United States Patent

[11] **3,547,139**

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[32] Priority **Feb. 23, 1968**
[33] **Canada**
[31] **No. 013,220**

[54] **FLUID LOGIC PACK**
12 Claims, 16 Drawing Figs.

[52] **U.S. Cl.** **137/81.5,** 137/608
[51] **Int. Cl.** **F15c 5/00**
[50] **Field of Search** 137/81.5; 235/201; 137/608

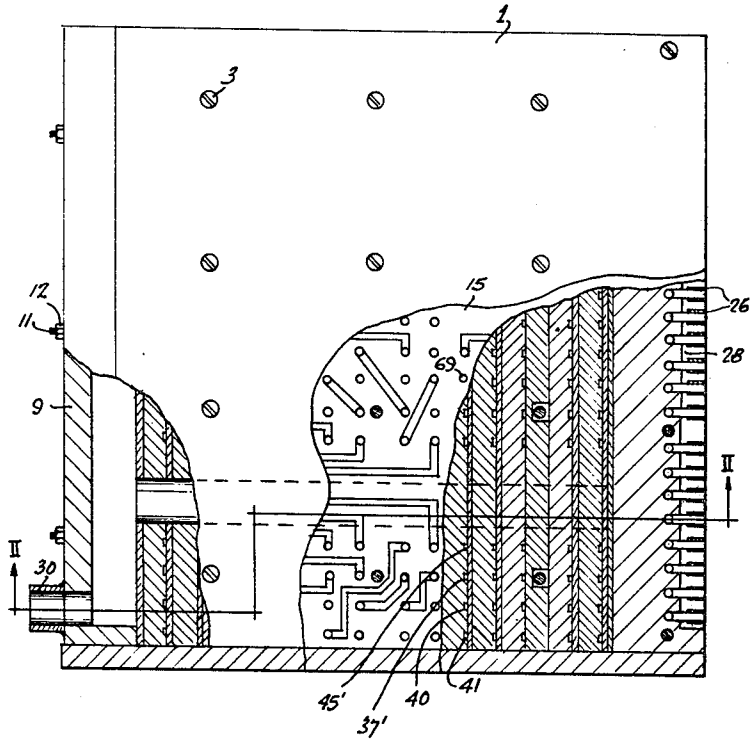
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Primary Examiner—William R. Cline
Attorney—Graham & Baker

ABSTRACT: A fluidic logic circuit assembly comprising a plurality of independent logic elements stacked together to provide a fluid supply conduit through the stack, conduit input and output passages in each of the elements brought to one face of the stack and circuit plates assembled against the one face to provide input and output connections and interconnections to the elements and to the pack. Venting passages for the elements are preferably brought to another face of the stack separate from that for the circuit plates. The fluidic devices may be formed directly in the elements or alternatively may be inserted into receptive pockets in wafers forming the stack. A booster arrangement for improving output of any elements from which there is considerable fan-out is also described.



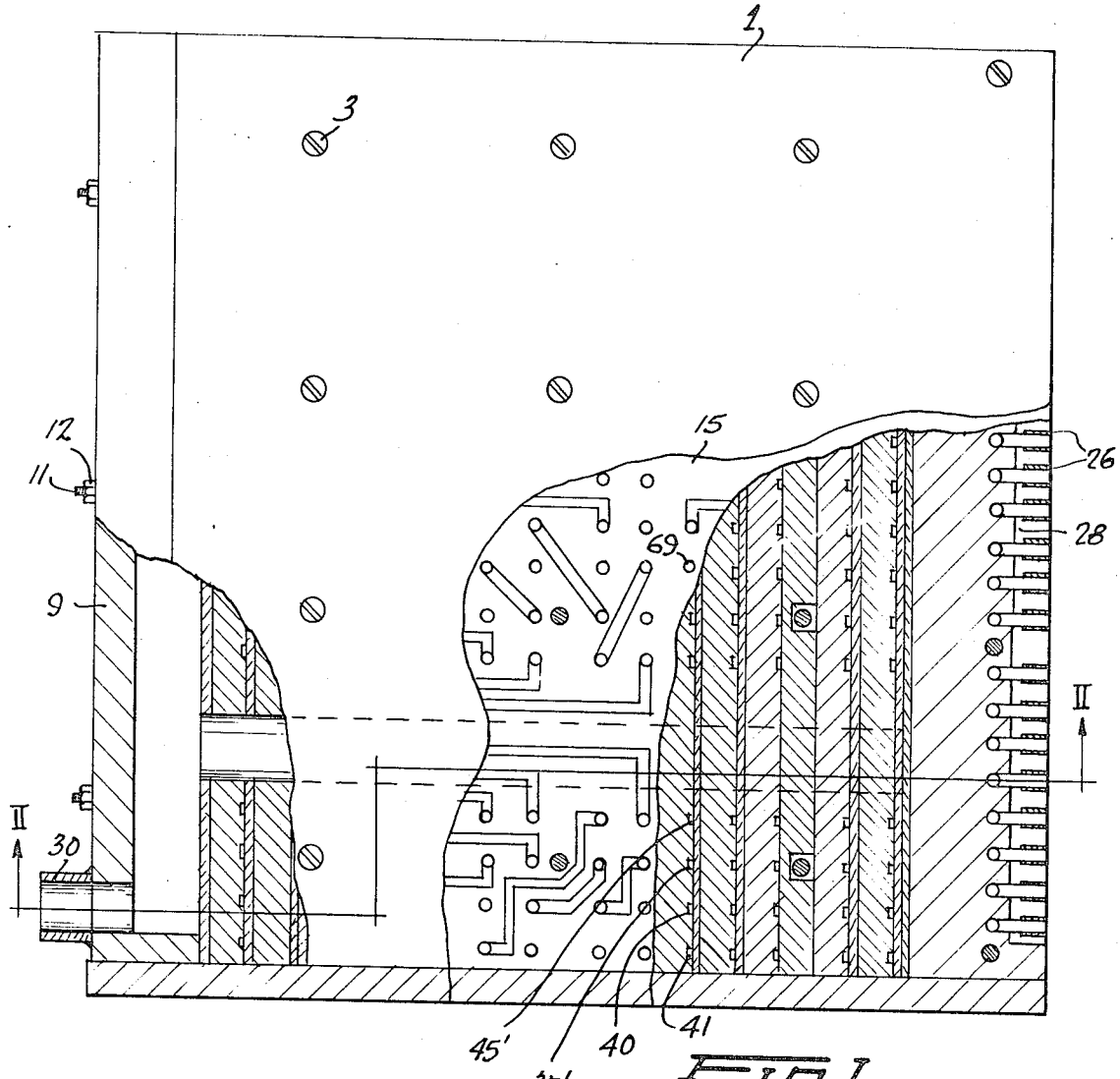

1
3
12
11
15
26
28
69
9
II
II
30
45'
37'
40
41

Fig. 1.

