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[11] **3,732,027**

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[54] METHOD AND APPARATUS FOR CONVERTING DIGITAL INPUT SIGNALS INTO DISTINCT OUTPUT POSITIONS OR VELOCITIES

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[52] **U.S. Cl.** **415/51,** 91/19, 91/410, 91/445

[51] **Int. Cl.** **F15b 11/12,** F15b 13/044

[58] **Field of Search** .....91/445, DIG. 1, 410, 91/19, 375; 415/51

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[57] **ABSTRACT**

Method and apparatus for converting digital input signals into output positions or velocities employing a flowing medium. A directional control valve receives an input signal and transmits the signal in the form of a flowing medium to a servo valve having a plurality of control ports and a slide with a plurality of closure members to shut off certain of the control ports. Flowing medium proceeds through the valve to actuate a motor means having an operating member. The operating member is directly connected to the slide member of the valve and, therefore, actuation of the operating member operates the slide to close off the control ports, thereby terminating the flowing medium and thusly stopping the operation. The directional control valve can also be hooked in parallel with the servo valve to communicate directly with the motor means.

5 Claims, 8 Drawing Figures

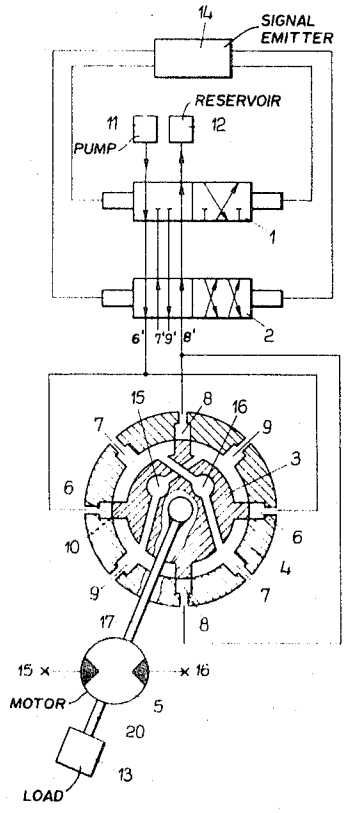
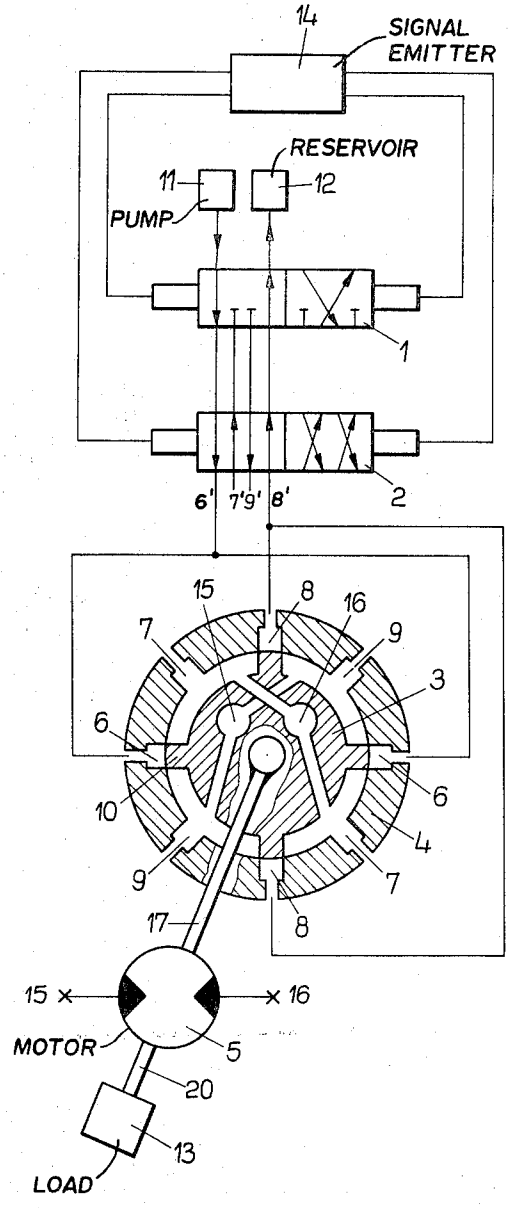


