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[21] Appl. No. 875,934
[22] Filed Nov. 12, 1969
[45] Patented Aug. 10, 1971
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[32] Priority Nov. 12, 1968
[33] Great Britain
[31] 53601/68

[54] FLUIDIC AMPLIFIER
4 Claims, 8 Drawing Figs.

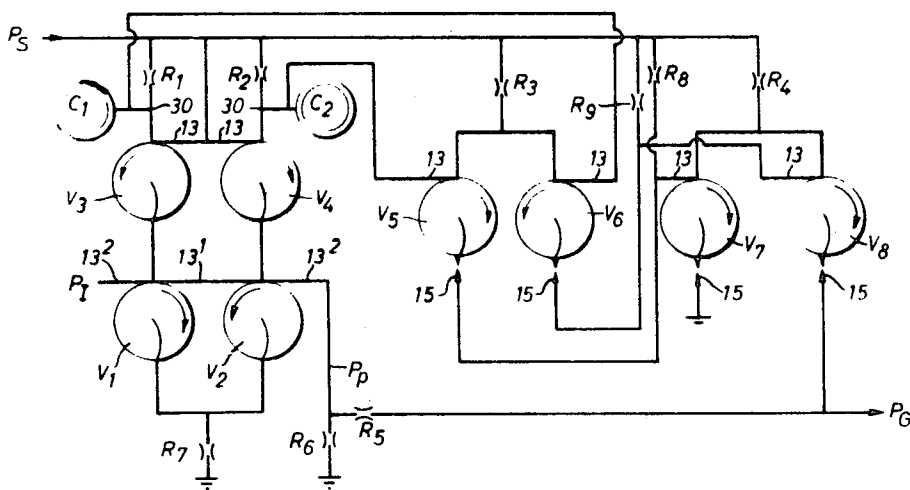
[52] U.S. Cl. 137/81.5
[51] Int. Cl. F15c 1/16
[50] Field of Search 137/81.5,
98, 100; 235/200, 201

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ABSTRACT: A fluidic amplifier comprising an amplifying section including a pair of probe-type fluidic vortex valves connected in push pull and sharing a common source of supply pressure, a comparing section including a pair of fluidic vortex valves, sharing a common source of supply pressure and connected in push pull with cross-connected control inlets, one having another control inlet subject to an input signal pressure to be multiplied and the other having another control inlet connected to receive a feedback signal from the amplifying section through a tapping from a fluid pressure potentiometer which provides for division of the pressure in said probe by the multiplying factor desired, and means for applying across the control inlets to the valves in the amplifying section the pressure difference established in the supply lines to the valves in the comparing section.