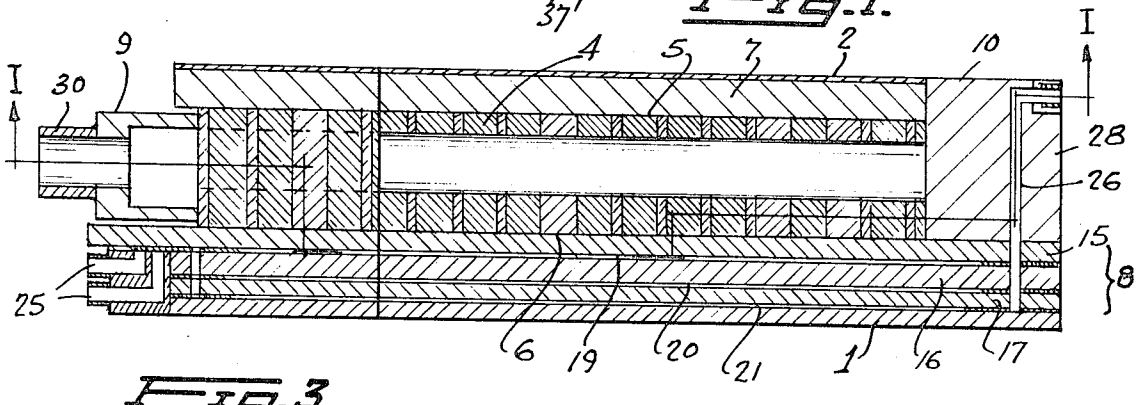

I
I
9
30
4
5
7
2
10
28
26
15
8
25
6
19
20
21
1
16
17

Fig. 3.

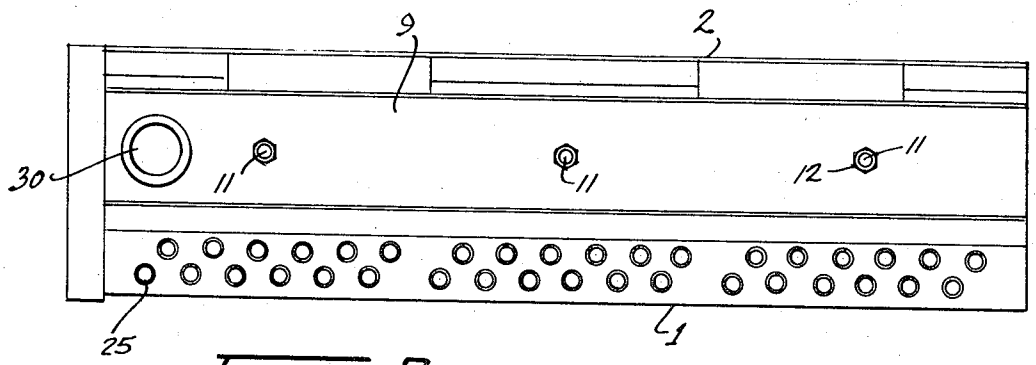


Fig. 2.

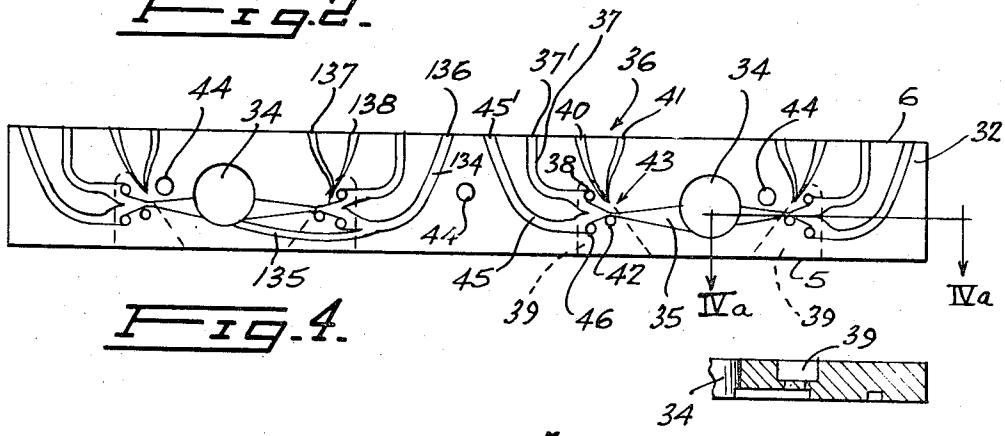


Fig. 4.

Fig. 4a.

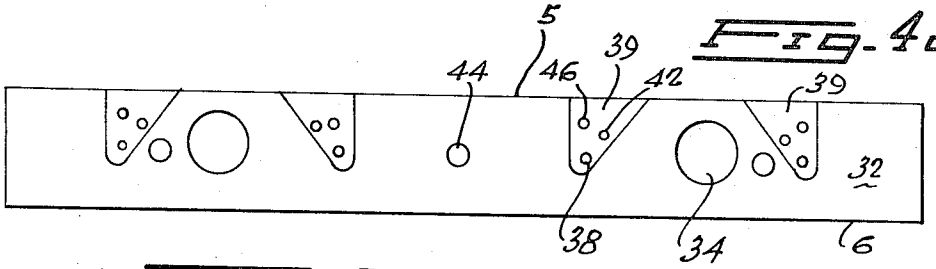


Fig. 5.

