United States Patent

Laakaniemi et al.

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[54] **FLUIDIC AMPLIFIER OR MODULATOR WITH HIGH IMPEDANCE SIGNAL SOURCE MEANS**

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[52] **U.S. Cl.** ....**137/81.5,** 235/201 ME

[51] **Int. Cl.** **F15c 1/20,** F15c 3/04

[58] **Field of Search** ....137/81.5; 135/201 ME

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[57] **ABSTRACT**

A fluid repeater connects a high impedance sensor to the nozzle of a fluidic modulator such that the nozzle is coupled to the respectively low output impedance of the repeater instead of the high sensor output impedance. The repeater is of the leak type or a fluidic cathode follower shown in U.S. Pat. No. 3,499,458. A fluid controller includes a plurality of high impedance signal sources and lines individually connected through repeaters to an impact summing modulator as a summing point connected to a diaphragm amplifier. The output of the repeaters can be connected directly to the opposed summing signal nozzles of an impact modulator, to a transverse deflection control nozzle; singly or in combination with a non-deflecting opposing modulating difference signal. A feedback restrictor connects the output of the diaphragm amplifier to the modulator. The repeaters in the circuit essentially eliminate all loading and attenuating of the high impedance sensors and permit a substantial simplification in the fluidic circuitry. Suitable "Ratio" and calibrating restrictors connect a regulated pressure supplying to the summing impact modulator. This provides a greatly improved controlling receiver of simplified, modular construction. An integrator may be readily formed by connecting a capacitor, coupling resistor and positive feedback restrictor to the input side of the controlling receiver.

