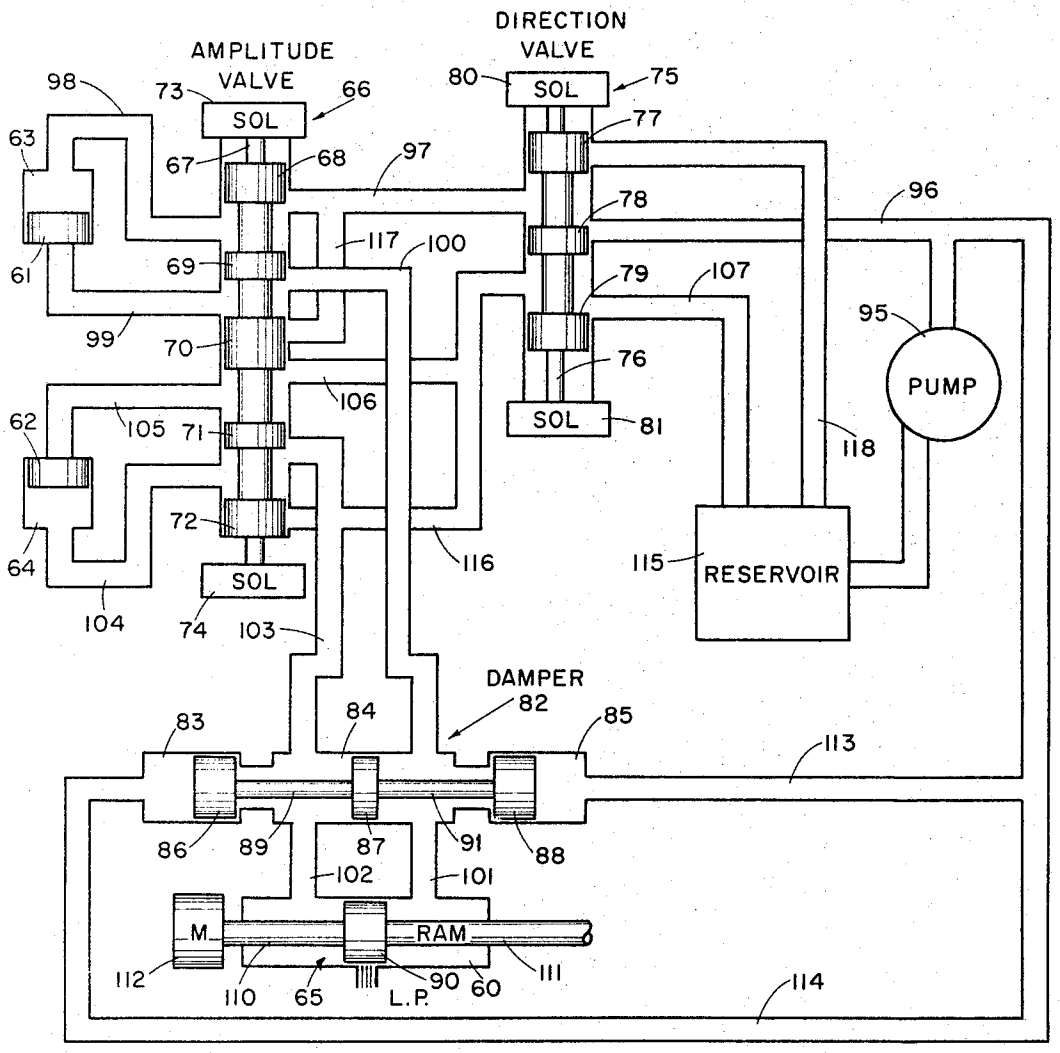

Fig. 2

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DIGITAL HYDRAULIC ACTUATOR

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ABSTRACT OF THE DISCLOSURE

The digital hydraulic actuator disclosed contains a fluid metering feature wherein a so-called "volume piston" is adapted to move back and forth from one end to the other of its accommodating cylinder to transfer fixed and equal amounts of fluid between a fluid supply and a control cylinder containing a movable ram. A solenoid-operated amplitude control valve allows this volume piston to move in the above manner and still feed fluid into one end of the control cylinder to advance the ram in equal incremental steps in a given direction. A solenoid-operated directional control valve determines whether this metered fluid flows into or out of this end of the control cylinder and, consequently, the direction of ram movement.

