

Sept. 9, 1969

W. G. KAUTZ ETAL

3,465,774

SEMI-INTEGRATED (FLUIDIC) LOGIC SYSTEM

Filed March 10, 1967

4 Sheets-Sheet 1

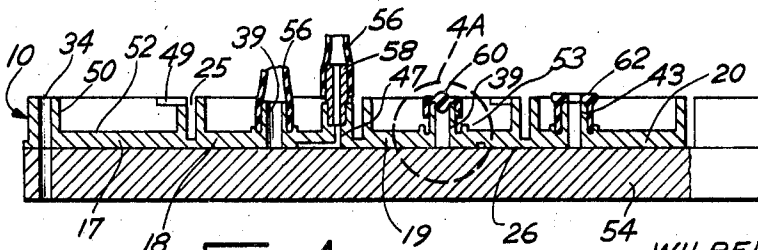
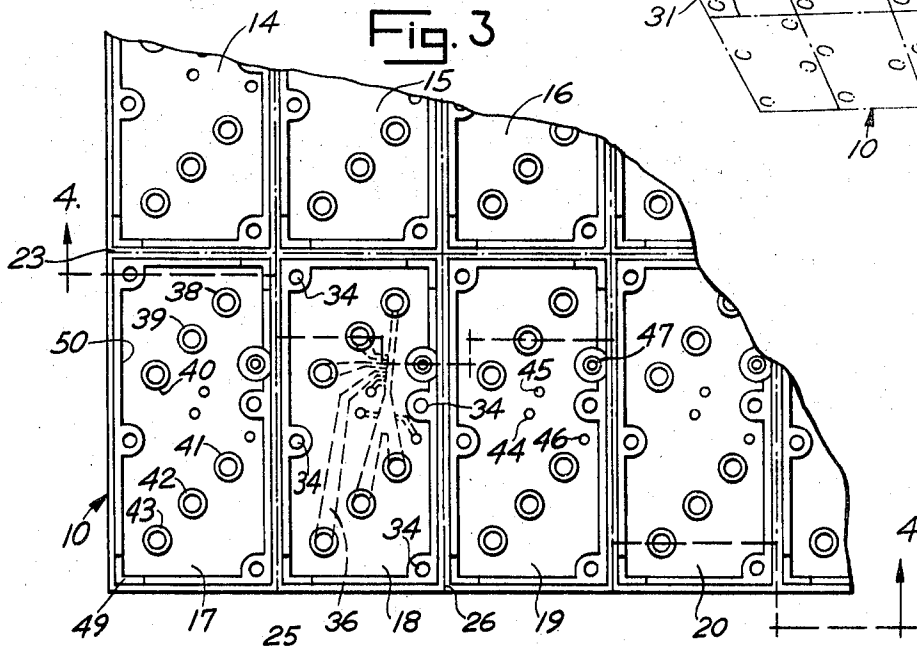
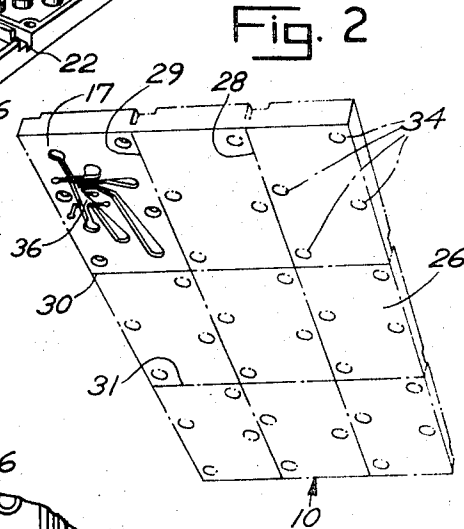
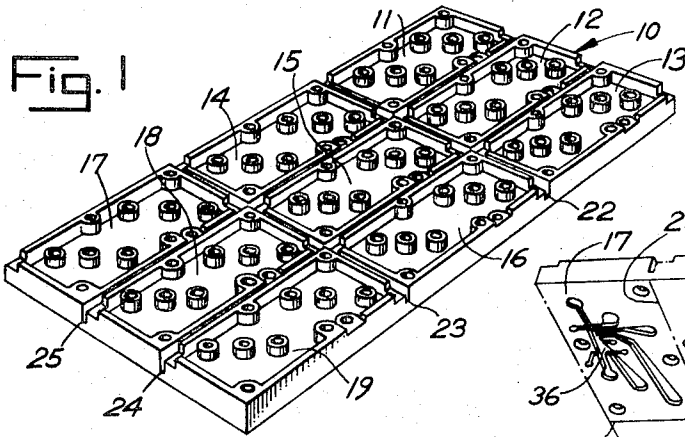