22 Claims, 11 Drawing Figures

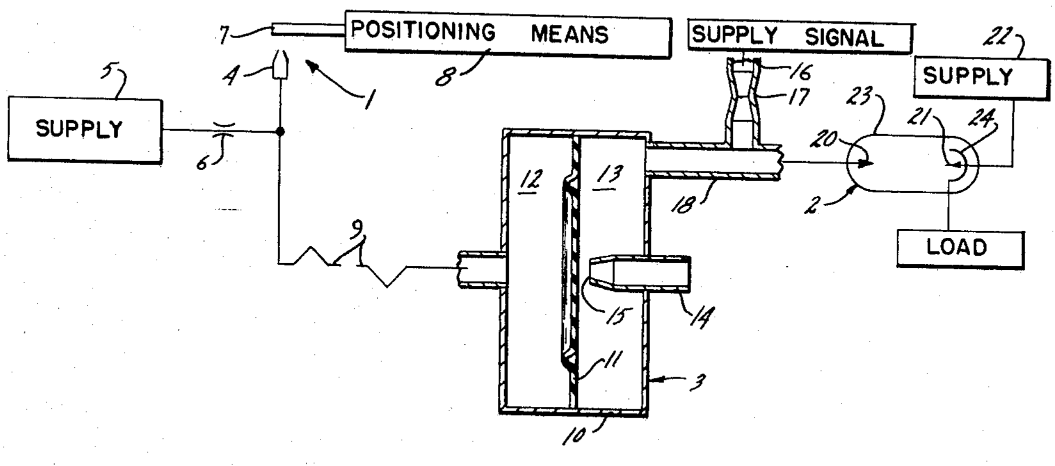


FIG_1

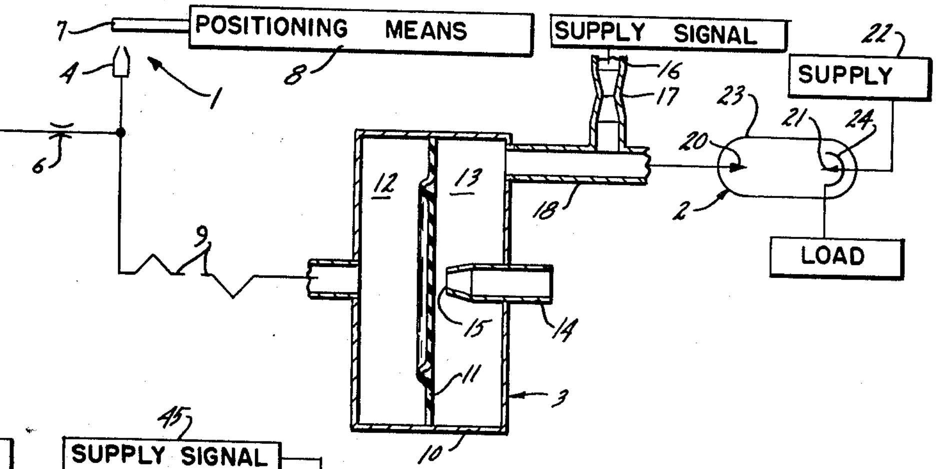


FIG_3

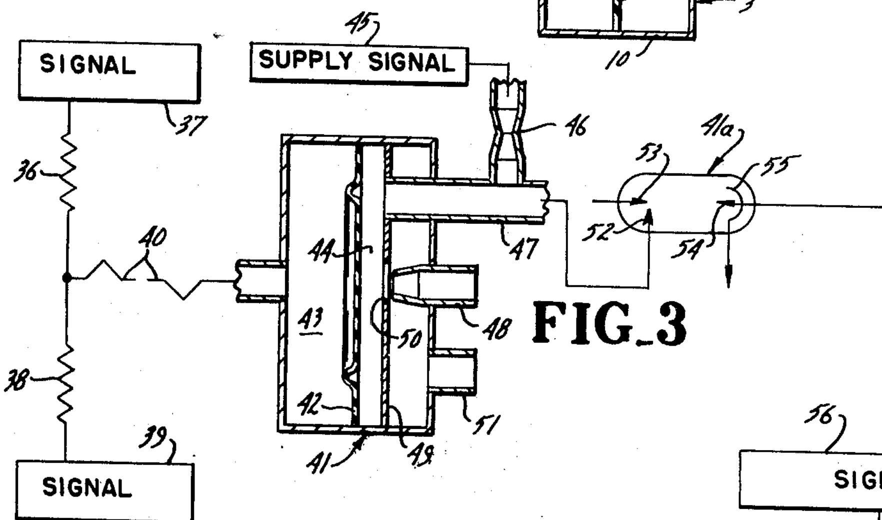


FIG_2

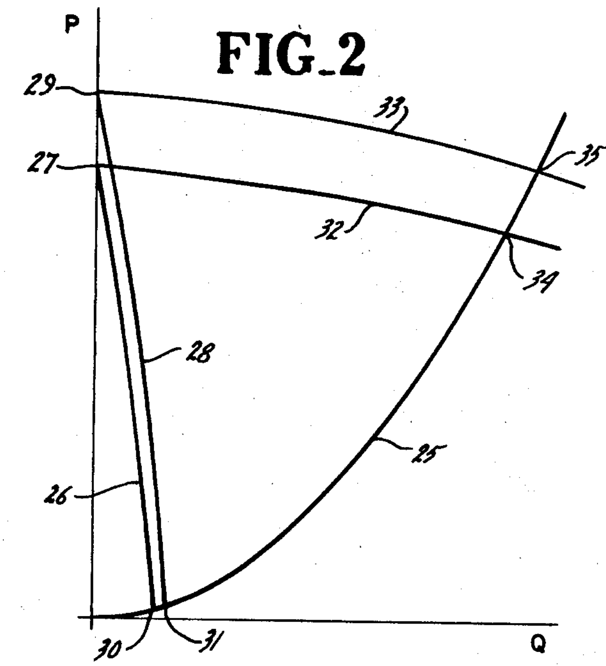
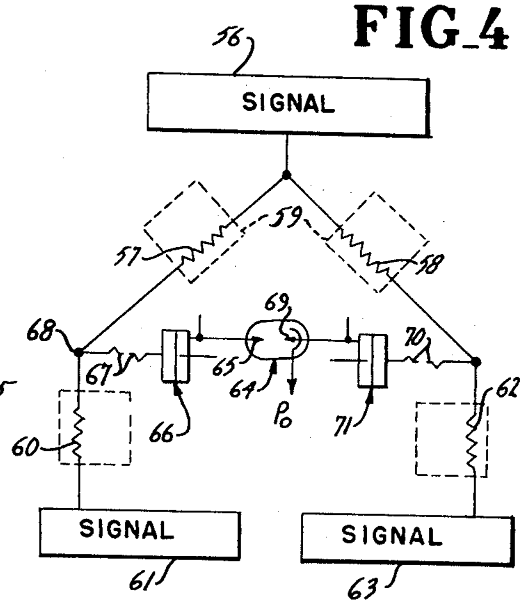


FIG_4



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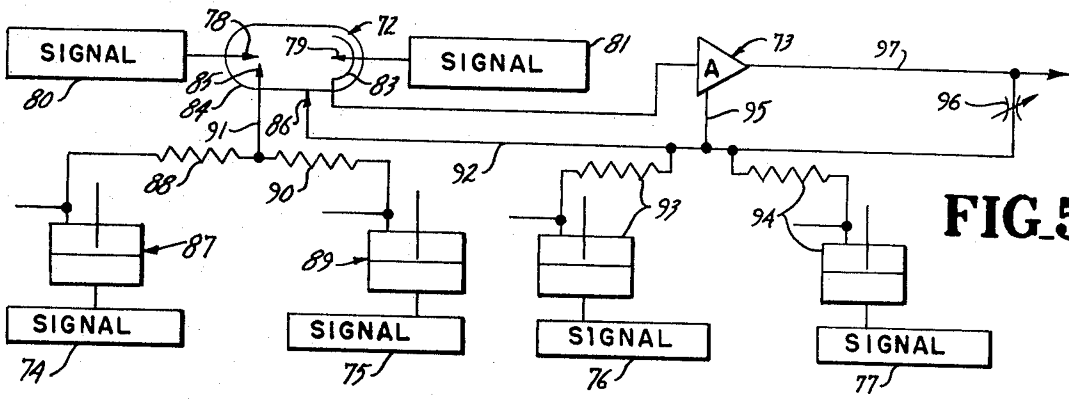