The present invention relates generally to electromechanical control systems and, more particularly, to apparatus for converting electrical signal information into mechanical displacement.

In numerous electromechanical control systems, it is necessary to convert digital electrical signals into analog movement. One type of apparatus which has been devised for this transformation is the so-called "digital hydraulic actuator." In this hydraulic device, the electrical signals actuate flow valves so that predetermined amounts of fluid corresponding to the information represented by these signals are transferred to and from a control cylinder for positioning an output piston in accordance with the movement desired.

It is accordingly a primary object of the present invention to provide a digital hydraulic actuator wherein a volume piston meters the amount of fluid transferred between the control cylinder and the fluid supply

Another object of the present invention is to provide a digital hydraulic actuator wherein the fluid entering and leaving the control cylinder is monitored simultaneously.

A still further object of the present invention is to provide a system for translating digital electrical signal information into mechanical movement.

A yet still further object of the present invention is to provide a digital hydraulic actuator with a fluid damping provision which insures a smooth displacement of the output piston between its successive positions.

A yet still further object of the present invention is to provide a digital hydraulic actuator having a controlled drift feature.

Other objects, advantages and novel features of the invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings wherein:

FIG. 1 illustrates one embodiment of the invention; and

FIG. 2 illustrates an embodiment wherein the fluid entering and leaving the actuating cylinder is metered.

Briefly and in general terms, the above objects of invention are achieved by utilizing as the fluid metering element of the hydraulic system a so-called "volume piston" which is adapted to travel back and forth from one end to the other of its cylinder to transfer fixed and

equal amounts of fluid between the fluid supply and the control cylinder. In one modification, a solenoid-operated amplitude control valve which can be set in either of two positions allows this volume piston to move in the bidirectional fashion mentioned above and still feed fluid into one end of the control cylinder to advance the output piston in equal incremental steps in a given direction. To reverse this direction, a second solenoid-operated valve, which likewise can be set in two positions, is employed, and this valve determines whether the metered volume of fluid flows into or out of this end of the control cylinder. The direction of this flow determines the direction of piston advance.

In an alternative embodiment, a pair of volume pistons are utilized, and these pistons meter simultaneously the amount of fluid flowing into one end of the actuating cylinder and the amount of fluid flowing out the other end thereof. The directional valve in this modification determines which end of the cylinder the metered flow enters and leaves.

Referring now to FIG. 1 of the drawings which illustrates an incremental digital actuator, according to one embodiment of the invention, it will be seen that the over-all hydraulic system contains a fluid supply or reservoir **1** to which is coupled a pump **2** for establishing a predetermined high pressure condition in line **3** and the various branch lines, such as **4**, **5** and **6** extending therefrom. Included in this system are a pair of solenoid-operated bistable valves **7** and **8**. The first of these, valve **7**, which controls the amplitude of movement of the output ram **9** accommodated in actuating cylinder **10**, includes a spool **11** having lands **12**, **13** and **14** mounted thereon. Valve **7** has as its electrical control elements a pair of solenoids **15** and **16** which cooperate with opposite ends of spool **11**. In the condition shown in FIG. 1, solenoid **15** has been energized and spool **11** is in its upper position. In this position, land **12** opens a passageway from lines **17**, **18** to line **19**, while lower land **14** blocks an alternative passageway from lines **17**, **20** to line **21**. Valve **7**, it will be appreciated, remains in the condition shown until solenoid **16** is operated. Then the first path described above is blocked and the second path opened.

Directional valve **8** includes a spool **22** having lands **23**, **24** and **25** mounted thereon. This valve, like valve **7**, has a pair of solenoids **26** and **27** cooperating with opposite ends of this spool for shifting it between its upper position, the position shown, and its lower position. In its upper position, this valve establishes a fluid passageway between high pressure line **4** and line **17**. At the same time, it isolates line **17** from the low pressure or return line **28** leading into reservoir **1**. In its lower position, these conditions are reversed. Consequently, a particular setting of directional valve **8** determines whether there is a high pressure condition applied to line **17** and a fluid flow into cylinder **31** or a low pressure condition terminating this line and a fluid flow from this cylinder into reservoir **1**.