Fig. 1

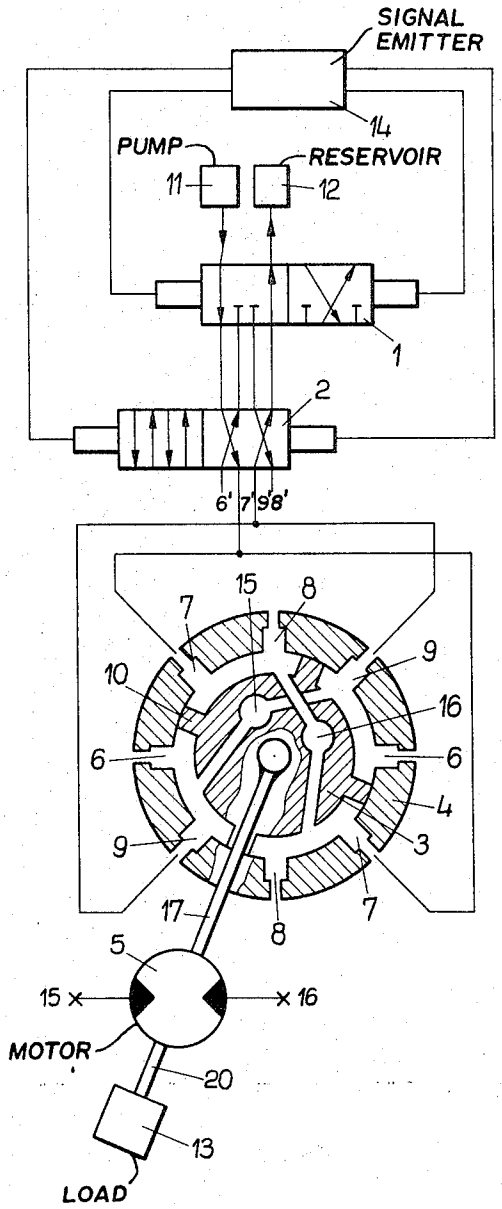


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Fig. 2



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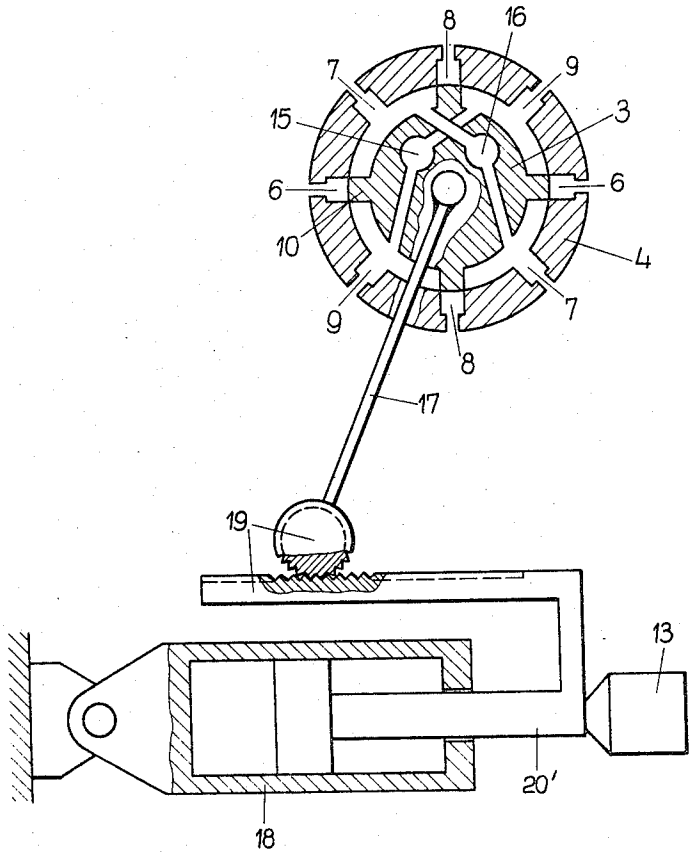