FIG_5

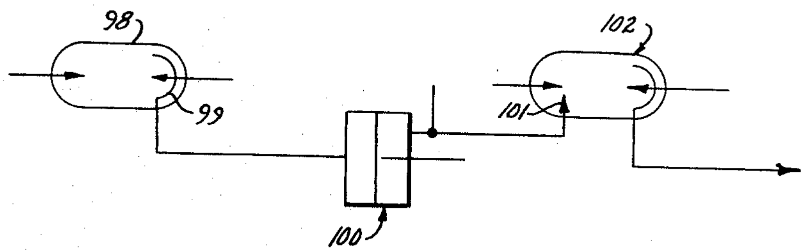

FIG_6

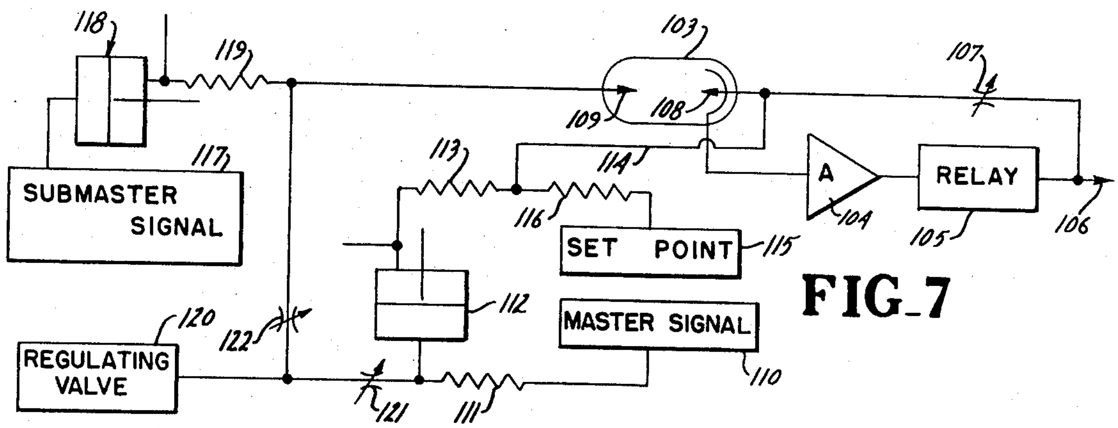

FIG_7

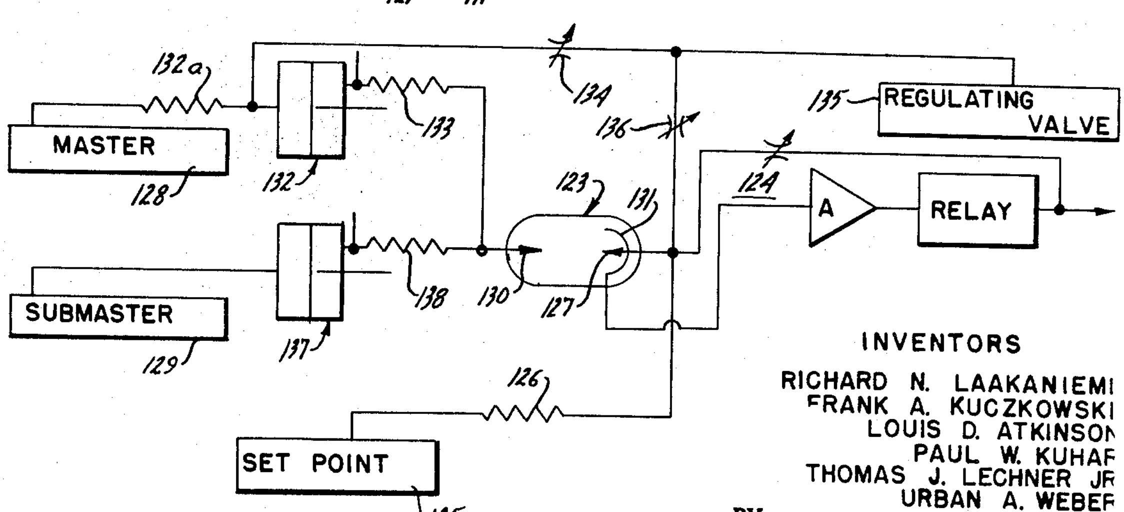

FIG_8

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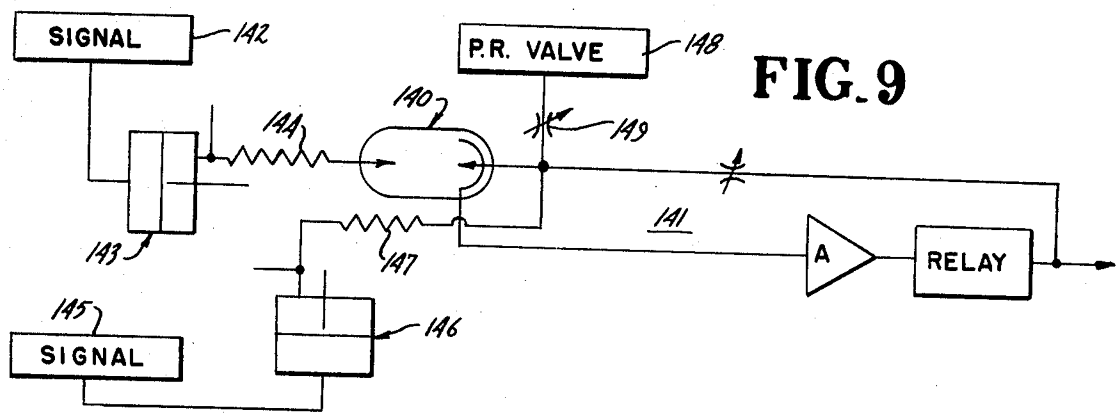
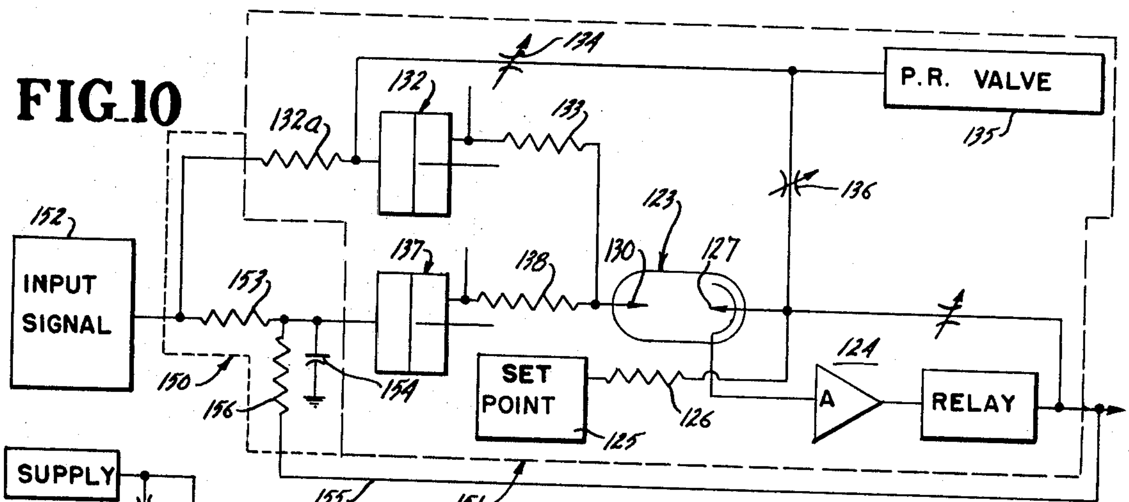


FIG. 9

FIG. 10



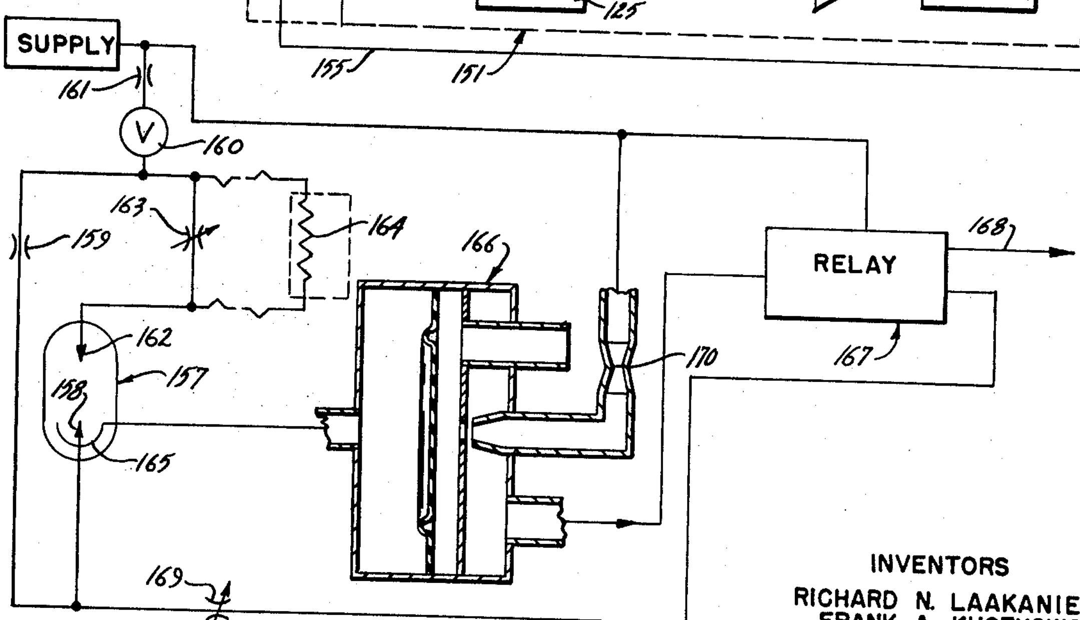


FIG. 11

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FLUIDIC AMPLIFIER OR MODULATOR WITH HIGH IMPEDANCE SIGNAL SOURCE MEANS

BACKGROUND OF THE INVENTION

The present invention relates to a fluidic modulator having a high impedance signal source means signalling the fluidic device to control a fluid output.