Fig. 4

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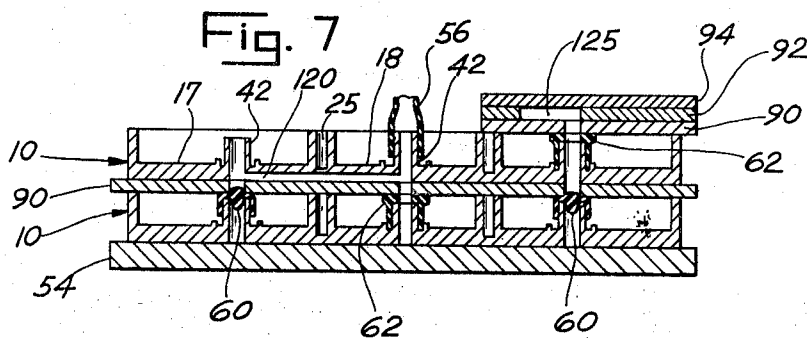
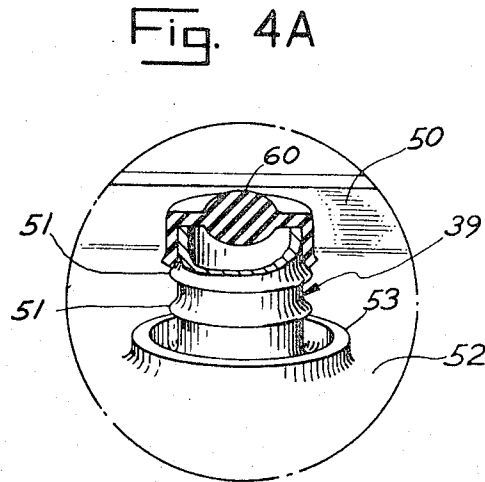
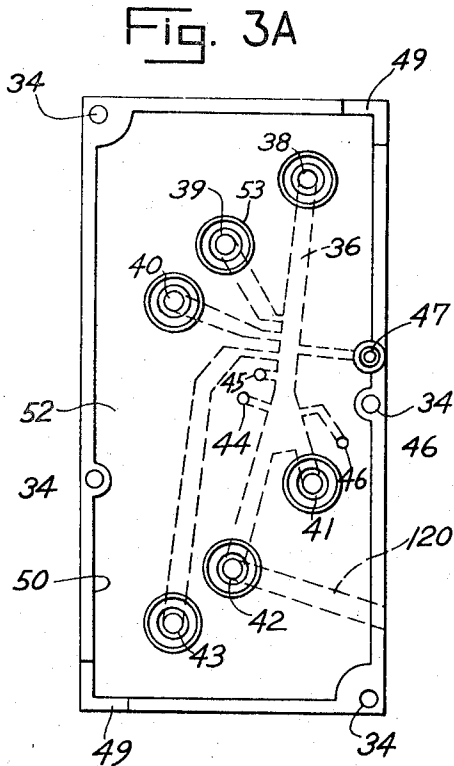
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SEMI-INTEGRATED (FLUIDIC) LOGIC SYSTEM