Volume piston **30** accommodated within cylinder **31** is the fluid metering element of the over-all system. Lines **19** and **21** enter opposite ends of cylinder **31**. This piston is adapted to travel from one end to the other of cylinder **31** with each stroke displacing a calibrated volume of fluid. The amount of fluid thus displaced determines the unit of movement of ram **9** in either its forward or backward travel.

Actuating cylinder **10**, which houses output ram **9**, is connected to amplitude valve **7** by lines **32** and **33**. A bidirectional flow of fluid takes place through these lines, depending upon the direction in which ram **9** is being moved. Ram **9** includes a piston head portion **34** whose

diameter corresponds to the inner diameter of cylinder **10** and a shaft portion **35** with reduced diameter to which is connected mass **38**, representing the mechanical apparatus or the mechanism which is to be controlled by the over-all system.

Actuating cylinder **10** is also connected at its other end to the high pressure pump **2** through lines **6**, **5** and **3**. It should be recognized that when equal pressures are coupled to opposite ends of cylinder **10** by means of lines **6** and **32**, ram **9** does not remain stationary but advances to the right because of the greater area of the left-hand face **36** of piston head **34** as compared to its right-hand area. In other words, the pressure applied through line **6** acts only on an annular area of piston head **34** because of the presence of shaft **35** which extends through the right-hand end wall of actuating cylinder **10**. In contradistinction, the pressure applied through line **32** acts over the complete face of this piston.

The over-all system also contains an energy storage provision which allows volume piston **30** and control valves **7** and **8** to operate at a high frequency while mass **38** moves smoothly to its proper position. This apparatus includes a pair of auxiliary pistons **40** and **41** accommodated within cylinders **42** and **43**, respectively. Each of these cylinders has a fluid capacity equal to cylinder **31**. Piston **40** has a body portion **44** which fits within line **46**. Likewise, piston **41** has a body portion **45** which fits within line **47**. The above two lines are coupled to the high pressure lines leading to pump **2**. Cylinders **42** and **43** are also connected through lines **49** and **50** and return line **51** to reservoir **1**.

In the condition illustrated, the high pressure condition established by pump **2** is acting through lines **3**, **4**, **17**, **18** and **19** into the top of cylinder **31**, forcing volume piston **30** to its lower position. When this piston was displaced previously to this position, it discharged a metered amount of fluid out of cylinder **31**, and this fluid passed through lines **21**, **33**, **32** into the left-hand end of actuating cylinder **10**, forcing ram **9** an incremental amount to the right, as viewed in this figure. This movement took place despite the high pressure condition acting on face **37** of piston **34** because of the explanation given hereinbefore having to do with the smaller area of the space as compared to face **36**. As ram **9** moved to assume the position shown, an appropriate amount of fluid passed out of the right-hand end of cylinder **10** into the high pressure system.

The system will remain in the condition shown until either amplitude valve **7** or directional valve **8** is operated by an appropriate electrical signal sent to solenoid **16** or solenoid **26**. When solenoid **16** is energized, spool **11** moves downwardly, land **12** blocks the passageway between lines **18** and **19**, and land **14** opens the passageway between lines **20** and **21**. With directional valve **8** in the condition shown, the high pressure condition now acts through lines **3**, **4**, **17**, **20** and **21** to shift volume piston **30** to the other end of its cylinder. Consequently, a second metered amount of fluid flows out of this cylinder, again through lines **19**, **33** and **32**, and into actuating cylinder **10**, once more displacing ram **9** an incremental distance to the right.

It will be appreciated from what has been described above that if valve **8** remains in the condition shown and amplitude valve **7** is sequentially operated by signals sent alternately to solenoids **15** and **16**, volume piston **30** will travel back and forth within its cylinder and ram **9** will be advanced step by step to the right.