Fluidic controls have been developed where interaction between streams of air or other suitable fluid provide a fluid control signal in accordance with one or more fluid input signals. All such fluidic devices require continuous flowing streams and, thus, consume fluid, Further, a fluid sensing device which is interconnected to signal the fluid device is therefore loaded by the fluid source. If the sensor has a relatively low output impedance this is not a particular problem. If, however, the sensing means or sensor has a high output impedance, the loading by the fluidic devices will severely attenuate the sensitivity of the sensor to the condition being sensed.

Although the present invention can be applied to any fluidic device employing any desired fluid medium it is particularly applicable to pneumatic systems employing air and furthermore to those employing the impacting stream concept which is disclosed in the basic U.S. Pat. No. 3,272,215 to B. G. Bjornsen et al. entitled "-FLUID CONTROL APPARATUS." In such devices a pair of main opposed impacting streams define an impacted stream balance position with respect to a control orifice. A reference chamber is provided to one side of the control orifice and an output chamber to the opposite side thereof. The main streams can directly be signaled or an additional interacting stream can be provided to provide a controlled output in response to a single signal or a plurality of different input signals. The impacting stream modulators as well as other fluidic devices employ continuously flowing streams and consume fluid. Consequently, when such fluidic devices are connected directly into sensors of high impedance characteristic, the sensitivity of the sensor may be severely attenuated. The sensing means may have a high impedance as a result of its internal construction such as nonrelay transmitters or controllers, leak port controls, high impedance condition sensitive restrictors, or the interconnection of a sensor through long signal lines may introduce a high impedance characteristic. The attenuation of the sensitivity of the sensing means adversely affects the characteristic of many systems particularly in a controlling receiver or the like wherein the output is connected in a closed loop to actuate an input device. Generally, the art has suggested complex, multiple stage fluid systems in order to produce a versatile and general purpose controlling receiver or operational fluidic amplifying systems. Further, any such system should be adapted to various controls including pure fluid integration, for example, as shown basically in the teaching of U.S. Pat. No. 3,294,319 which issued as of Dec. 27, 1966 to B. G. Bjornsen et al. and is entitled "PURE FLUID INTEGRATOR." Although that patent discloses a highly satisfactory fluidic fluid amplifier it does require a substantial number of amplifying stages in order to produce optimum functional results.

SUMMARY OF THE PRESENT INVENTION

The present invention is particularly directed to a novel fluid amplifying unit or modulator having a special input coupler interconnecting the high impedance signal source to the fluidic modulator in a manner essentially eliminating the loading effect of the fluidic device and thereby essentially eliminating any attenuation of the sensitivity of the sensor. Generally, in accordance with the present invention a fluid repeater is connected between the high impedance sensor and the signal nozzle with the connection being made at the fluidic device. A fluid repeater is a device having a one-to-one gain with or without offset. Further, and more important, the repeater has an essentially infinite input impedance and a finite and relatively low output impedance. Highly satisfactory repeaters are shown in the presently pending application of L. D. Atkinson et al. entitled "FLUID DIAPHRAGM MODULATOR" which was filed on Nov. 18, 1970 with Ser. No. 90,707 and is assigned to the same assignee as the present application which may advantageously employ the convoluted diaphragm construction shown in the co-pending application of U.A. Weber et al. entitled "BLEED TYPE FLUID PRESSURE CONTROL APPARATUS AND DIAPHRAGM UNIT THEREFOR" which was filed Jan. 13, 1971 and having Ser. No. 106,185 and which is now U. S. Pat. No. 3,662,779 issued May 16, 1972 and is assigned to the same assignee. In the above constructions, a diaphragm unit overlies and divides a housing into a pair of closed chambers. A nozzle and orifice means terminates in opposed relation to the orifice within one chamber which is also connected to a fluid supply and to the load. The positioning of the diaphragm unit forms a variable restrictor to an exhaust such as atmosphere and determines the output load pressure. The opposite closed chamber is coupled to the sensor and presents a deadended load thus establishing a high input impedance which can be coupled to a high impedance sensing device such as a nonrelay transmitter or controller, a resistance network, long signal lines and the like without loading of the sensor. The output of the repeater on the other hand has a relatively finite and much lower impedance. The output impedance of the repeater can be increased or decreased conveniently by varying of a pressure dropping resistor in the supply connection and/or changing of the bleed orifice unit to exhaust. The repeater thus negates the sensor output impedance and the fluidic modulator signal nozzle now is coupled to the finite output impedance of the repeater instead of the high sensor output impedance. The leak type repeater is advantageously employed because of its very low hysteresis characteristic, the input-output characteristic is very linear and the repeater can be made as a relatively small compact unit particularly when employed in the convolute diaphragm concept of the above identified application. It has been found however that any other high input impedance device can also be employed, such as the fluidic cathode follower type unit shown in the U.S. Pat. No. 3,499,458 to L. B. Korta et al. which issued Mar. 10, 1970 for a "FLUID JET MODULATING CONTROL." The cathode follower structure has the desirable very high input impedance and a relatively low output impedance. Further, the potential construction can be constructed as a relatively small compact unit with a linearity similar to that of the diaphragm repeater constructions. In addition, the fluidic cathode follower has the additional advantages associated with pure fluidic devices such as resistance to shock vibration and radiation insensitivity as well as a long reliable operating life.