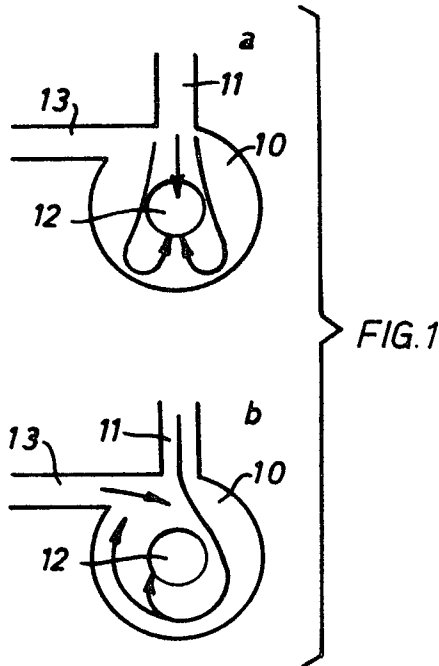


FIG. 2

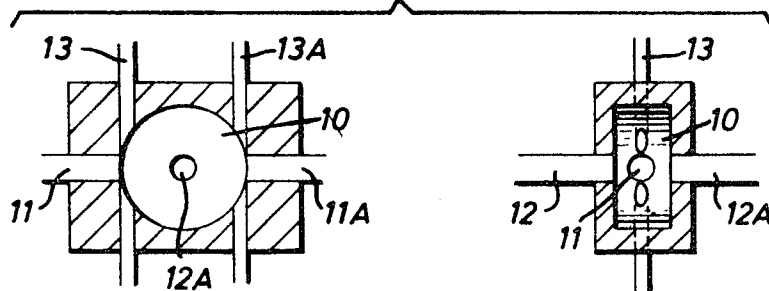


FIG. 3

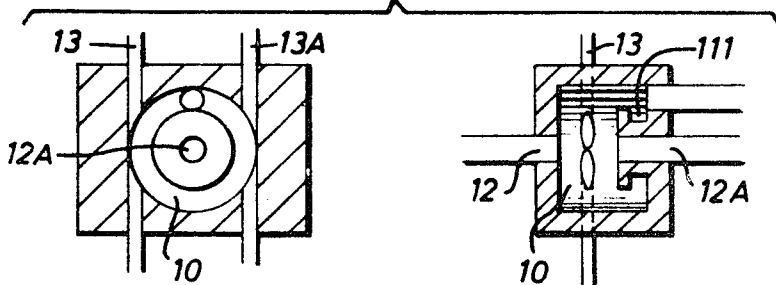


FIG. 4

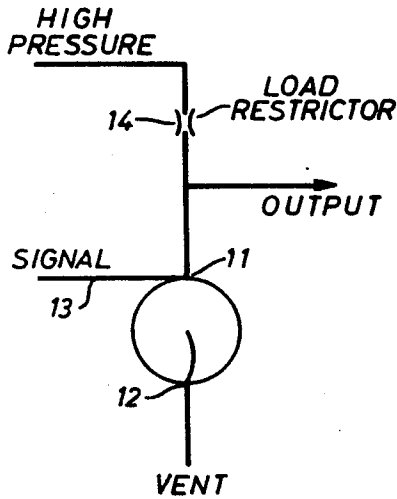


FIG. 5

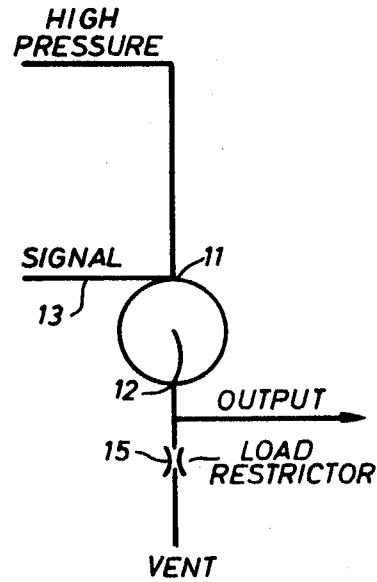


FIG. 6

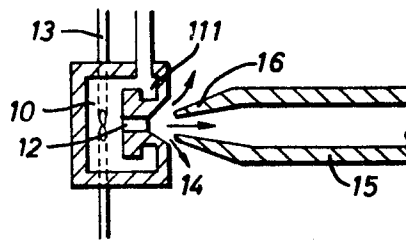


FIG. 8

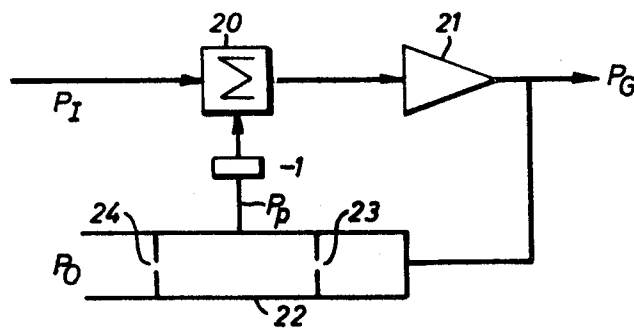
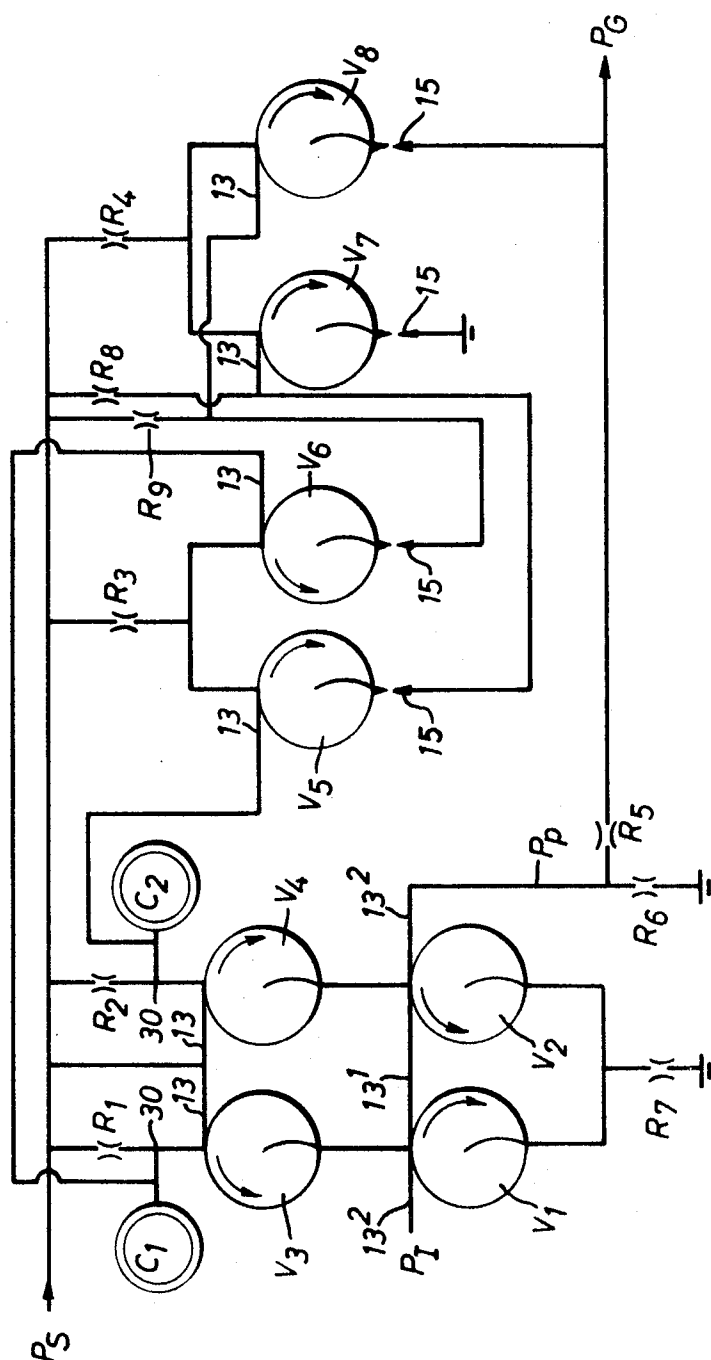


FIG. 7



FLUIDIC AMPLIFIER

This invention provides a fluidic amplifier devoid of moving parts and embodying fluidic vortex valves, for multiplying an input fluid pressure. One useful application of such a fluidic amplifier is in a pneumatic pressure ratio sensor as described in my copending U.S. Pat. application No. 875,949.

The expression "fluidic vortex valve" as used herein means a flat disclike cylindrical chamber having a supply inlet providing for a radial flow of supply fluid into the chamber, an outlet providing for axial flow of fluid out of the chamber and a control inlet providing for tangential flow of control fluid into the chamber. Such a valve can be used both with gaseous and liquid fluids and has the characteristic that, when fluid is supplied to the control inlet at a certain control pressure greater than the pressure of admission of the supply inlet a vortex flow will be established in the chamber with the result that the pressure drop between the supply inlet and the outlet is greatly increased for the same flow throughout.

The valve may have a plurality of supply and control inlets and a pair of outlets at each end of the chamber. The supply flow may be provided by one or more radial holes in the peripheral wall of the chamber or by providing the chamber with a porous peripheral wall. Alternatively the supply inlet may be in an end wall of the chamber and communicate with an annulus within the chamber.

Typical examples of fluidic vortex valves are illustrated in FIGS. 1—3 of the accompany drawings.

FIG. 1, which is purely diagrammatic, shows a valve having a chamber 10, a radial supply inlet 11, an axial outlet 12 and a tangential control inlet 13. The flow in the absence of control flow is indicated by the arrows in the upper sketch *a* of FIG. 1 and the flow under conditions of positive control flow is indicated by the arrows in the lower sketch *b*.

FIG. 2 shows in mutually perpendicular cross-sectional views, a valve having a chamber 10, two alternative radial supply inlets 11, 11A, two alternative axial outlets 12, 12A and two alternative tangential control inlets 13, 13A.

FIG. 3 shows, in similar fashion to FIG. 2 another form of valve having a single annular supply inlet 111.