To reverse the direction of ram movement, it is only necessary to change the setting of directional valve **8**. The position of this valve, it will be seen, determines whether the high pressure condition is applied to line **17** or whether the low pressure condition of reservoir **1** is applied to this line. In the first case, there will be a fluid flow into line **17** and into one or the other end of cylinder **31**, depending upon the setting of amplitude valve **7**. In the second case, there will be a fluid flow into line **28** and reservoir **1** from one or the other end of cylinder **31**, also depending upon the setting of amplitude valve **7**. If directional valve **8** is shifted to its lower position by an appropriate electrical signal sent to solenoid **27**, then land **24** will isolate line **4** from line **7** and connect line **28** to this same line. The high pressure condition heretofore holding volume piston **30** in the position shown will now no longer be available for this purpose. Consequently, with amplitude valve **7** in the position shown, fluid will flow from actuating cylinder **10** through lines **32**, **33** and **21** into cylinder **31**, displacing piston **30** to its upper position. This flow comes about because of the high pressure condition still acting against face **37** of piston **34**. Ram **9** will therefore move an incremental distance to the left, which distance, because of the action of volume piston **30**, will equal one of the steps it previously took to the right. The fluid discharged from cylinder **31** by the upward stroke of volume piston **30** will pass through lines **19**, **18**, **17** and **28** back into reservoir **1**.

To continue this movement of ram **9** to the left, solenoid **16** of amplitude valve **7** may be operated. This will cause another metered volume of fluid from actuating cylinder **10** to flow out through lines **32**, **33** and **19** into cylinder **31**, forcing volume piston **30** back to the position shown. A metered amount of fluid will again be discharged back into the reservoir through lines **21**, **20**, **17** and **28**, with the high pressure condition acting on face **37**, again bringing about this flow.

From what has been described above, it will be seen that with directional valve **8** in one position and solenoids **15** and **16** sequentially operated, ram **9** will move in equal increments in a first direction and, with directional valve **8** in its other position and these same solenoids again sequentially operated, ram **9** will move in equal increments in an opposite direction. It would also be pointed out that whenever directional valve **8** is shifted from one position to another, ram **9** also moves a single step in the new direction selected.

Auxiliary pistons **40** and **41** are shown in their equilibrium positions, that is, with no energy stored in this portion of the system. If at any time amplitude valve **7** or directional valve **8** is moved to cause fluid to be metered into actuating cylinder **10**, a condition which may be considered a positive input to the system, the pressure in chamber **52** communicating with cylinder **43** and line **32** will build up and when it reaches a predetermined level auxiliary piston **41** will move off of its stop. Its cylinder **43** will therefore be able to accept the calibrated fluid volume discharged from cylinder **31**. Hence, volume piston **30** will be able to reach its limit of travel within this cylinder and be prepared to accept another command from the electrical control devices even through ram **9** has not attained its ultimate position. The high pressure acting on the rear face of piston **41** will cause this piston subsequently to move back towards its original position, and the fluid discharged from its cylinder **43** will pass into actuating cylinder **10**. Thus, ram **9** will move to the right, and this movement will continue until auxiliary piston **41** returns to its equilibrium position. When it is in this position, ram **9** will come to rest at a final position.

Auxiliary piston **40** performs in a similar manner when fluid is metered out of actuating cylinder **10**. When this discharge takes place from cylinder **10**, the pressure in chamber **53** communicating with line **32** and cylinder **42** drops until it reaches a predetermined level. Then, piston **40** moves off of its stop and a metered amount of fluid is discharged from cylinder **42** into cylinder **31**, displacing volume piston **30** to its other position. This piston is therefore again prepared to respond to an appropriate command delivered to it by either amplitude valve **7** or directional valve **8**. The fluid discharged out of cylinder **42** is subsequently recovered as ram **9** moves to the left under the action of the high pressure acting on its surface **37**. Thus, piston **40** is restored to its initial equilibrium position at the same time ram **9** assumes its final setting.

It will therefore be seen that auxiliary pistons **40** and **41** and their associated cylinders permit energy to be stored in the system so that the setting of the various electrical control devices may be changed prior to the time ram **9** takes up the position required by a previous control signal.

FIG. 1 also includes a feature which causes the ram to drift to a center position when no input signals are applied to the various control devices. This arrangement can be used to initialize the system. It can also be used, for example, in a missile guidance control system where two null seeking digital actuators are controlling the pitch of the missile through gimballing of the thrust chambers. When the hydraulic power is turned on, these actuators will drift to their neutral positions, thus insuring that the thrust vector acts initially through the center of mass of the missile. After lift-off, the continual drift towards the center will insure that these two actuators perform together and in a compatible manner.