The present invention is advantageously applied with summing impact modulator devices and has been found to significantly increase the pressure gain of the sensing circuitry as well as the sensitivity of the circuit to the sensed change particularly where a fluidic sensing resistor is employed. Further, the concept of the coupling repeater in combination with the high output impedance sensing source and the fluidic amplifier permits ready interconnection of a plurality of signals to one or more signal nozzles of the impacting modulator. Thus, the present invention can be applied directly to the opposed summing signal nozzles of an impact modulator, to a transverse deflection control nozzle; singly or in combination with a non-deflecting opposing modulating difference signal. It can be equally applied with great advantage to the differential types of pressure sensing systems shown in U.S. Pat. No. 3,382,883 which issued to R. N. Laakaniemi et al. on May 14, 1968 for a "DIFFERENTIAL PURE FLUID PRESSURE SENSOR." A fluid bridge device, as shown therein and modified in accordance with the teaching of the present invention, results in an increase in sensitivity and response by a factor of fifty or more.

In addition, the present invention is most advantageously employed in a basic receiving controller circuit as a basic unit for various control systems. Thus, the several signal means are individually connected through appropriate repeaters to a fluidic summing device which in turn is interconnected through a high gain forward loop which employs a diaphragm amplifier such as shown in the Atkinson et al application previously identified in combination with the feedback resistance element to the fluidic summing device to produce a controlled output. The repeater in the controlling receiving circuit essentially eliminates the loading and attenuating of the sensors as discussed above and thereby permits a substantial simplification in the fluidic circuitry. In particular, the forward gain amplifier may be a single stage diaphragm amplifier which produces a very high forward gain with a minimal consumption of air or other fluid. The system can be compared, for example, with the basic fluidic system shown in U.S. Pat. No. 3,417,769 which issued to B. G. Bjornsen et al. for "FLUIDIC AMPLIFIER" on Dec. 24, 1968. The controlling receiving circuit may also set all of the inputs and the outputs to the same calibrated pressure usually or advantageously the middle of the input or the output operating range of the circuit. This will provide for a highly stable set point with changes in the feedback and ratio resistance controls because there is essentially no pressure drop through the resistance elements and therefore no flow. Even at points other than the mid-range input and output conditions, the set point variation with resistance adjustment minimizing the possible pressure drop across the variable resistance elements. The simplified controlling receiver can be employed as a fluidic integrator by merely introducing an integrating input assembly consisting of the necessary integrating capacitor input coupling resistor and the necessary positive feedback restrictor to the input side of the capacitor. The sensitivity and response of the integrating circuit is further improved as the result of the reduction in the loading and attenuating of the sensors.

The present invention thus provides a highly improved fluidic modulating device including in combination a fluidic amplifier and a high impedance sensing means which essentially eliminates attenuation of the source sensitivity. The invention is particularly applicable to a very simplified and low cost fluidic controlling receiving circuit for control systems and the like.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of a leak port type sensing assembly coupled to a summing impact modulator through a repeater in accordance with the teaching of the present invention;

FIG. 2 is a graphical illustration of the operating characteristics of high impedance circuitry, with and without the repeater coupling of the present invention to clearly illustrate the dramatic improvement in the operating characteristic which results from the present invention;

FIG. 3 is a schematic view similar to FIG. 1 showing the invention applied to a resistance dividing network and illustrating an alternative application of the invention;

FIG. 4 is a view similar to FIG. 3 illustrating the application of the present invention to a bridge type fluidic sensing network for sensing one or more different temperature conditions and one or more pressure conditions;

FIG. 5 is a schematic circuit illustrating the summation of a plurality of input signals via a summing transverse impact modulator and interconnecting the output into a single stage controlling receiver;

FIG. 6 is a schematic diagram illustrating the repeater interposed between a pair of fluidic stages to provide isolation therebetween;

FIG. 7 is a schematic circuit diagram of a controlling receiver connected in a master-sub-master control with a direct action and direct readjustment characteristic;

FIG. 8 is a view similar to FIG. 7 illustrating a similar controlling receiver with a direct action and reverse readjustment;

FIG. 9 is a schematic diagram of a dual input controlling receiver similar to that shown in FIGS. 7 and 8;

FIG. 10 is a similar schematic circuit of the controlling receiver interconnected with an integrating input assembly to provide for integration of a fluid signal; and

FIG. 11 is a schematic diagram illustrating a temperature sensing network with a diaphragm amplifier in the forward loop functioning as an isolating and amplifying member to simplify the control and without the repeaters shown in the prior circuits.