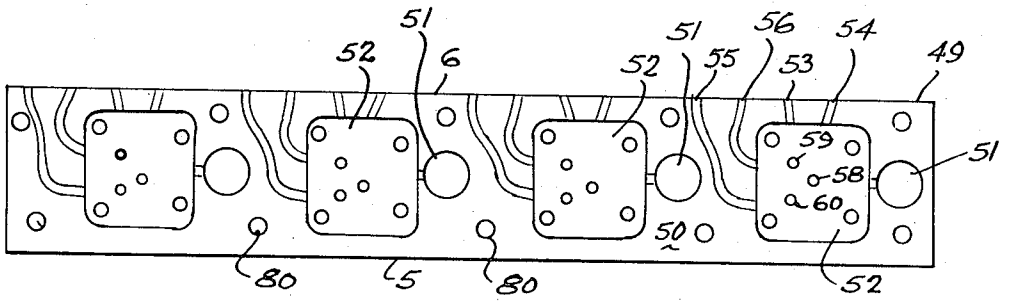


Fig. 6.

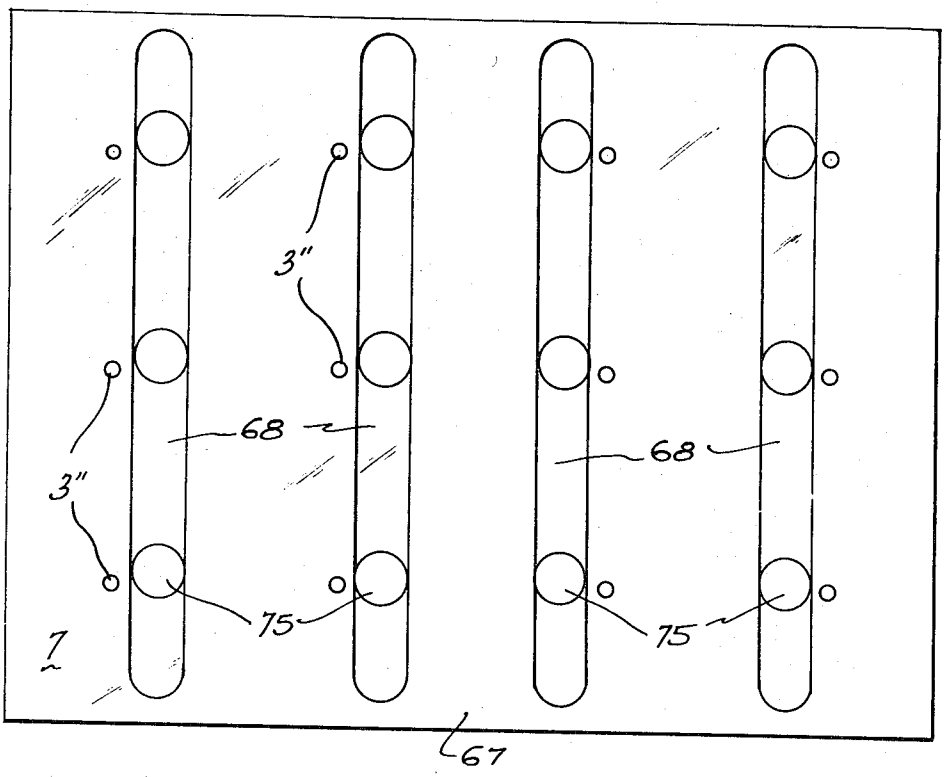


Fig. 8.

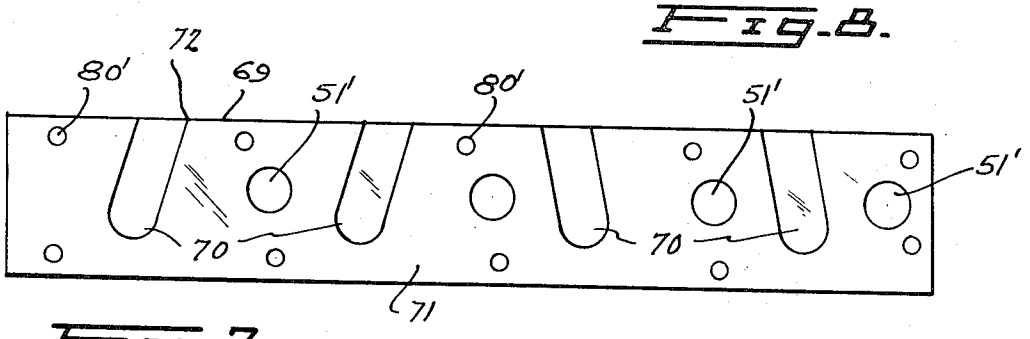


Fig. 7.

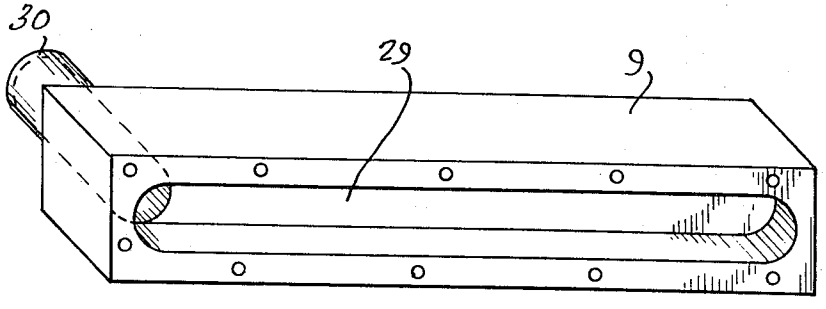


Fig. 11.