In the system of FIG. 1, the equilibrium condition of ram **9** has a high pressure on the side with the smaller effective area and a medium pressure on the side with the larger effective area. Consequently, there is a tendency for the ram to drift to the right as fluid leaks from the right-hand end to the left-hand end of cylinder **10** through the external leakage path **55**. However, if the ram is, for example, in the right-hand half of this cylinder, there is additionally leakage out through drift path **56**, located in the middle of cylinder **10** and connected by a line, not shown, to reservoir **1**. Thus, there is a tendency for the ram to drift to the left. However, if this drift to the left is made larger than the drift to the right, the direction of net drift of ram **9** will always be towards the center of actuating cylinder **10** and the objectives mentioned above will be achieved. Leakage paths **55** and **56** can be formed in many ways. One simple method is to force a screw into the line so that the fluid flow can only take place around the finite helical path provided by the screw threads. A restriction **57** may also be placed in line **6** at a point adjacent to its connection to actuating cylinder **10** to provide damping of output ram **9**.

FIG. 2 illustrates an alternative modification of the invention in which the fluid entering one end of actuating cylinder **60** and that leaving the other end of this cylinder are metered simultaneously by a pair of volume pistons **61** and **62** accommodated within cylinders **63** and **64**, respectively. These cylinders have the same fluid capacity so that both pistons displace equal fluid volumes. In this system the pressure acting on one side of piston **90** of output ram **65** is raised to the high pressure level while that on the other side is lowered concurrently to the return pressure. For a given size actuating cylinder a greater force is therefore available for moving the load **112** connected to the ram.

In this alternative system, amplitude valve **66** has a spool **67** on which are mounted lands **68**, **69**, **70**, **71** and **72**. Solenoids **73** and **74**, when selectively energized, shift this spool between an upper position, the one shown, and a lower position. Directional valve **75** has a spool **76** on which are mounted lands **77**, **78** and **79**. Solenoids **80** and **81**, when selectively energized, shift this spool between a lower position, the position shown, and an upper position.

This system also includes an arrangement for dampening the movement of ram **65**. This apparatus, generally represented by reference character **82**, consists of three interconnected cylinders **83**, **84** and **85**. Each cylinder contains a free moving piston, such as **86**, **87** and **88**, and these pistons are separated by cylindrical rods **89** and **91**. The three pistons are not connected to these rods but rather these rods merely contact their faces. Cylinders **83** and **85** are connected to the high pressure pump **95** by means of lines **113** and **114**. Since equal high pressures are applied to the free ends of pistons **86** and **87**, these pistons normally occupy the positions shown, holding piston **87** in the center of its cylinder **84**.

The operation of the damping device is as follows: If a metered amount of fluid, for example, is discharged from cylinder **63** as a result of a downward stroke of volume piston **61**, this fluid will flow via lines **99** and **109** into the right-hand end of cylinders **84**, forcing piston **87**, rod **89** and piston **86** to the left against the restraining action of the high pressure backing up piston **86**. Thereafter, this back pressure will be effective to restore these elements to their original position and the previously transferred fluid will pass out of the right-hand side of cylinder **84** through line **101** into the right-hand side of actuating cylinder **60**, forcing piston **90** of ram **65** to the left to assume its proper position. Thus, the impact initially accompanying the fluid transfer brought about by a stroke of the volume piston will be taken up by an appropriate response of the damping apparatus and not the ram.

Piston **90** of ram **65**, unlike its counterpart in FIG. 1, has faces of equal area because of the presence of shafts **110** and **111** which extend through opposite end walls of actuating cylinder **60**. The load represented by **112** may be connected to one of these shafts, such as **110**.

It is believed that a detailed discussion of the operation of the complete system of FIG. 2 is unnecessary in view of the analysis of FIG. 1 given hereinbefore. However, it would be pointed out that in the condition illustrated, the high pressure condition produced by pump **95** is acting through lines **96**, **97** and **98**, forcing volume piston **61** to the position shown. When this piston previously moved to this position, a metered amount of fluid passed out of its cylinder **63** through lines **99** and **100**, first into the right-hand side of cylinder **84** of the dampening apparatus and then into the right-hand side of actuating cylinder **60**. Ram **65**, consequently, moved an incremental distance to the left to allow this fluid to be accepted by this cylinder.