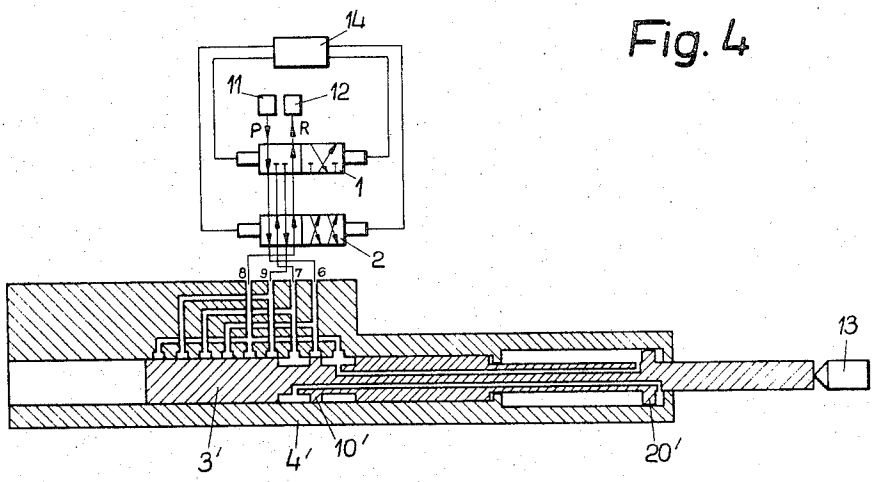
Fig. 3

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Fig. 4



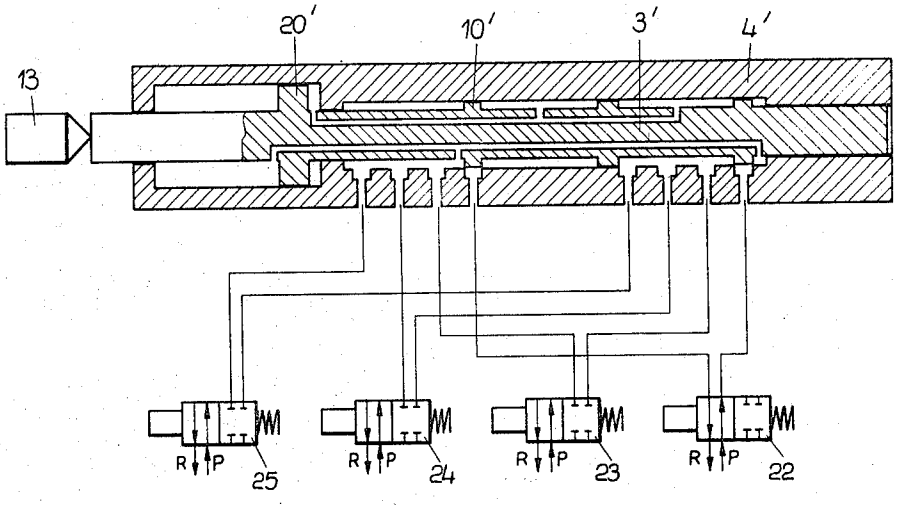


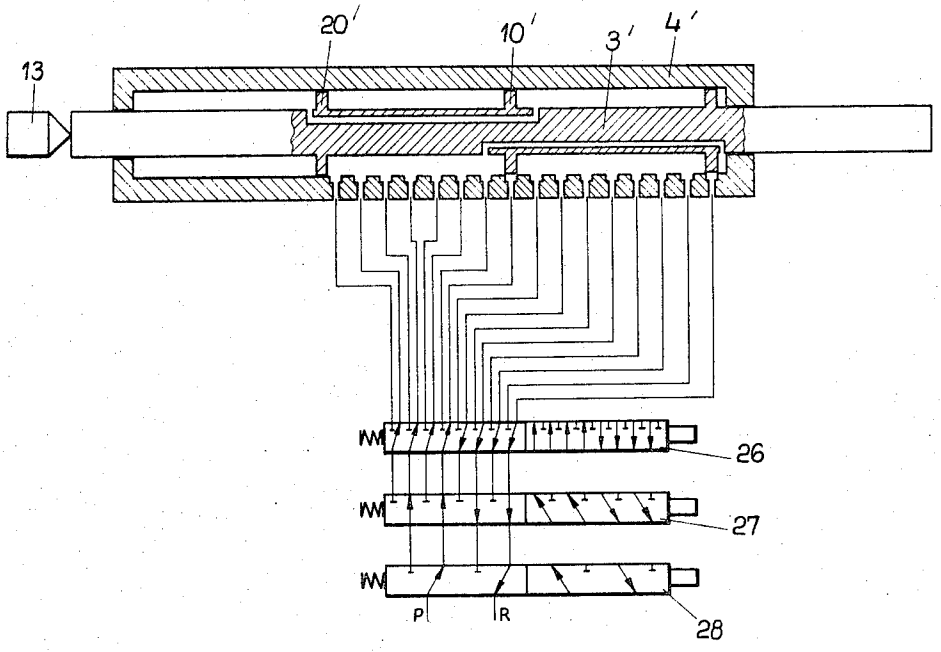
Fig. 5

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Fig. 6

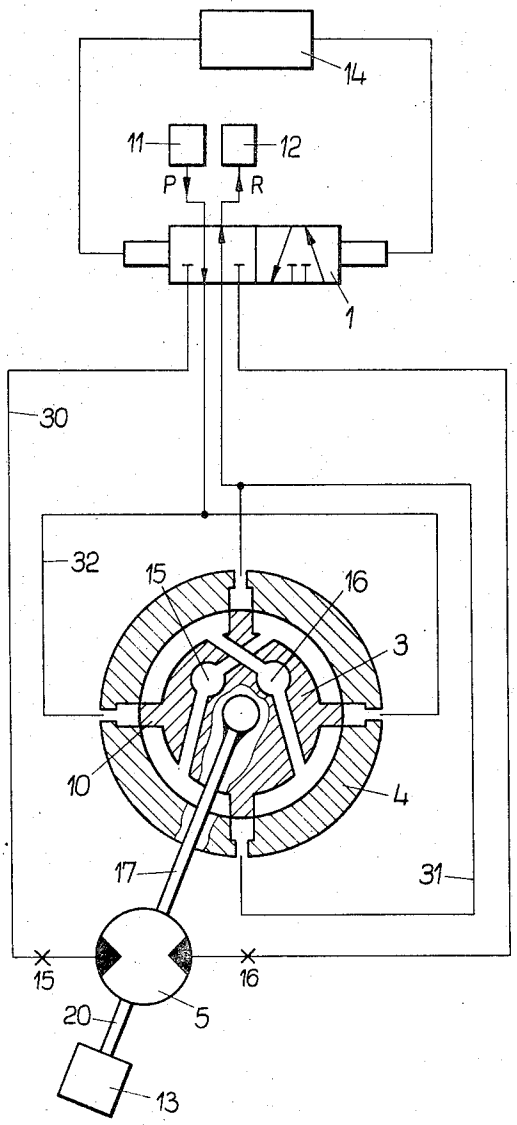


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Fig. 7

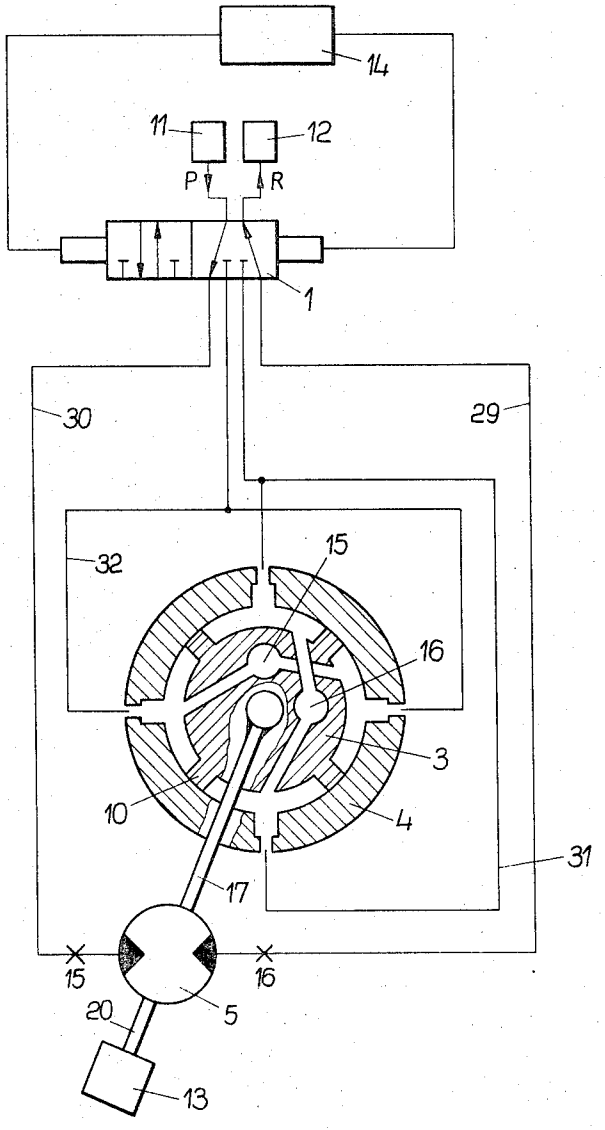


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Fig. 8



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METHOD AND APPARATUS FOR CONVERTING DIGITAL INPUT SIGNALS INTO DISTINCT OUTPUT POSITIONS OR VELOCITIES

This invention relates to a method and apparatus for converting digital input signals into distinct output positions or velocities and, more particularly, to a method and apparatus which employs a flowing medium to accomplish this end.

Drive units such as adjusting drives and velocity drives that employ a flowing media to intervene in a control operation or regulation for positioning or moving an apparatus connected to an output member of the drive unit are known in the art.