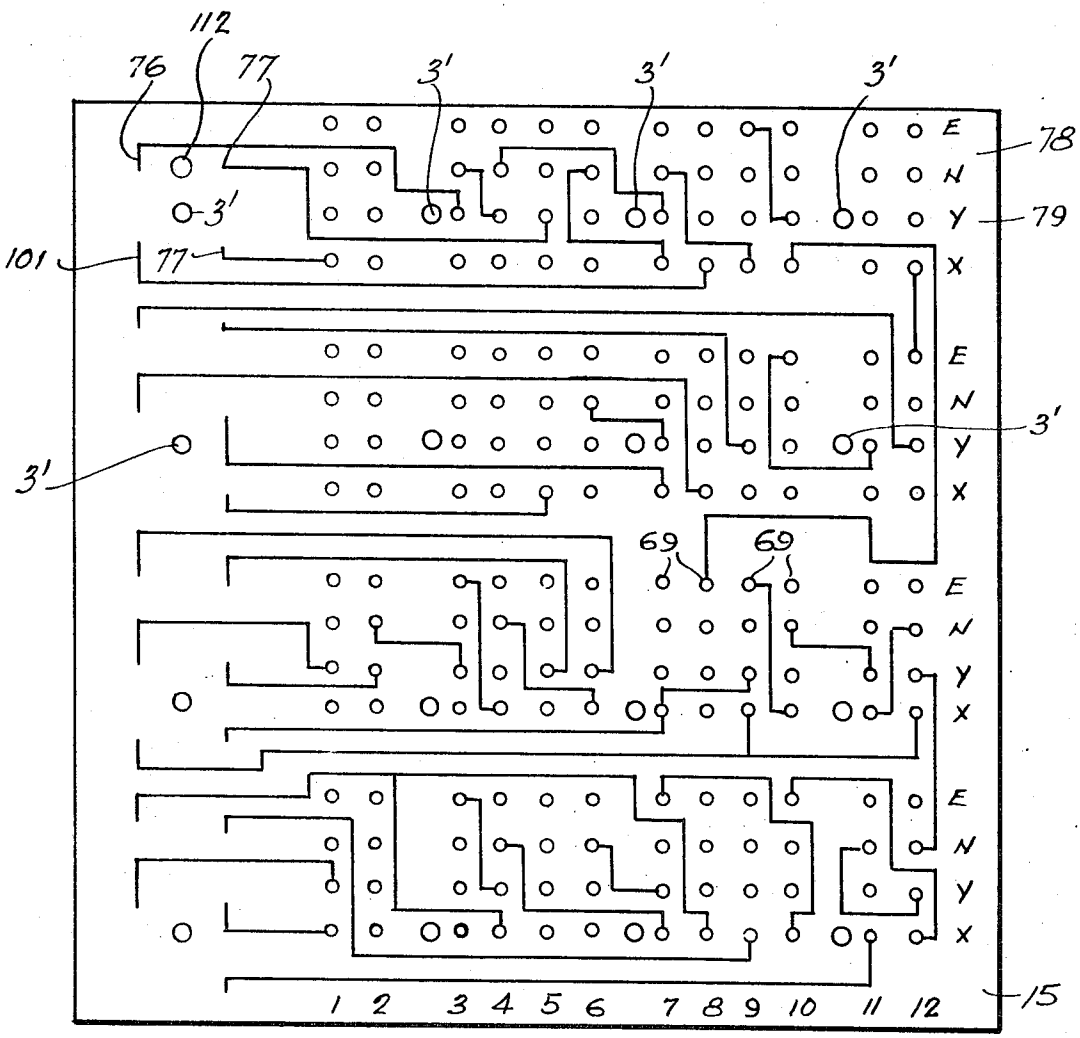


Fig. 9.