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4 Sheets-Sheet 2



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4 Sheets-Sheet 4

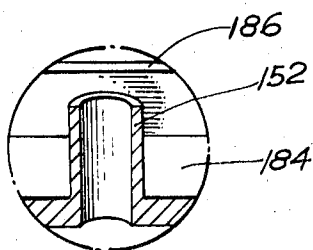
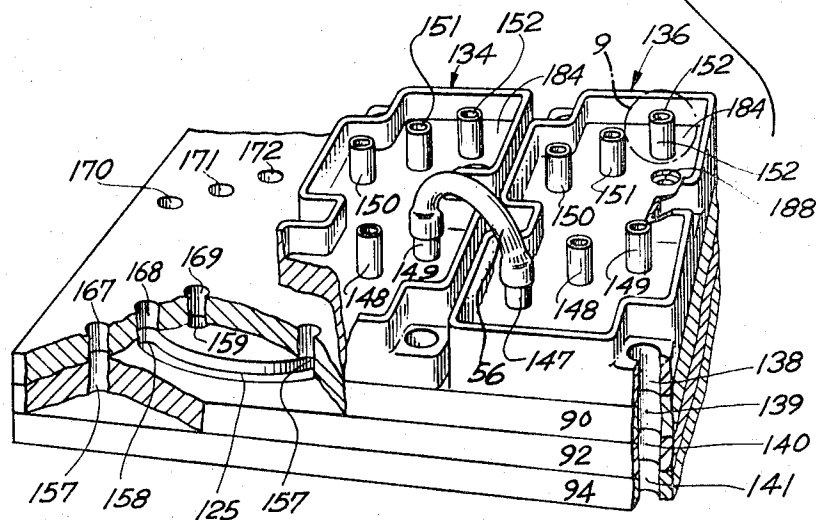


Fig. 9

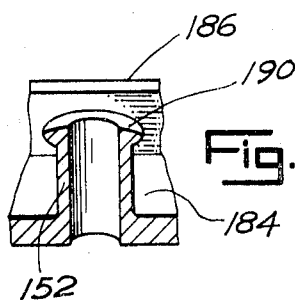


Fig. 9A

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SEMI-INTEGRATED (FLUIDIC) LOGIC SYSTEM
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U.S. Cl. 137—81.5

6 Claims

ABSTRACT OF THE DISCLOSURE

A modular "fluidic" (fluid logic) system which includes multiple fluidic devices. Each fluidic device, regardless of its function, takes the form of a standardized, modular element or "building block" having port locations positioned to mate with the interconnecting passageways in a mounting assembly. Access ports are provided at both the top and the bottom of each modular element so that a three dimensional, stacked array of elements may be formed. Ports may be exposed, allowing the operation of the apparatus to be altered by manipulating interconnecting conduits, sealing plugs, and the like.

Background of the invention

This invention relates to fluid operated devices and, more particularly, to "fluidic" logic and control apparatus constructed of interchangeable modular units.

Fluidics is the science of using interacting fluid flows to perform switching and logic operations. Fluidic devices, which use no moving parts other than the flowing fluid streams themselves, are capable of performing logical operations similar to their electronic counterparts. Fluidic devices have heretofore been produced as separate units and then interconnected by conduits to produce the desired, complex fluid logic system.

A problem encountered in the construction of prior fluidic systems has been their individual construction complexity and the time required to interconnect separate elements in order to obtain a workable complex circuit. Moreover, the various interconnecting conduits may often affect the operating characteristics of the complex circuit in an unanticipated and unfavorable manner.

A complex circuit may, of course, be milled or cast as a single unit. When this is done, however, the separate elements within the circuit cannot be replaced. Moreover, the operation of such a unit cannot be conveniently modified to meet different or changing needs. Such complications increase the cost, reduce the flexibility and increase the complexity of fabricating complex fluid circuits.

Summary of the invention

In a principal aspect, the present invention consists of single or several distinct, unconnected, fluidic devices, for example "OR," "AND," "NOR" devices, molded individually or multiply in one face of a sheet or block of material. According to the invention, individual fluidic devices in the block are confined to individual, modular areas or modules of the block, or each device may be molded in a separate modular block or module. When molded multiply, each module may be separated from the block into separate modules by fracturing the block along recesses which defined break lines separating the modules. Fluid input, control and output ports which communicate with the fluidic devices are located in a regular array on each module or element to register with interconnecting passageways defined in a mounting assembly. The mounting assembly comprises various combinations of plates on which the modules are mounted in substantially fluid tight relationship. Access ports are preferably defined on each major face of each module or ele-

ment so that the modules may be "stacked" in a three-dimensional array in combination with the mounting assembly to create a complex yet compact fluidic system.