These drive units generally consist of a signal transformer such as a control magnet with the ultimate transformation of electric input signals into mechanical output signals. A power controlling structural member, such as a valve, and a power converter, such as a cylinder or motor, are employed. A power signal in the control magnet causes a mechanical transposition of the valve control mechanism, thereby conducting a flow of power into the cylinder and evoking a piston velocity. In order to attain the desired velocity independently of external influences, the prevailing value of the velocity is measured and compared with the nominal value. The deviation of the measured value from the nominal value is the input signal directed to the control magnet and thereby into the control valve. If proportionality is desired between the input signal into the drive unit and the position of the piston, the position of the piston is measured and is compared with the nominal value. Drive units with feedback of the output signal, compared to a nominal value, operate on an analogous basis.

Drive units are also known which operate without a feedback and without comparison of the output signal with the input signal. In such a drive unit a differentiation is made between parallel digital and incremental digital positioning units.

Parallel digital positioning units, as a rule, process binary coded input signals. Depending on the particular coded signal, the piston of a cylinder assumes a position assigned to that signal.

In the incremental digital drive unit, the particular position is proportional to the number, that is, the sum of the impulses. The impulses represent an input signal of constantly equal value.

Incremental digital positioning drives are known that consist of an electric stepping motor, a control valve and a motor with an internal feedback of the output signal to the control valve. This combination of a motor and control valve with internal feedback is frequently referred to as a torque amplifier. The drawback of this particular combination of apparatus lies in its susceptibility to interference, its lack of dependability and the cumbersome method of construction of the electric stepping motor in connection with the control valve.

Our invention eliminates all of these drawbacks by employing an auxiliary power for processing the signal on the input side. This then means that the signal conversion in the first stage can be made on a very low power level.