In a typical case the diameter of the chamber may be 0.6 inch its depth 0.1—0.3 inch, the diameter of each supply inlet may be 0.139 inch, the diameter of each control inlet may be 0.1 inch, and the diameter of the outlet may be 0.196 inch.

A fluidic vortex valve is analogous to an electronic vacuum triode since a small control flow can be utilized to control a large supply flow and the vortex flow can be controlled by modification of the control pressure. The vortex flow can also be controlled by modifying the back pressure at the outlet since such modification will vary the pressure at the supply inlet and therefore the relation between the supply pressure and the control pressure.

When two control inlets are provided these may be utilized to provide contrarotating vortex flows in the chamber and in this case the valve can be brought into its operating state by applying to the control inlets control pressures which differ by a predetermined amount.

Such a valve can be used as an amplifier by taking from it an output as indicated in FIG. 4 or in FIG. 5 of the drawings. As will be seen in each case the input signal pressure to be amplified is applied to the control inlet 13 of the vortex valve, the outlet 12 is vented and fluid under high pressure is supplied to the supply inlet 11. In the case of FIG. 4, the outputs is taken from a point in the pressure supply line between a restrictor 14 and the supply inlet 11. In the case of FIG. 5, the output is taken from the vent line at a point between the outlet 12 and a restrictor 15. In both these cases the gain is of the order of 0.6—1. A variant yielding a much higher gain and herein referred to as a probe-type vortex valve is shown in FIG. 6. In this modified construction the outlet flow is partially vented at 14 and partially recovered in an output probe 15 which preferably has a divergent pressure recovery section 16 at its inlet end. With this construction substantial gain can be

achieved, e.g., of the order of 10 in respect of flow and of the order of 20 in respect of pressure.

The fluidic amplifier according to the invention comprises an amplifying section including a pair of probe-type fluidic vortex valves connected in push-pull and sharing a common source of supply pressure a comparing section including a pair of fluidic vortex valves, sharing a common source of supply pressure and connected in push-pull with cross-connected control inlets, one having another control inlet subject to an input signal pressure to be multiplied and the other having another control inlet connected to receive a feedback signal from the amplifying section through a tapping from a fluid pressure potentiometer which provides for division of the pressure in said probe by the multiplying factor desired, and means for applying across the control inlets to the valves in the amplifying section the pressure difference established in the supply lines to the valves in the comparing section.

One example of such an amplifier will now be described with reference to the remaining figures of the accompanying drawings, in which FIG. 7 shows the layout of the constituent fluidic vortex valves and FIG. 8 is a circuit diagram.

The basic principle of operation will first be described with reference to FIG. 8. As there shown, the signal pressure F_1 is passed through a pneumatic device 20 to a high gain fluid amplifier 21, from which air at pressure P_0 is fed back through an air potentiometer 22 having a choked outlet. Under these conditions the pressure P_p tapped from the potentiometer 22 will be an exact fraction αP_G of the pressure P_G , α being less than unity, determined by the areas of the two restrictors 23, 24 in the potentiometer. The device 20 subtracts the pressure P_p from the signal pressure P_1 and applies to the input of the amplifier 21 an air pressure equal to $P_1 - P_p$.

If G be the gain of the amplifier

$$P_G = G(P_1 - P_p)$$

$$\therefore P_G = G(P_1 - \alpha P_G) = \frac{G}{1 + \alpha G} P_1$$

If therefore G is sufficiently large,

$$P_G = \frac{1}{\alpha} P_1$$

and α can be so selected that P_G is, for example, three times P_1 . For high accuracy the gain of the amplifier must be high and the feedback flow from the air potentiometer must be a small fraction of the flow through the potentiometer if sonic velocity is not attained in the signal flow.

The arrangement shown in FIG. 7 produces the result just described. In this FIG. $V_1 - V_8$ represent fluidic vortex valves, $V_5 - V_8$ being of the probe type shown in FIG. 6, $R_1 - R_9$ represents restrictors and C_1 and C_2 are capacitive storage spaces in which gas is compressed or decompressed, these being provided for stabilization purposes.

The valves $V_5 - V_8$ correspond to the amplifier 21 of FIG. 8, the restrictors R_5, R_6 constitute the air potentiometer 22, the flow through R_6 being choked and the valves $V_1 - V_4$ perform the function of the device 20.