It is a principal object of the invention to avoid complex assembly operations each time individual fluidic devices are to be combined into a complex fluidic circuit.

It is a further object of the invention to provide a semi-integrated fluidic system which is compact, easily assembled, and readily modified to perform new functions.

These and other objects, features and advantages of the present invention may be more clearly understood through a consideration of the following detailed description. In the course of this description, reference will frequently be made to the attached drawings.

Brief description of the drawings

FIGURE 1 is a perspective view showing the top surface of nine modular fluidic elements in a single casting.

FIGURE 2 is a perspective view showing the bottom surface of the nine modular fluidic elements shown in FIGURE 1 with the passageways defining a typical fluidic device shown molded into the bottom surface of one of the nine elements.

FIGURE 3 is a partial, top plan view showing several fluidic elements in more detail.

FIGURE 3A is a top plan view of a single, molded modular fluidic element.

FIGURE 4 is a side cross-sectional view taken substantially along the lines 4—4 of FIGURE 3 showing the fluidic elements stacked in fluid tight relationship with a base plate and illustrating the use of various interconnecting and sealing devices.

FIGURE 4A is a perspective view of the encircled typical nipple protrusion shown in FIGURE 4.

FIGURE 5 is an exploded, perspective view of a second embodiment of the invention wherein the modular elements are stacked in a three-dimensional array.

FIGURE 6 is a perspective view showing assembled stacked and interconnected fluidic elements.

FIGURE 7 is a cross-sectional view of FIGURE 6 substantially along the lines 7—7.

FIGURE 8 is a perspective view showing an alternative combination of interconnected fluidic elements.

FIGURE 9 is a perspective view of the encircled nipple shown in FIGURE 8.

FIGURE 9A is a perspective view of a modification of the nipple shown in FIGURE 9.

Description of the preferred embodiments

A single molded casting 10 comprising nine separable modular fluidic elements numbered 11 through 19 is shown in FIGURE 1. The modular elements 11 through 19 are substantially identical and may be cast separately or separated into individual elements by breaking or otherwise separating the integral casting 10 along recessed break lines 22 through 25. The recessed break lines 22 through 25 also act as vent channels for the fluidic elements when they are stacked (as described later).

FIGURE 2 shows the underside 26 of the casting 10 shown in FIGURE 1. Dashed lines 28 through 31 indicate the boundaries of the separable elements 11 through 19 along the break line recesses 22 through 25. Four holes 34 for fastening each element 11 through 19 are shown penetrating the bottom surface 26 of the casting 10. For illustrative purposes, a typical fluidic device 36 is shown molded or etched in element 17. In actual practice, such a device would be defined in the bottom surface of each of the modular surface areas bounded by the dashed lines 28 through 31. The devices could all be the same; for example, NOR gates could be defined in the bottom surface of all of the elements. On the other hand, there could be a combination of devices defined in the

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bottom surface of the elements; for example, in FIGURE 1, elements 11 through 15 could have NOR gates defined therein while elements 16 through 19 might constitute R-S gates. Since fluidic devices are very common and the choice of the devices to be used in a casting depends upon the requirements of the fabricator, great varieties of combinations are possible depending upon the logic system desired or the job to be performed. Furthermore, the number of elements in a casting may vary from a single element to multiple elements each containing a separate fluidic device depending, once again, upon the fabricator's requirements and desires.

The plan view of FIGURE 3 further illustrates the relationship between the modular elements. The casting 10 is divided into several modular elements including those numbered 14 through 19. The modular elements 14 through 19 are separated by recessed break lines 23, 25 and 26. A typical fluidic device 36 is shown in phantom defined in the bottom surface of the element 18. Each of the modular elements 14 through 19 are substantially identical on their upper surfaces and each has hollow, nipple-like protrusions as shown, for example, at 38 through 43 on element 17. Likewise, each element has vent ports or channels as shown, for example, at 44 through 46 on element 19. Each element also has a vacuum port or channel as shown at 47 on element 19. There are indentations or slots in the circumferential ridge which bounds each fluidic element. These slots are positioned at opposing corners of the modular element as illustrated by the slots 49 in the circumferential ridge 50 which extends around the modular element 17.