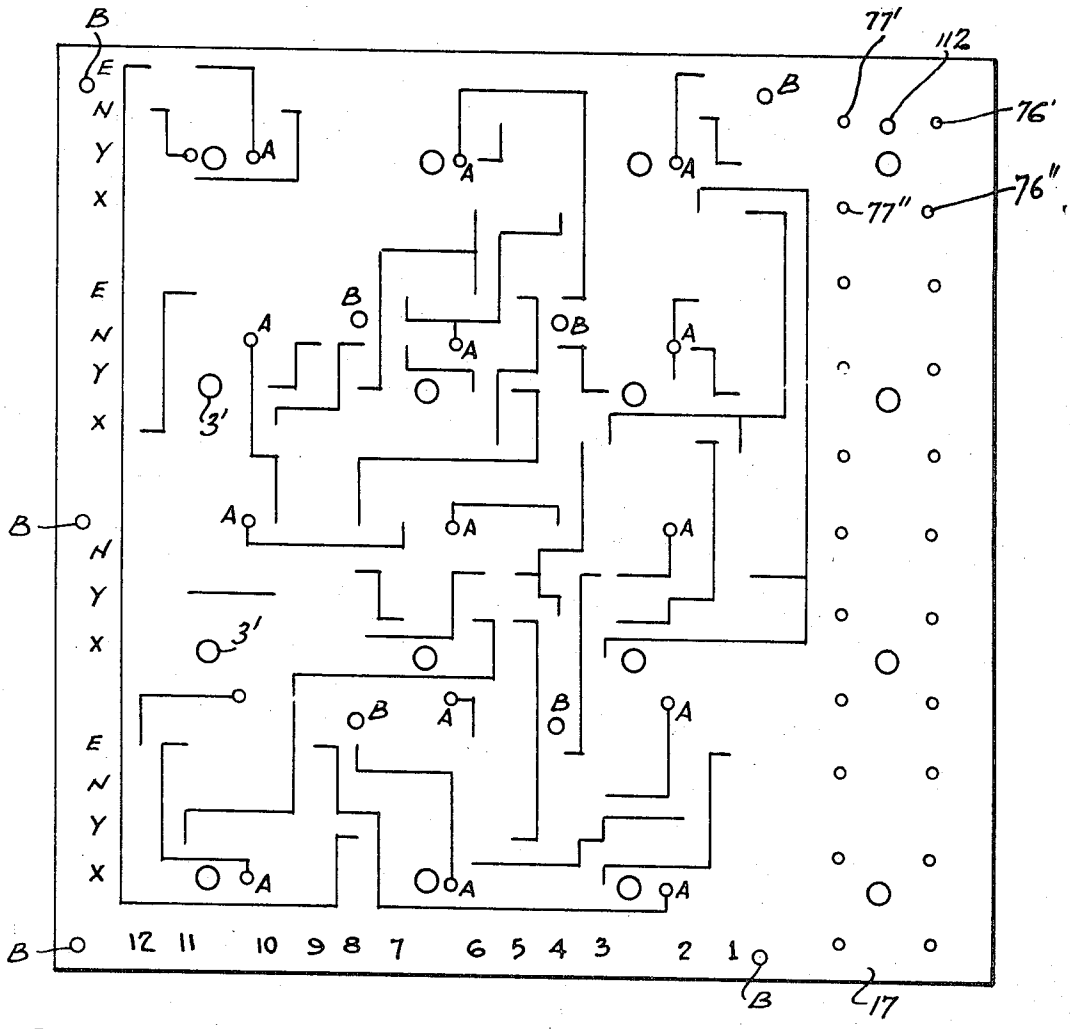


Fig. 10.

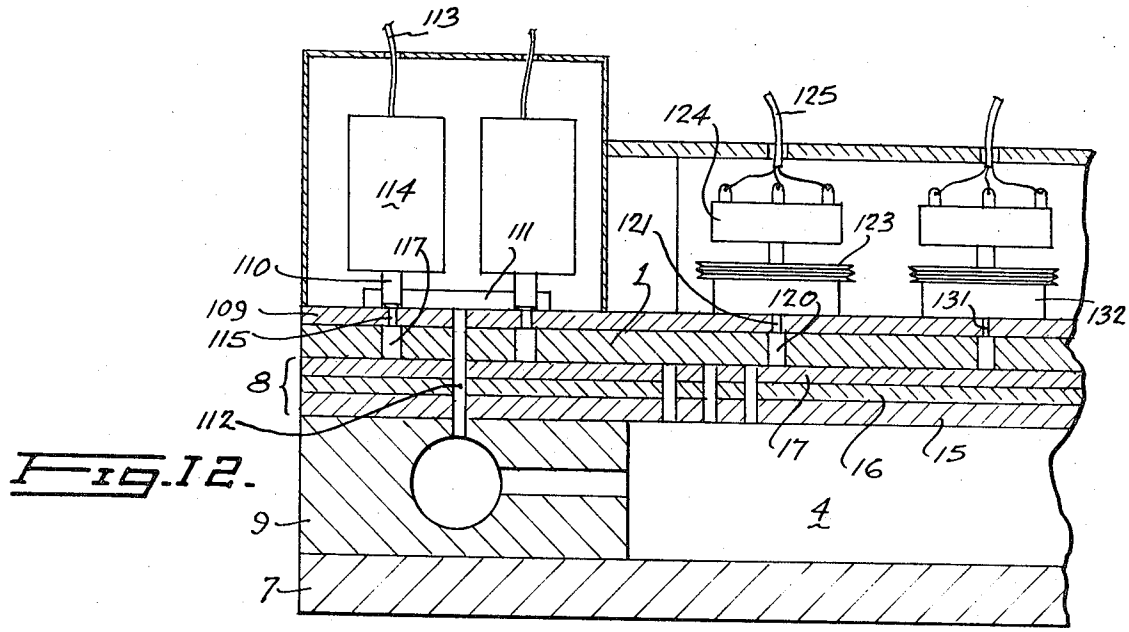


Fig. 12.

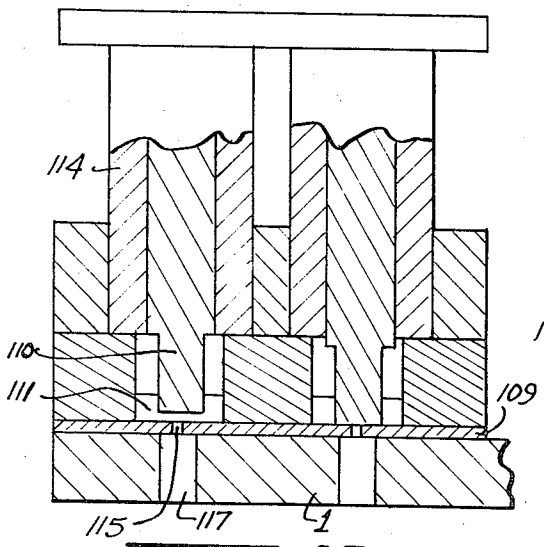


Fig. 13.

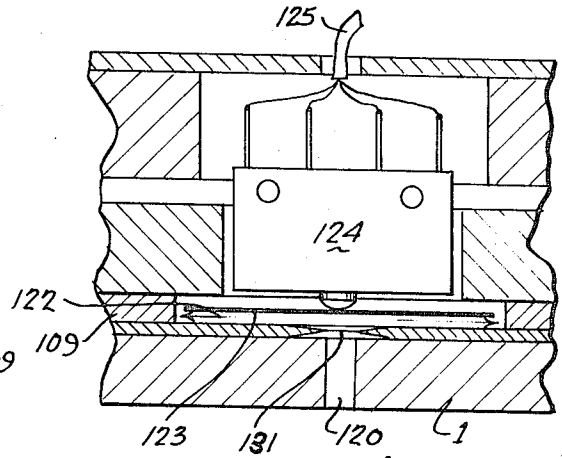


Fig. 14.

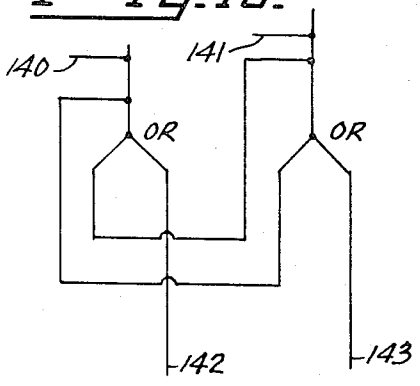


Fig. 15.