Our invention relates to a process and to the devices associated therewith for converting digital input signals into distinct output positions or velocities by use of a flowing medium as the auxiliary power for attaining high amplifications and short positioning times. It is characterized by the transmission into a control valve system of mechanical, pneumatic or electric control impulses which direct a flowing medium as the bearer of the power to provoke a movement of a motor or a piston and consequently the load that is to be moved. A servo slide valve is employed wherein the valve casing has a plurality of control ports for receiving the flowing medium and the slide member has a plurality of closure members to shut off the control ports. The slide is directly connected to the output member and, therefore, movement of the output member moves the slide to shut off the control ports, thus stopping the flowing medium and bringing the output member to a standstill. The output member is not moved again until a new signal is introduced by the delivery of a new control impulse into the valve system. The control may also be connnected in parallel with the servo slide valve.

In the accompanying drawings, we have shown our presently preferred embodiments in which:

FIG. 1 is a schematic flow diagram of our control valve system, including a rotary slide valve;

FIG. 2 shows the control valve system of FIG. 1 having received a new input impulse;

FIG. 3 shows a control valve system of FIG. 1 wherein the output signal is a stroke;

FIG. 4 is an embodiment of our invention employing a longitudinal slide valve;

FIG. 5 is a further embodiment of our invention employing control valves;

FIG. 6 shows the embodiment of FIG. 5, except that the number of control valves is reduced;

FIG. 7 is still a further embodiment wherein the solenoid valves and rotary slide valves are connected in parallel; and,

FIG. 8 shows the embodiment of FIG. 7 wherein the control valve has received an impulse of short duration.

As shown in FIGS. 1 through 4, the apparatus of our invention includes a control valve system, a servo valve, and a motor or piston cylinder arrangement. The control valve system includes two directional control valves such as solenoid valves 1 and 2, which are connected in tandem arrangement and by a servo valve connected in series to these directional control valves on their outlet side. The control valve 2 has output ports 6', 7', 8' and 9'. The servo valve consists of a valve slide 3 connected to an output member 20 of a motor 5 or cylinder 18 and a valve slide casing 4 within the housing of the servo valve. The slide valve casing 4 has control ports 6 – 9 that serve as inlet and outlet openings for a flowing medium which is fed by pump 11 and controlled by solenoid valves 1 and 2. The control ports 6, 7, 8 and 9 on the servo valve are connected respectively to the output ports 6', 7', 8' and 9' of the control valve 2. The control ports 6 – 9 that serve as inlet and outlet openings are closed by the guiding edges of closure members 10 of the valve slide 3 after each step of the output member so that the output member comes to a standstill and does not carry out the next step until a new input signal is on hand. The impulse frequency then determines the stepping frequency on the output side, and the overlap ratios between the guiding edges of closure members 10 of the valve slide 3 and the control ports 6 – 9 determine

whether there should be an actual standstill between two consecutive steps or an output movement that continues uniformly proportional to the impulse frequency. However, at the end of the impulse sequence, the position arrived at by the output member will be proportional to the number of impulse type input signals. This position will be maintained even if the signal or the valve system should be inoperative.

In FIGS. 1 and 2, motor 5 drives load 13. The control valve system, consisting of two electrically operated solenoid valves 1 and 2, directs the flowing medium, such as a stream of oil, into motor 5 through the servo valve comprising the slide 3 and the casing 4. As soon as the motor 5 rotates, the rotary slide valve 3 also turns. This shuts off the control ports 6 – 9, thereby stopping the movement of the motor. The respective control ports 6 – 9 in the slide casing 4 are closed after an angular step of 45°. Only when solenoid valve 1 or 2 receives a new input signal does the next angular step take place. In other words, the activity can cease when the input signal is still engaged.