The enlarged view of FIGURE 3A shows the construction details of a single molded modular element. Passageways extend downwardly through each of the nipples 38 through 43 from the flat top of the nipples through to the undersurface of the element. The passageways interconnect with the various input, output and control channels of the fluidic device 36. Vent ports or channels 44 through 46 are merely passageways extending from the top surface 52 of the fluidic element through to the undersurface where they, in turn, connect to the fluidic device 36. In the same manner, a vacuum port 47 has a passageway extending through the fluidic element and connected to a channel which is connected to the typical fluidic device 36. When any port is not employed (38 through 43 and 47), it is often left open and treated as a vent port.

The fluidic device 36 shown in phantom is typical of the numerous devices available and the invention is not limited to use with particular devices. Generally such devices comprise an input channel for receiving a constant fluid flow and one or more fluid output channels with various control and vent channels branching off from the chamber area where the input and output channels join or branching from the input or output channels themselves. In FIGURE 3A, for example, the channel connected to the nipple 38 could be the input channel, the channels connected to the nipples 41 and 42 could be output channels, and the channels connected to the remaining nipples could be control channels. Similarly, channels are connected to the vent ports 44, 45 and 46 and the vacuum port 47. The important feature of an element, as typically shown in FIGURE 3A, is the standardized construction of the element and standardized placement of the nipples with channels in the undersurface defining the fluidic device connected to the nipple passageways.

Fastening means holes 34 are also shown in the modular element of FIGURE 3A passing through the element. Slots 49 cut into the ridge 50 permit excess fluid such as air and the like which is escaping through the vent ports 44 through 46 to escape from the area above the top surface 52 of the element. This is especially helpful when the fluidic element is surrounded on all sides and the top by other elements or plates. For example, referring back to FIGURE 1, it can be seen that an element such as 15

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which is surrounded on all sides by other elements and which has a plate (not shown) positioned on top of the casting 10 provides no vent outlet to the atmosphere except for those vents or slots corresponding to 49 in FIGURE 3A which permit the fluid to pass through slots into the channels defined by the recessed break lines 22 through 25 and out into the atmosphere.

The nipple-like protrusions 38 through 43, since it may be desirable to vent them also, do not extend above the element surface 52 to the same height as the ridge 50. Thus, when a plate is placed against the ridge 50 in order to cover the element, fluid may escape from any of the nipple-like protrusions 38 through 43 and out through the slots 49. Note that the vacuum connection 47 also extends to a height above the upper surface 52 of the element but below the height of the ridge 50.

FIGURE 5 is a cross-sectional view taken substantially along the line 4—4 of FIGURE 3. The casting 10 is shown mounted on a cover plate 54 by fastening means (not shown) passing through the fastening means hole 34.

The fastening means hole 34 is shown in the circumferential ridge 50. As can be seen, the ridge 50 extends above the top surface of the casting and has the slots 49 defined therein. The recessed break line 25 is shown defining the boundary between adjacent fluidic elements 17 and 18. A conduit or hose 56 is shown positioned over a typical nipple-like protrusion 39 extending above the surface 52 of the modular element 18. As noted before, the height of the protrusion 39 is less than the height of the ridge 50.

FIGURE 4A illustrates a preferred method of constructing the protrusion 39. An annular ring 53 is integrally cast into the element upper surface 52 and barb-like circumferential ridges 51 are cast to extend outwardly from the outside surface of the protrusion 39. Thus, the hose 56 which is slipped over the protrusion 39 is grasped firmly by the barbs 51 on the protrusion and fits snugly into the space between the annular ring 53 and the protrusion 39, thereby promoting a more efficient seal between the hose 56 and the protrusion 39.

The vacuum port 47 is integrally molded into the ridge 50. As with the nipple-like protrusions, the vacuum port or vent 47 does not extend to the same height as the ridge 50. FIGURE 4 shows a preferred method of interconnecting the vacuum port 47 to a hose or conduit 56. A vacuum ferrule 58 is inserted into the passageway of the vacuum vent 47 and a hose 56 is in turn slipped over the vacuum ferrule 58. Such an interconnection is necessitated by the fact that the vacuum port is situated in the circumferential ridge 50 thus making it impossible to slip a conduit 56 over the vacuum port 47.