FLUID LOGIC PACK

This invention relates to a fluidic logic circuit assembly and has particular reference to an integrated assembly which can be built up from standard parts, and which lends itself to modification in a simple manner.

Fluidic logic circuits are becoming increasingly prevalent particularly for the control of items which require movements suitably executed by hydraulic or fluid actuators. Examples of these are boiler control systems, hydraulic machinery, lathes, earth-working equipment, space vehicles, stable platforms and indeed many items which conventionally are operated by electronic circuitry. Fluid circuitry offers the advantage of being particularly reliable less subject to shock and damage, impervious to nuclear radiation damage and being able to be run quite independently of electrical supplies.

The type of circuit and apparatus with which fluidics can be used is disclosed in my copending U.S. Pat. application, Ser, No. 674,903 filed Oct. 12, 1967, now abandoned.

While partly integrated fluidic circuits have been described in the past, they have in general tended to be of the bread board type requiring many interconnecting pipes similar in many ways to the wired type of electronic circuit. This scheme while effective for some purposes makes it difficult in the space available to include as many active units as may be desired and a balance between volume occupied, speed of operation, and the number of circuit components has to be made.

In practicing the present invention, circuitry more akin to the integrated type of electronic circuit has been made possible resulting in a compact fast operating and economic unit.

More particularly in accordance with the invention there is provided a fluidic logic assembly pack which comprises a plurality of independent logic elements said elements being stacked and providing a continuous fluid supply conduit through said stack, input and output passages in each of said elements brought to a single face of each said element and providing a multiplicity of ports on one face of said stack, circuit plates assembled against said one face of said stack and providing interconnecting passages between selected ones of said ports, means for fastening said stack and said plates, means for supplying fluid to said conduit and means for connecting fluid input signals to and for receiving output fluid signals from said plates. The apparatus may also include venting passages for each element which preferably are discharged to the opposite face of the stack occupied by the circuit plates. Alternatively the elements may be made up of discrete units inserted into receptive pockets in wafers forming the stack. Fluid booster means may be provided by leading supply fluid to those passages from which there is considerable "fan-out" and electrical input and outputs can be provided by the use of electrically operated fluid valve inputs and fluid operated electric switch outputs.

A description of specific embodiments of the invention now follows having reference to the accompanying drawings in which:

FIG. 1 shows a side partly sectional view of a typical integrated fluidic circuit constructed in accordance with the invention;

FIG. 2 shows a rear view;

FIG. 3 shows a top view of the device of FIG. 1;

FIG. 4 is a plan view of an active element assembly wafer;

FIG. 4*a*, is a partial section of FIG. 4 along the line IV*a*–IV*a*;

FIG. 5 is a reverse view of the wafer of FIG. 4;

FIG. 6 shows a plan view of an alternative active element wafer intended to take insert units;

FIG. 7 shows a vent plate for use in conjunction with the apparatus of FIG. 6, and

FIG. 8 a back up plate for use with the vent plate of FIG. 7;

FIG. 9 is an inner circuit plate for supply of signals to and receiving signals from the upper edges of the wafers of FIGS. 4 and 6;

FIG. 10 is an outer circuit plate operating in conjunction with the circuit plate of FIG. 9;

FIG. 11 shows a supply manifold for introducing operating fluid for the wafer stack;

FIG. 12 is a partly diagrammatic section of the assembled pack showing suitable apparatus for feeding electrical signals to and from the fluidic logic circuit;

FIG. 13 shows in greater detail a suitable solenoid assembly for use in the assembly of FIG. 12;

FIG. 14 shows a suitable electrical output circuit for use in the assembly of FIG. 12; and

FIG. 15 is a schematic diagram of a pair of OR elements connected as a bistable.

One assembly constructed in accordance with the invention is shown in FIGS. 1, 2 and 3. This comprises a stack 4 of wafers carrying active logic elements fastened to a source manifold header 9 and an end block 10. Bolts 11 pass through these items and can be drawn up tight by suitable means such as nuts 12. This first assembled subunit is then placed as a sandwich between the circuit plate assembly 8 faced by a capping plate 1 which contacts face 6 of the stack 4 and a vent backup plate 7. Bolts 3 pass through the assembly from the capping plate 1 to the backup plate 7 drawing the whole assembly into a secured unit. Details of the wafer stack 4 will be given later with reference to FIGS. 4, 5 and 6.

The circuit plate assembly 8 consists of a plurality of circuit plates, exemplified as 15, 16, and 17 (though more may be provided if needed) separated from one another and from the clamping plate 1 by gaskets 19, 20 and 21. The plate assembly 8 is further provided with input/output connections 25, at the rear of the unit and, if desired, alternative front input/outputs, at 26 in block 28 secured to assembly 8, and connected into the circuit plate assembly 8 by passages formed in the block 28.

Fluid for supplying the sources of the fluidic elements in the wafer stack 4 is introduced at 30 in header 9.

Referring now to FIGS. 4 and 5, a typical wafer plate 32 forming one member of the stack 4 has four "OR" units engraved into the surface of the wafer. Holes 34 are formed in the wafer which when assembled with other wafers form continuous conduits traversing the stack 4 and connecting with the manifold 9. The manifold 9 is shown in detail in FIG. 11, the passages formed by the holes 34 connecting with groove 29.

Fluid, is thus available in the conduit formed by holes 34 and can bleed off at the source entrance 35 of a typical OR unit 36 when (in the absence of other inputs) an output will appear in limb 37 at port 37' on edge 6. Venting relief is given to limb 37 at hole 38 which allows excess fluid to vent through the wafer 32 where it collects in cut out vent cavity 39 to bleed away through vent plate 7 at edge 5. Inputs to the fluidic unit 36 can be fed in at ports 40 or 41 and are vented beyond the neck 43 of the unit at hole 42 again into cavity 39. In the presence of an input at 40 or 41 the flow through the neck 43 shifts and appears in limb 45 instead of limb 37 providing an output at port 45'. Venting is again provided at hole 46 to allow excess fluid to pass into cavity 39.