The fluid discharged from the left-hand side of actuating cylinder **60** in response to this movement passed into cylinder **64** via lines **102**, **103** and **104**, forcing volume piston **62** to the position shown. The fluid discharged from this cylinder by this stroke of volume piston **62** passed into reservoir **115** via lines **105**, **106** and **107**.

During this previous movement of ram **65**, it should be appreciated, a high pressure condition acted on the right side of piston **90** and a low pressure exerted on the left side of this piston. Consequently, as mentioned hereinbefore, the net force available for displacing this piston was greater than that experienced by ram **9** in FIG. 1. Here, for the same size actuating cylinder, the arrangement of FIG. 2 can control a greater load.

If amplitude valve **66** is now shifted to its lower position by an appropriate signal sent to solenoid **74**, the high pressure condition will act through lines **96**, **97**, **117** and **99** to displace volume piston **61** to its upper position, a metered amount of fluid will again enter the right-hand end of actuating cylinder **60** and ram **65** will once more move to the right a calibrated amount. The fluid discharge from the left-hand end of cylinder **60** will be metered as it passes into cylinder **64** through lines **102**, **103** and **105**, volume piston **62** will shift to its other position and an appropriate amount of fluid will flow back into the reservoir through lines **104**, **116** and **107**. It will thus be seen that amplitude **66** in this modification performs like amplitude valve **7** of FIG. 1.

Likewise, if directional valve **75** is shifted to its upper position by an appropriate signal to solenoid **80** and with amplitude valve **66** left in the position shown and the various volume pistons also in the positions shown, the high pressure condition will act through lines **96**, **106** and **105** to force volume piston **62** to its other position and a metered amount of fluid will pass out of its cylinder **64** through lines **104**, **103** into first the left-hand end of cylinder **84** of the damping apparatus and then out therefrom and through lines **102** into the left-hand end of actuating cylinder **60**. Consequently, ram **65** will

be moved an incremental amount to the right. The fluid discharge from the right-hand end of actuating cylinder 60 to accommodate this movement will be metered as it flows through lines 101, 100 and 99 into cylinder 33. When this flow occurs, volume piston 61 will be moved to its other position and an appropriate amount of fluid will pass from this cylinder through lines 98, 97 and 118 back into reservoir 115.

It will thus be seen that ram 65 in this embodiment can be selectively controlled to the same extent as ram 9 in FIG. 1. In practice, the computer associated with these systems will determine whether a positive increment is needed, whether a negative increment is needed, or whether the present position of the ram is proper. It will then generate an appropriate code to the various solenoids associated with the amplitude and directional valves to bring about the required movement.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A digital hydraulic actuator comprising, in combination,

a first enclosed cylinder having a fluid opening at each end thereof;

a free moving piston accommodated within said cylinder and adapted to travel from one end to the other of said cylinder thereby to discharge through one or the other of said fluid openings a metered amount of fluid;

an enclosed actuating cylinder having a fluid opening at each end thereof;

a ram accommodated within said actuating cylinder,

said ram comprising a cylindrical piston head and a shaft portion of reduced diameter which extends through one end wall of said actuating cylinder for attachment to a load device;

a high pressure fluid source;

said high pressure fluid source being applied to a portion of the back face of said piston head so as to bias said ram in one direction;

a low pressure fluid source;

means for controlling the flow of fluid between said sources, said first cylinder and said actuating cylinder such that

whenever said high pressure source is connected to one opening of said first cylinder, a metered amount of fluid is discharged to the other opening of that cylinder into one opening of said actuating cylinder to move said ram an incremental distance in the opposite direction, and

whenever said low pressure source is connected to one opening of said first cylinder a metered amount of fluid is discharged out of said one opening of said actuating cylinder into the other opening of said first cylinder and said ram is moved the same incremental distance in said one direction by said high pressure fluid source applied to a portion of the back face of said piston head;

and energy storage means cooperating with said first enclosed cylinder and said actuating cylinder for initially accepting the fluid discharge from said first enclosed cylinder and then transferring it to said actuating cylinder and for initially accepting the fluid discharge from said actuating cylinder and then transferring it to said first enclosed cylinder whereby said free moving piston can start to travel from one end to the other end of said first enclosed cylinder before said ram reaches its final setting.