Various seals are shown at 60 and 62 in FIGURE 4. At 60, a double-dimpled seal is shown positioned over a typical nipple 39. At 62 there is shown an interconnecting seal which slips over the typical nipple-like protrusion 43 thereby creating an unbroken passageway from the protrusion to a plate (not shown) which can be positioned over the modular element 20.

FIGURE 5 is an exploded view of a cover plate 54, with a casting 10 mounted thereon, upon which is mounted a base plate 90, which in turn is mounted by another casting 10, upon which is mounted a second base plate 90, a circuit module 92 and a top cover plate 94. Fastening means such as a bolt 96 is positioned through holes such as 98, 99, 100, 34, 101, 102 to hold the entire configuration in fluid tight relationship. The cover plate 54 has holes 102 corresponding to the fastening holes 34 of the casting. The same is true of the top cover plate 94. However, the base plate 90 and circuit module 92 have additional holes such as 109 through 114 which are positioned over the nipples 38 through 43 of the casting 10. The base plate 90 has holes such as 101 corresponding to holes 34 of the casting 10.

Circuit module 92 also has channels such as 125 cut through circuit module which terminate at positions cor-

responding to the nipple positions in the casting 10. Of course, many configurations of channels 125 may be cut in the circuit module 92 depending upon the fabricator's desires. Stopper seals 84 and connecting seals 86 as described before (not shown in FIGURE 5) may be used in conjunction with a casting 10, a base plate 90 and circuit module 92. Note how vent slots 49 act in combination with vent recesses 23 and 24 to provide venting means to the element 19 of the casting 10 covered by the plate 90.

FIGURE 6 discloses still another and very practical way of creating complex fluidic circuits by means of the present invention. Six elements 11, 12, 14, 15, 17, 18 are shown with a conduit 56 which interconnects various pairs of nipples. As in FIGURE 6, part of the fluidic elements may be interconnected by conduits 56, part by circuit modules 92, and part by stacking a base plate 90 and stopper 84 or connecting seals 86 (not shown) and a casting 10 upon another or first casting 10 as more clearly illustrated in FIGURE 5. The base plate 90, cover plate 54, circuit module 92, and top cover plate 94 may be flush with the casting sides or may, as in FIGURE 6, extend beyond the casting sides to act as protection for the elements. Separate elements may be replaced in any configuration with a minimum of time and effort since they are modular.

One further method of interconnecting elements is illustrated in FIGURE 7 which is a cross-sectional view of FIGURE 6 substantially along the line 7—7. A channel 120 is milled in the base of the casting 10. The channel 120 interconnects separate devices defined in the base of the adjacent elements 17 and 18. The depth of the channel 120 is sufficient to allow passage of fluid but not great enough to cause the channel 120 to intersect the recess 25.

Summarizing, FIGURE 7 illustrates four methods by which complex fluid circuits may be created from interconnecting fluidic devices molded in the separate fluidic elements: (1) by means of a milled channel 120 between planar elements, (2) by means of stopper 60 and connecting seals 62 in combination with a base plate 90 between stacked elements, (3) by means of a circuit module 92 having channels 125 cut therein in combination with base 90 and cover plates 94, and (4) by means of conduits or hoses 56 attached to nipples 38 and 43, thereby connecting the various modular elements to one another or to external sources.

The fluidic elements claimed in this application may also be interconnected by means described in the application for a Fluid Logic Circuit Mechanism, Ser. No. 570,663, filed Aug. 5, 1966 by Karl A. Brandenburg now Patent No. 3,407,834. FIGURE 8 illustrates such a means for interconnecting the individually or multiply molded fluidic elements 132, 134 and 136 by mounting the elements on modular plates. The modular plates comprise a cover plate (CP) 94, a circuit module (CM) 92 and a base plate (BP) 90 stacked one upon the other and held together in substantially fluid tight relationship by fastening means (not shown) passing through the openings 138, 139, 140 and 141 in the element 136, the base plate 90, the circuit module 92, and the cover plate 94 respectively. The fastening openings 138 through 141 also serve to align the various components in proper stacked relationship.