Reference to FIG. 6 shows an alternative form 50 for one of the wafers forming a stack 4. Source fluid passes through the stack by way of a conduit formed by holes 51 in each wafer. A plurality of recesses 52 are formed in each wafer into which a respective active fluidic element may be inserted. Such elements are available commercially, for instance from Aviation Electric Ltd., Montreal, Canada If a typical OR unit were inserted in the wafer 50 of FIG. 6, inputs would be provided at ports 53 and 54 and outputs would be available at ports 55 and 56. Venting for the inputs can occur through hole 58 and for the outputs at 59 and 60 respectively. In this instance a vent plate 71 (FIG. 7) is provided behind each wafer 50 so that vent holes 58, 59 and 60 connect with the vent passage 70 of the vent plate 71 bleeding away at the edge 72 (aligned with edge 5) into the exhaust plate 7 (FIG. 3).

It can now be seen that connection is made to the circuit plate assembly 8 by the engagement of edge 6 of the stack 4 against the assembly. The input and output ports at the edge 6 of each wafer are made to mate with holes such as 69 in plate 15 (See FIG. 1 and FIG. 9) and fluidic connections are made between these holes and selected other holes in the plate 15 by

engravings formed in the plate. Where crossovers occur, connection between the respective holes in plate **15** can be made by forming engravings in plate **16** whose holes line up precisely with those of plates **15**. If double crossovers are required additional engravings can be made in plate **17** corresponding to the holes for plates **15** and **16**. The gaskets **19**, **20** and **21** pierced in an exactly similar pattern of holes to the plates **15** and **16** prevent any passage of fluid except in the axial directions of the respective holes and through the engravings. This assembly **8** therefore carries out the connection between the elements in stack **4** to the input/output terminal faces **25** and **26**. All holes are blind-ended by the clamping plate **1** or the plate **17** except where connection may be required to the exterior for input or output. If additional circuit plates are necessary in any particular construction they can be introduced under the plate **1** or **17** with suitable gaskets and will be made with the same pattern of holes as the other plates and be engraved for those interconnections desired to be made. The bolts **3** (FIG. **1**) pass through the holes **3'** of FIGS. **9** and **10**.

The structure of the stack **4** differs slightly depending upon whether it is constructed of wafers of the form of **32** FIGS. **4** and **5**) or of wafers **50** (FIG. **6**). When using wafers **32** each will be separated from the next by a flat spacer plate pierced with holes corresponding to the holes **44** in each wafer **32** for the bolts **11** (FIG. **1**), and also with holes corresponding to **34** of wafer **32** to define the source fluid conduits. The spacer plate thus confines the fluidic flow in each element to its designed passages.

When a wafer of the type shown in FIG. **6** at **50** is employed, each wafer is separated from the next by a vent plate **71** of FIG. **7**. This includes holes **51'** corresponding to holes **51** in the wafer **50** as source fluid conduits, and also fastening holes **80'** corresponding to holes **80** of wafer **50** to accommodate fastening bolts corresponding to the bolts **11**. The manifold **9** also includes holes **11'** for these bolts (FIG. **11**). Since the grooves **70** of vent plate **71** do not pass right through the plate **71** both venting for the holes **58**, **59** and **60** and capping of the adjacent wafer **50** to confine the fluidic flow in that element to the designated passages is provided. That end of the stack **4** employing wafer **50** which is not adjacent to the header **9** has a blind ending plate (which can replace end block **10** of FIG. **1**) and caps off the source fluid conduits formed by holes **51** and **51'**. The modification with the blind end plate is employed when front input/output terminals are not required. The stack **4** includes spacer places (not shown) between certain adjacent wafers which include grooves for allowing the bolts **3** to pass across the stack. These plates also have suitably defined holes to extend the source fluid conduits through them.

Input and output connections to the circuit plate assembly **8** can be made by carrying the circuit passages to regions such as **76** and **77** of FIG. **9** (which connect with the holes **76'** and **77'** in the circuit plate **17** of FIG. **10**). The regions **76** and **77** can then be connected with inputs and outputs **25** (FIG. **1**). Similarly by taking the circuit passages to the regions **78** and **79** (corresponding to holes **78'** and **79'**) inputs and outputs at **26** can be made available if needed. In a prototype embodiment it was found desirable to introduce all inputs to regions **76** and **77** through the capping plate **1** and take outputs directly from the circuit through the capping plate **1**. This arrangement is described later with respect to FIGS. **12**, **13** and **14**.

The face **67** of back up plate **7** FIGS. **1** and **8**) butts against the edge **69** of exhaust plate **71** (FIG. **7**) so that grooves **68** receive vented fluid from passages **70** which in turn receive fluid from holes **58**, **59** and **60** (FIG. **6**). Alternatively, when used with a stack **4** of wafers **32** (FIG. **4**) exhaust plates **71** are absent and the grooves **68** then receive vented fluid directly from cavities **39**. The holes **3''** (FIG. **8**) receive the bolts **3** (FIG. **1**). Holes **75** lead the fluid from grooves **68** to be delivered into a discharge conduit. This would particularly be required if the fluid used were not expendible and were operating in a closed cycle.

It will be understood that with certain circuit elements it may be found satisfactory to vent to the circuit plate assembly **8** rather than to a separate vent space and this can be provided by bringing the vents through passages to ports on edge **6**.

With reference to FIG. **12** and **13** inputs instead of passing through **25** (FIG. **1**) may be provided by a solenoid operated plunger such as **110** from a manifold **111** connected to the supply header **9** by passage **112**. The plunger seals against gasket **109**. When an electrical input at leads **113** is provided to solenoid **114**, plunger **110** is raised and fluid passes from the manifold **111**, via passage **115** in gasket **109**, to the connecting input passage **117** formed in the clamping plate **1**. The fluid then feeds by the means already described through the circuit plate assembly **8**.