DESCRIPTION OF THE ILLUSTRATED EMBODIMENT

Referring to the drawings and particularly to FIG. 1, the invention is shown applied to a bleed type sensing system wherein a leak port sensing unit 1 is connected to signal a summing impact modulator 2 through a fluidic repeater 3. In the illustrated embodiment of the invention, the leak port sensing unit **1** is diagrammatically illustrated including a leak port nozzle **4** which is connected to a fluid supply **5** through a suitable pressure dropping restrictor **6**. Although the apparatus can be employed with any suitable fluid system it is preferably employed with a pneumatic system which can be referenced and exhausted to atmosphere and the like and is hereinafter described with an air supply **5**. The leak port sensing unit **1** further includes a lid **7** positioned over the nozzle **4** with the spacing of the lid controlled by a suitable positioning means **8**. The lid **7** can be mechanically, electromagnetically, or otherwise, positioned in accordance with a sensed condition. Further, lid **7** can be attached to or formed as an integral part of an object the position of which is to be sensed, and if desired controlled. The position of lid **7** determines the exhaust of the supply pressure to the atmosphere and thereby controls the pressure at the discharge or downstream side of the restrictor **6**. A signal line **9** which is shown with a break to indicate that it may be a relatively long signal line is connected to the downstream side of the restrictor **6** and to the upstream side of the nozzle **4**. The signal line **9** connects the nozzle **4** to the input side of the fluidic repeater **3** which couples the pressure signal to the summing impact modulator **2** and particularly without loading of the nozzle **4** so as to eliminate the usual attenuation of the source sensitivity.

The illustrated repeater **3** is a leak type. Generally, the repeater is diagrammatically illustrated as a leak type unit including a housing **10** divided into a pair of chambers by a centrally located convoluted diaphragm unit **11** which preferably is constructed as disclosed in the previously identified co-pending application of Weber et al. A closed or dead-ended input chamber **12** is formed to the one side of the diaphragm unit **11** and connected to the signal line **9** to provide a dead-ended coupling to the signal line **9** which eliminates all significant flow in line **9** and thereby positively eliminates loading of the sensor unit **1**. The opposite side of the diaphragm unit **11** is a controlled output or load chamber **13** including a nozzle exhaust unit **14** connected to atmosphere or any other suitable reference. The position of the diaphragm unit **11** over the nozzle **14** and particularly the nozzle orifice **15** controls the exhausting of the chamber **13** to the atmosphere. A supply line **16** is connected to the common air supply or to a local air supply and includes a restrictor **17** to supply a pressurized air flow to the chamber **13**. An output line or port **18** is connected in common in the illustrated embodiment of the invention to the input supply line to the downstream side of the restrictor **17**, and provides an input signal to the summing impact modulator **2**. Thus, the output pressure appearing in the chamber **13** also appears in the line or port **18**. This, in turn, is directly controlled by the relative position of the diaphragm unit **11** relative to the nozzle orifice **15**, which in turn is established by a balance between the signal pressure in the input chamber **12** and the opposing or balanced output pressure established in the chamber **13**. if the diaphragm unit **11** presents equal effective areas to the two pressures, the device will provide a one-to-one pressure gain and thus the output pressure will reflect the signaled pressure without loading of the sensing means **1**.

The output line **18** is coupled to the input of the summing modulator **2** which, in the illustrated embodiment of the invention, is diagrammatically illustrated in accordance with the modulator shown in U.S. Pat. No. 3,272,215 to Bjornsen et al. Generally, the summing impact modulator **2** includes a pair of opposing nozzles **20** and **21**, with the nozzle **20** connected to the output line **18** and with the opposing nozzle **21** connected to a suitable reference or set point pressure signal source **22**. The opposing nozzles **20** and **21** establish a pair of opposing impacting streams within a housing **23** with the impact position located with respect to an output chamber or collector **24**. In the actual construction, an intermediately located control orifice defines a reference chamber to one side and an output or collector chamber to the opposite side thereof. The output in the collector **24** is proportional to or controlled by the relative position of the impact position with respect to the control orifice. The signal stream from the nozzle **20** is directly controlled by the signal established by the repeater **3** to thereby directly control the output of the summing impact modulator **2**. The impact modulator **2** is coupled however to the low output impedance of the repeater **3** and not directly to the sensor or sensing means **1**.

The improvement associated with the present invention is graphically illustrated in FIG. **2** wherein the operating characteristics of a leak port sensor coupled to a nozzle, with and without a repeater, is illustrated. In particular, the graphical illustration clearly indicates the substantial increase in the sensitivity of the detection circuit. The sensitivity is defined as the change in the pressure downstream of the nozzle **4**, which, in the circuit of FIG. **1**, would be the discharging free stream from the summing impact nozzle **20**, divided by the change in the sensed signal. The graphical illustration is derived from a nozzle which accurately corresponds to a nozzle such as the nozzle **20** as well as those subsequently described hereinafter.