The direction of rotation depends upon the circuit combination of the input signals into the solenoid valve. FIG. 2 illustrates the operation of our invention by showing an example in which a new input signal from a signal emitter 14 has reached solenoid valve 2. Solenoid valve 2 assumes the position shown whereupon the flowing medium, such as a pressurized fluid or compressed air from pump system 11 enters control ports 7. The flowing medium then enters communicating line 16 and flows into motor 5 to activate it in a rotational clockwise direction. The flowing medium returns from the motor through communicating line 15 into control ports 9 of the valve slide casing and from there by way of the valves into a reservoir 12. Because of the rigid connection 17 of the rotor of the motor 5 with rotary slide valve 3, the latter is also rotated. As soon as the guiding edges of closure members 10 of the rotary slide valve 3 turn off control ports 7, the motor 5 stops rotating. Only after a new signal is received would the solenoid valve 1 be moved to permit pressure into control opening 8 so that the rotor and rotary valve slide are rotated an additional step further, namely 45° in FIG. 2. By a continuous sequence of impulses, it is possible for the control ports to be turned simultaneously by steps of 45°. This produces a hydraulic rotating field which motor 5 follows.

As shown in FIG. 3, the motor 5 can be replaced by a cylinder 18 and a piston 20'. In other words, the output signal is not an angular position or angular velocity but rather a stroke or rectilinear movement. However, once again the output position is fed back to the rotary slide valve, this time by means of gear 19 or a cable line. The magnitude of the angular step can be altered and depends upon the number of control ports in the valve slide casing. By selecting suitable intermediate gears, it is possible to influence the stepping and thereby the dissolution of the output magnitude. It is necessary for the proper functioning of the rotary valve slide at high pressures that the control ports each have the same pressure and that the guiding edges of the valve slide be oppositely disposed.

The rotary slide valve 3 can be replaced by a longitudinal valve slide 3' that moves in a valve slide casing 4' and is fixedly connected to the piston 20', see FIG. 4. This then eliminates the gear or the cable line of the earlier embodiment. Again the number of piston positions depends upon the number of control ports in the valve slide casing. The signaling, however, is the same as for the apparatus of FIGS. 1 – 3.

Solenoid valves 1 and 2, which operate in tandem, can be replaced by individual controlling valves 22 to 25, each of which converts an input signal into a distinct output position, see FIG. 5. The output position need not only be proportional to the number of control impulses, but may also be coordinated with the prevailing sequencing of the valves. This then permits the arrangement to be operated as a parallel-digital positioning drive. The number of valves 20 to 25 may be combined, as shown in FIG. 6, to valves 26 to 28. With the three control valves, it is possible by the circuitry shown to arrive at $2^3 = 8$ positions. As shown in FIGS. 5 and 6, the pistons and the slide valve are combined in a single unit.

The distinguishing feature of the equipment of FIGS. 1 – 6 lies in the fact that the solenoid valves and the rotary slide valves are connected in a series. However, as shown in FIG. 7 and FIG. 8, the solenoid valves and the servo valve can be connected in parallel. The servo valve itself can function in the same manner, for example, guiding edges of closure members 10 of the rotary slide valve 3 cover the control ports in the valve casing, thus allowing no flow to and from the motor 5. However, it is possible, as shown in FIG. 8, to directly send the flowing medium from the solenoid valve to the motor 5 by the parallel hookup arrangement. Rotation by 180° can be accomplished even though control valve 1 receives an impulse whose duration is smaller than the time needed for a 180° rotation. During the duration of the impulse, the control valve assumes the position shown in FIG. 8. The motor is directly connected to valve 1 through influx and reflux lines 29 and 30, respectively. If the control valve is switched again, as shown in FIG. 7, lines 29 and 30 are closed and instead, lines 31 and 32, through the servo valve, are connected to the influx and reflux lines. Now the motor rotates only until the guiding edges of closure members 10 cover the control ports. If the motor is to run continuously, the control valve remains in the position indicated in FIG. 8.