When employing the input system just described it may also be useful to take outputs from the clamping plate **1** through passages **120** and **121** connecting with the circuit plate assembly **8** into, for instance (FIG. **14**), a volume chamber **122** connected to a bellows **123** which can operate a limited movement switch **124** and provide an output at leads **125**. As exemplified in FIG. **14**, if desired the passage **121** can be resistive by providing orifice plate shaping at **131** or by restricted passage **120**. Volume chamber **122** can provide capacitive action in conjunction with this resistance. When using this input and output system the circuit plates, except plate **15**, can include output holes A (See FIG. **10**) offset from the grid pattern described heretofor which mate with output passages **120** in the capping plate **1**. Air supply passage **112** for the solenoid header **111** is shown in FIGS. **9** and **10**, and threaded holes B used in the prototype for clamping the bellows assemblies to the capping plate **1** are shown in FIG. **10**. It can thus be seen that the invention permits the design of virtually every type of possible interconnection which might be required between any fluidic element in any of the wafers **32** or **50**. Each circuit plate may be made identically with the others, initially by providing ports at each one of the positions at which an input or output may be present on a wafer, and the interconnections between these ports then subsequently made to suit the particular circuit operation desired, additional holes may be formed in the plates to allow other connections, not directly to an active element.

It is clear that this logic circuit pack can be modified in many ways as determined by the particular operations needed. Fewer wafers could be included by merely providing dummy spacer sections which are pierced to allow the source fluid to pass to the wafers that are active. The number of circuit plates can be altered, as required by the total circuit function, because they are of standard format. The stack **4** can also be made shorter by merely providing the number of active element wafers required and then capping off the stack. Although the circuit plates will overhand the stack since they are a standard format there will be no interference with the circuit function because the holes in the plate which would correspond with the ports in the absent active elements are merely not connected in circuit. Additional elements can be added later when new circuit plates can be made up, or the existing ones modified, to include the new elements.

It is an advantage to vent to the surface opposite from that in which the circuit functions occur and by providing a manifold collection system, the fluidic units can be used with any type of fluid whether in a closed or open cycle. It should also be understood that the stack **4** may contain a mixture of different types of active fluidic elements thus wafers containing bistable elements may be inserted in the stack along with wafers containing OR and memory and amplifier elements, etc. because all wafers in the stack are made to a standard format compatible with the basic grid pattern of holes in the circuit plate assembly **8**. The scheme of providing for plug-in fluidic elements enables conventionally available types to be used, even for those in which venting may occur on the same face as the inputs and the outputs. Crossovers of venting and input and output channels can readily be provided, even though many fluidic circuits may require a variety of elements

such as AND, OR and bistable devices. If desired, bistables can be avoided for instance by interconnection of two OR's in known manner, (FIG. 15). This in general, has been found to be more stable and less subject to bounce or faulty operation due to system noise than the standard single fluidic flip-flop unit. Separate triggering inputs are fed in at 140 and 141 and outputs are available at 142 and 143.

A booster system can be included by providing an additional flow of supply fluid to those ports of the circuit where flow or pressure is insufficient for proper operation. This system is particularly satisfactory in a circuit where the output in one limb of an element is required to feed several further units. In such a "fan-out" additional fluid can be bled into the limb 134 (FIG. 4) by making a connection shown by the engraved passage 135. Since ample additional fluid is available at the conduit formed by the series of holes 34, effective boosting results. By control of the size of passage 135 the avoidance of insufficient pressure to produce an output at 136 except when inputs occur at 137 or 138 can be achieved. In cases where it is undesirable to modify the fluidic element itself, the booster passage can be formed in the circuit plate assembly 8. Suitably a passage having booster fluid from the manifold 9 (FIG. 1 and 11) can be run across the plate assembly 8, and can be bled from there to any passage or port requiring a boost.

I claim: 1. A fluidic logic assembly pack which comprises a plurality of independent fluidic logic elements, said elements being stacked and having means providing a continuous fluid supply conduit through said stack, input and output passages in each of said elements, said input and output passages being brought to a single face of each said element forming ports therein, said single faces being aligned to provide a multiplicity of ports on one face of said stack, circuit plates assembled against said one face of said stack, said circuit plates having means therein providing interconnecting passages between selected ones of said ports, means for fastening said stack and said plates together, means for supplying fluid to said conduit and means for connecting fluid input signals to and for receiving output fluid signals from said plates.

2. Apparatus as defined in claim 1 each said element including venting passages separate from said input and output passages connected to a chosen face of said element and thus to a chosen face of said stack.

3. Apparatus as defined in claim 2 said chosen face being different from said first mentioned face.

4. Apparatus as defined in claim 3 comprising manifold means connecting said venting ports.

5. Apparatus as defined in claim 1 including gasket means separating each of said circuit plates, holes defined in said circuit plates, holes defined in said gasket means for connecting said circuit plates in alignment with said plate holes, and passages defined in said plates for interconnecting chosen ones of said holes.

6. Apparatus as defined in claim 1 including means adjacent said circuit plates for receiving output fluid therefrom, fluidic operated mechanical means receiving said output, and means connecting an electrical switch to said fluidic operated means for providing an electrical output from said unit.

7. Apparatus as defined in claim 1, including fluidic booster means in at least one of said elements and comprising a passage connecting said fluid supply conduit and the output of said one element independently of fluidic connection through said element.

8. Apparatus as defined in claim 1, including fluidic booster means for at least one of said elements and comprising a passage in at least one of said plates for leading booster fluid from a supply fluid source to said element.

9. Apparatus as defined in claim 1 said elements being provided in wafers and at least one element in each said wafer.

10. Apparatus as defined in claim 9 each of said wafers including a receptive pocket defined therein for receipt of a discrete fluidic element device, passages defined in said wafer for connection to passages in each said device, and sealing means in said stack for preventing fluidic flow in any one of said devices from passing to any other of said devices except through said circuit plates.

11. Apparatus as defined in claim 1 comprising electrically operated valve means adjacent said circuit plates for feeding signals into said plates at chosen points upon operation of said valve means.

12. Apparatus as defined in claim 11 including fluidic supply means adjacent said valve means and connected to said continuous fluid supply conduit for supply fluid upon operation of said valve means.