2. In an arrangement as defined in claim 1 wherein said means for controlling the flow of fluid between said sources, said first cylinder and said actuating cylinder includes:

a bistable directional valve and a bistable amplitude valve,

said bistable directional valve in one of its positions connecting said high pressure source and in the other of its positions connecting said low pressure source to one or the other opening of said first cylinder, depending upon whether said amplitude valve is in one or the other of its positions.

3. In an arrangement as defined in claim 2 wherein said amplitude valve connects the high pressure source or the low pressure source depending upon the position of said bistable directional valve to one or the other of said openings of said first enclosed cylinder.

4. In a digital hydraulic actuator comprising, in combination,

a first enclosed cylinder having a fluid opening at each end thereof;

a free moving piston accommodated within said cylinder and adapted to travel from one end to the other of said cylinder, thereby to discharge through one or the other of said fluid openings a metered amount of fluid;

an enclosed actuating cylinder having a fluid opening in each end thereof;

a ram accommodated within said actuating cylinder,

said ram having a cylindrical piston head and a shaft portion of smaller diameter which extends through one end wall of said actuating cylinder for attachment to a suitable load device;

a reservoir having fluid stored therein;

a pump having an input and an output side with said input side connected to said reservoir;

a bistable directional valve having first, second and third fluid openings,

said valve in one of its positions permitting a fluid flow only between said first and third openings and in its other position permitting a fluid flow only between said first and second openings;

a bistable amplitude valve having first, second, third, fourth and fifth fluid openings,

said amplitude valve in one of its positions permitting a fluid flow only between said first and second openings and between said third and fourth openings and in its other position permitting a fluid flow only between said second and third openings and said fourth and fifth openings;

conduit means connecting the output of said pump to both the third opening of said directional valve and the opening in said actuating cylinder which is at that end of said actuating cylinder through which said shaft extends, said reservoir to the first opening of said directional valve, the second opening of said directional valve to both the first and fifth openings of said amplitude valve, the second opening of said amplitude valve to one of the openings of said first enclosed cylinder, the fourth opening of said amplitude valve to the other opening of said first enclosed cylinder and the third opening of said amplitude valve to the other opening of said actuating cylinder;

and energy storage means connected between the conduit means that connects said third opening of said amplitude valve to the other opening of said actuating cylinder and the conduit means which connects the third opening of said directional valve to the opening of said actuating cylinder which is at that end thereof through which said shaft extends for initially accepting the fluid discharge from said enclosed cylinder and then transferring it to said actuating cylinder and for initially accepting the fluid discharge from said actuating cylinder and then trans-

ferring it to said first enclosed cylinder whereby said free moving piston can start to travel from one end to the other end of said first enclosed cylinder before said ram reaches its final setting.

5. In an arrangement as defined in claim 4, wherein an external fluid passageway of restricted area interconnects the opposite ends of said actuating cylinder, and wherein said actuating cylinder has a third fluid opening at a point midway between its end walls and a fluid passageway of restricted area connected between said reservoir and said third fluid opening.

6. A digital hydraulic actuator comprising, in combination,

a first enclosed cylinder having a fluid opening at each end thereof;

a second enclosed cylinder of the same size as said first cylinder having a fluid opening at each end thereof;

each cylinder having a free moving piston accommodated therein which is adapted to travel from one end to the other end of the cylinder thereby to discharge through one or the other of said fluid openings a metered amount of fluid;

an enclosed actuating cylinder having a fluid opening at each end thereof;

a ram accommodated within said actuating cylinder, said ram comprising a cylindrical piston having shaft portions of smaller diameter secured to opposite sides of said piston which extend through opposite end walls of said actuating cylinder;

a low pressure fluid source;

a high pressure fluid source;

and means for controlling the flow of fluid between said sources, said first and second cylinders and said actuating cylinder, such that whenever said high pressure source is connected to one opening of said first cylinder a metered amount of fluid is discharged through the other opening of that cylinder into one opening of said actuating cylinder and a metered amount of fluid is discharged from the other opening of said actuating cylinder into one opening of said second cylinder and said ram moves an incremental distance in one direction, and such that whenever said high pressure source is connected to one opening of said second cylinder a metered amount of fluid is discharged from the other opening of that cylinder into one opening of said actuating cylinder and a metered amount of fluid is discharged from the other opening in said actuating cylinder into one opening of said first cylinder and said ram moves an incremental distance in an opposite direction.

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