The base plate 90 and circuit module 92 are similar as they both have modularly positioned openings 167 through 172 and 157 through 162 respectively, corresponding to the port openings of the nipples 147 through 152 respectively, on the modular fluidic elements 132, 134 and 136. However, the openings in the circuit module 92 are interconnected in a prescribed manner dependent upon the desired fluidic circuit. For example, the channel 125 connects the opening 158 to the opening 157. The circuit openings 157 and 158 are connected respectively to the base plate openings 167 and 168 which, in turn, connect

with the bottom of the nipple 147 in element 132 and 143 in element 134 respectively. This would correspond in function to connecting a conduit from the nipple 147 in element 132 to the nipple 148 in element 134 respectively. In a preferred mode of use, the power input fluid pressure source would be fed into the circuit module 92 to the various elements. Then the outputs of the elements would be interconnected as desired by conduits 56 to give the desired fluidic circuit.

The fluidic device 180 defined in the undersurface of the element 132 has a semi-crushable flange 182 surrounding the device 182 and each fastening opening 133. The flange or dam 132 is slightly crushable to approximate a seal when the element 132 is mounted on the stacked base plate 90.

In the stacking arrangement illustrated in FIGURE 8, the elements 132, 134 and 136 have nipples 147 through 152 which extend from the top surface 184 of the elements above the height of the circumferential protective wall 186. This alternative construction of the nipples 147 through 152 and wall 186 prevents stacked arrangement of elements; however, the utility of the modular elements is not diminished since they may still be connected by circuit modules 92 and conduits 56.

The vacuum port 188 is shown in element 136 as similar in construction to the vacuum port 147 in FIGURE 4; however, the vacuum port 188 is flush with the top surface 184 of the element 136.

FIGURE 9 shows the nipple 152 as cast and FIGURE 9A shows the nipple 152 after the tip end has been heated and molded to form a flange or lip 190 which promotes attaching a conduit 56 over the nipple 152.

What is claimed is:

1. A modular fluidic element block comprising, in combination:
 - a block having a circumferential side surface, a bottom surface and a top surface substantially parallel to said bottom surface, at least three passageways passing through said block substantially perpendicular to said top and bottom surfaces, protrusions extending from said top surface coincident with each of said passageways, said passageways extending through said protrusions to provide fluid flow passages through said blocks,
 - a fluid logic element recessed in said bottom surface, said element having at least one fluid inlet, at least one fluid outlet and at least one fluid control inlet, each of said inlets and said outlets being connected with a single passageway,
 - vent passages through said block from said fluid logic element to said top surface,
 - a substantially circumferential ridge around the periphery of said block extending from said top surface above said protrusions,
 - at least one notch through said ridge, and
 - means for spacing the outside surface of said ridge from the outside side surface of the ridge of an adjacent block.
2. A plurality of logic blocks of the type set forth in claim 1 in combination with a planar base against the bottom surface of said blocks and also including tubes for interconnecting protrusions to thereby define a complex fluid logic circuit.
3. The logic element block of claim 1 including at least one gasket member adapted to cooperate with a single protrusion of said block to facilitate a fluid circuit connection between a passageway and a fluidic logic element recessed in an adjacent logic block positioned over said block.
4. The logic element block of claim 1 including recessed channels for connecting said recessed element to the recessed element of an adjacent block.
5. The modular fluid logic element block of claim 1 wherein the passageways are arranged in a uniform pat-

tern for all fluidic elements recessed in said bottom surface.

6. A plurality of the fluid logic element blocks as set forth in claim 5 in combination with
a cover plate;
a circuit module comprising a sheet of material with slots connecting various first prepositioned openings in said module, said openings arranged to form a plurality of patterns, each pattern coincident with a pattern of a block; and
a base plate comprising a sheet of material with second openings arranged in a plurality of patterns, each pattern also coincident with a pattern of a block, said cover plate, said circuit module and said base plate being stacked respectively one upon the other with a plurality of logic element blocks being stacked upon said base plate coincident with a pattern of openings to form an assembly, said assembly being in a substantially fluid type relationship to form a complex fluidic circuit.

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SAMUEL SCOTT, Primary Examiner

U.S. Cl. X.R.

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