Air at supply pressure P_1 flows in parallel, through restrictors R_1, R_2 to pairs of vortex valves V_3, V_1 and V_4, V_2 and thence through the restrictor R_7 to exhaust. The supply pressure is also applied directly to the control inlets 13 of the valves V_3, V_4 . The valves V_1, V_2 have cross-connected control inlets 13^1 , and each also has another control inlet. The other control inlet 13^2 of V_1 is subject to input signal pressure P_1 and the other control inlet 13^2 of V_2 is subject to a feedback signal pressure, viz the output pressure P_G from the valve V_8 after attenuation by the potentiometer R_5, R_6 to the value $P_p = \alpha P_G$.

The difference in the signal and feedback pressures is reflected in a difference in vortex impedance of the valves V_1 and V_2 to the outflow from the valves V_3 and V_4 , which are biased to the vortexing mode by the restrictors R_1, R_2 . A differential signal ΔP corresponding to this difference appears at the points 30 and, after delay by the storage spaces C_1 and C_2 , is applied across the control inlets 13 of the valves V_5 and V_6 .

The amplified pressure difference, e.g., of $100 \Delta P$ developed between the probes 15 (see also FIG. 6) of the valves V_5 and V_6 is applied to the control inlets 13 of the valves V_7 and V_8 and a further amplified pressure difference of $10^4 \Delta P$ appears across the probes 15 of the valves V_7 and V_8 , the first of which is 'earthed' and the other of which provides the feedback through the potentiometer R_5, R_6 .

In a typical case, the supply pressure P_s may be 60 p.s.i., the average input signal pressure P_i 10 p.s.i., the average output pressure P_o 30 p.s.i., and the average pressure at the points 30, 40 p.s.i. In a typical case a variation of ± 1 p.s.i. in input pressure P_i will yield a variation in pressure of $\pm \frac{1}{2}$ p.s.i. at the points 30.

The restrictors R_8 and R_9 which provide bias control flow for the valves V_7 and V_8 reduce the demand on the output power of the valves V_5 and V_6 . The output pressure should be determined solely by the difference between itself and input signal pressure and should not contain any component depending upon the level of the input signal pressure. This is prevented:

a. because of the common mode rejection caused by any tendency for the control inputs to the valves V_5 and V_6 to rise due to increase in input signal pressure which causes these valves to react to raise their supply pressures,

b. because the restrictor R_7 causes any change in pressure downstream of the restrictor R_1 arising from a change in input signal pressure to be reflected in a corresponding change of pressure downstream of the restrictor R_2 .

The above-described amplifier can also be used for amplifying a liquid pressure. Under ordinary conditions of noncavitating flow accurate multiplication will be achieved in terms of the pressure differentials between for example the input and exhaust and the output and exhaust. The choked air potentiometer feedback makes multiplication possible in terms of absolute pressure.

What I claim as my invention and desire to secure by Letters Patent is:

1. A fluidic amplifier comprising an amplifying section including a pair of probe-type fluidic vortex valves connected in push-pull and sharing a common source of supply pressure, a comparing section including a pair of fluidic vortex valves, sharing a common source of supply pressure and connected in push-pull with cross-connected control inlets, one having another control inlet subject to an input signal pressure to be multiplied and the other having another control inlet connected to receive a feedback signal from the amplifying section through a tapping from a fluid pressure potentiometer which provides for division of the pressure in said probe by the multiplying factor desired, and means for applying across the control inlets to the valves in the amplifying section the pressure difference established in the supply lines to the valves in the comparing section.

2. An amplifier as claimed in claim 1 in which the amplifying section includes a second pair of probe-type fluidic vortex valves, also connected in push-pull, having their control inlets connected to the comparing section and their probes connected to the control inlets of the pair of valves which provide the feedback signal.

3. An amplifier as claimed in claim 1, in which the inlets of the vortex valves in the comparing section are connected to the outlets of another pair of vortex valves having their supply inlets and also their control inlets subject to the common supply pressure the connections to the control inlets of the valves in the amplifying section being taken from points upstream of the supply inlets to said other pair of valves in the comparing section.

4. A pneumatic amplifier as claimed in claim 3, having capacitive storage spaces connected to the supply inlets to the other pair of valves in the comparing section.

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