We claim:

1. A fluid actuated control system for converting a sequence of digital input signals into output positions of a fluid actuated working element (5) in a fluid actuated system having a pump (11) and reservoir (12) comprising:

an impulse valve means (2) for directing the fluid power to first (6', 8') and second (7', 9') sets of output ports, each set having a pump connected port (6', 7') and a reservoir connected port (8', 9');

a servo valve (3,4) having spaced input ports (6, 7, 8, 9), said input ports connected to the two sets of output ports (6', 7', 8', 9') of the said impulse valve means (2), the first set pump connected impulse valve output port (6') being connected to a first one (6) of said input servo valve ports (6, 7, 8, 9), the second set pump connected impulse valve output port (7') being connected to a second one (7) of said input servo valve ports (6, 7, 8, 9), the

first set reservoir connected impulse valve output port (8') being connected to a third one (8) of said input servo valve ports (6, 7, 8, 9), the second set reservoir connected impulse valve port (9') being connected to a fourth one (9) of said input servo valve ports (6, 7, 8, 9), the servo valve ports being spaced around the servo valve in the order of first input port, second input port, third input port and fourth input port, said servo valve having a slide (3) therein having closure members thereon which are spaced to cover every other input port in the servo valve and forming two sets of interconnected chambers, one set of chambers being connected to one port (15 or 16) of the fluid actuated work element (5) and the other set of chambers to the other port (16 or 15) of the fluid actuated work element, and one of said servo valve input ports (6, 7, 8 or 9), said slide valve being physically connected (17) to the mechanical output of the work element such that as the work element moves it advances the slide valve to cause each closure element to cover the next input port whereby the work element is incrementally advanced with each change of position of the impulse valve.

2. A fluid actuated control system for converting a sequence of digital input signals into output positions of a reversible fluid actuated working element (5) in a fluid actuated system having a pump (11) and reservoir (12) comprising:

a directional control valve means (1) for directing the fluid to control valve output ports therein, said valve selectively connecting the control valve outlet ports to either the pump or reservoir, respectively;

an impulse valve means (2) connected to the output of the directional control valve means (1) for directing the fluid to first (6', 8') and second (7',9') sets of output ports, each set having a pump connected port (6',7') and a reservoir connected port (8',9');

a servo valve (3,4) having spaced input ports (6, 7, 8, 9), said input ports connected to the two sets of output ports (6', 7', 8', 9') of the said impulse valve means (2), the first set pump connected impulse valve output port (6') being connected to a first one (6) of said input servo valve ports (6, 7, 8, 9), the second set pump connected impulse valve output port (7') being connected to a second one (7) of said input servo valve ports (6, 7, 8, 9), the first set resevoir connected impulse valve output port (8') being connected to a third one (8) of said input servo valve ports (6, 7, 8, 9), the second set resevoir connected impulse valve port (9') being connected to a fourth one (9) of said input servo valve ports (6, 7, 8, 9), the servo valve ports being spaced around the servo valve in the order of first input port, second input port, third input port and fourth input port, said servo valve having a slide (3) therein having closure members thereon which are spaced to cover every other input port in the servo valve and forming two sets of interconnected chambers, one set of chambers being connected to one port (15 or 16) of the reversible fluid actuated work element (5) and one of said servo valve input ports (6,7,8 or 9) and the other set of chambers to the other port (15 or 16) of the reversible fluid actuated work element and an input port, said slide valve being physically (17) connected to the mechanical output of the work element such that as the work element moves it advances the slide valve to cause each closure element to cover the next input port whereby the work element is incrementally advanced with each change of position of the impulse valve and the direction of the movement of the work element is controlled by the directional control valve.

3. A valve control system for converting digital input signals into a plurality of intermediate output positions of a fluid actuated work element supplied by a pump through said control valve system comprising:

impulse valve means for receiving one of said input signals and in response thereto initiating flow from the pump to the work element;

servo valve means for intermittently directing flow from the pump to the work element, said servo valve having a plurality of spaced ports for receiving said flow and a slide valve having a plurality of spaced closure elements for closing said ports, said slide being rigidly connected to the output of said work element whereby said work element moves until the closure elements on the said slide moved by the said work element close the next encountered control ports whereupon blocking the flow from the pump to the work element and the work element remains at a standstill until a new input signal is transmitted to the impulse valve.

4. The valve control system of claim 3 wherein the impulse valve means is two solenoid valves in tandem.

5. The valve control system of claim 4 wherein the servo valve is a rotary slide valve, the control ports being in a valve casing and the closure members being on the rotary slide.

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