Referring particularly to FIG. **2** the pressure is shown on a vertical axis and flow through the nozzle is shown on the horizontal axis. Of the several traces illustrated, a nozzle load or input characteristic trace **25** begins at the zero point and increases geometrically with nozzle flow. Thus, the slope of trace **25** increases significantly with increasing flow. A first output characteristic trace **26** derived without the use of the repeater is shown beginning from a first signal pressure point **27** and rapidly decreasing with increasing flow. Trace **26** intersects the load flow characteristic trace **25** in the relative initial portion of the load characteristic. Thus, the pressure upstream of the nozzle **20** (FIG. **1**) and the nozzle flow are determined by this intersection. A second output characteristic trace **28**, once again without the repeater, is illustrated for a step change in the sensed pressure or variable. This is reflected by the output characteristic trace **28** beginning at the second pressure point **29** which is related to a zero flow pressure change. This second trace generally parallels the first load line and moves into and intersects the load characteristic trace **25** once again in the initial portion. Thus, the two intersecting points **30** and **31** of the load line **25** with the output characteristics **26** and **28** are relatively closely spaced. The change in the pressure downstream of the nozzle is proportional to the vertical distance between the two intersecting points **30** and **31**, and, as shown in FIG. **2**, is very minimal.

A pair of similar output characteristic traces **32** and **33** for the circuit with the addition of a repeater **3** (FIG. **1**), as taught by the present invention, are shown beginning at the corresponding sensed variable pressure points **27** and **29**. These traces **32** and **33** extend outwardly with a minimum slope and the slope decreases at a much lesser rate than traces **26** and **28**. As a result, the output traces **32** and **33** are generally parallel and intersect the load characteristic trace **25** on the upper portion of the nozzle characteristic load trace **25** and in particular where the load trace **25** has a much greater slope. Consequently, the related intersection points **34** and **35** are substantially spaced along the trace **25** and indicate a very substantial pressure differential upstream of the nozzle **20** (FIG. **1**) with the repeater **3** connected in the circuit. Thus, the repeater produces a drammatic increase in sensitivity. This drammatic increase in the pressure change of the repeater **3** is due both to the lesser slope of the output characteristic and the greater slope of the nozzle characteristic at the point of intersection. The improvement is further the result of the isolation of the sensor due to the infinite input impedance of the repeater such that the fluidic device with its relatively low impedance does not load the sensing device but rather is coupled to the auxiliary supply through the finite and relatively low output impedance of the repeater. This permits a substantial increase in the pressure gain of the summing impact modulator **2** or other fluidic device as well as increasing the sensitivity of the circuit to a sensed condition.

A similar system is shown in FIG. **3** wherein a simple resistance network permits summing of a pair of signals and/or sensing of a pair of two difference conditions. In FIG. **3**, a first fluidic resistance **36** has one side connected directly to a first signal pressure **37**. It is to be understood that the term fluidic resistance includes both non-linear restrictors and linear resistors. The resistance **36** is connected in parallel with a resistance **38** to a second signal pressure source **39**. The junction of the resistances **36** and **38** is connected to a repeater **41**. The output of the repeater **41**, in turn, is connected to signal a transverse impacting modulator **41a**. The illustrated repeater is diagrammatically shown in accordance with the teaching of the Atkinson et al. application for purpose of illustrating its use in the present invention. Thus, the repeater **41** includes a diaphragm unit **42** which is preferably constructed as a convoluted diaphragm unit as in FIG. **1** and defines an input chamber **43** connected to the signal line **40** and a first output control chamber **44**. A supply **45** is connected via a resistance **46** and a common input-output line **47** to control chamber **44**. An exhaust nozzle **48** is aligned with the diaphragm unit **42** but spaced therefrom. Further, an intermediate fixed wall **49** defines an exhaust chamber having an orifice **50** aligned with the exhaust nozzle **48**. The exhaust chamber is provided with an exhaust port **51**. Repeater **41** generally functions in the same manner as the repeater **3** to variably exhaust the line **47** upstream of the resistance **46** and thereby correspondingly controlling the output pressure in the line **47**.

This signal is applied as the input to an impacting modulator device **41a** and particularly to a signal nozzle **52** which establishes a deflection control stream to control the relative strength of one of a pair of main streams. Thus, the transverse impact modulator **41a** includes a pair of nozzles **53** and **54** connected to a suitable fixed supply for establishing an impacting position with respect to the collector **55**. The signal nozzle **52** is mounted to establish a deflection control stream engaging the main stream issued by nozzle **53** and variably deflecting such stream with respect to that from the nozzle **54**. The output stream of the signal nozzle **52** thereby controls the impact position with respect to the collector **55** and correspondingly controls the output signal in accordance with the relative input signal. The input signal can be changed by a change in either one of the signal sources **37** or **39** and/or by a change in the resistance value of the signal resistances **36** and **38**. Thus, the resistances **36** and **38** may provide a resistance value proportional to temperature, thermal radiation or the like.

The circuit operates basically in the same manner as that described with respect to FIG. **1** and will produce an output characteristic similar to that described with respect to FIG. **2**. Thus, a change in the signal pressures, or the resistance values of the resistances **36** and **38**, results in a corresponding change in the pressure at the signal line **40**. This pressure change reappears essentially without flow in the input reference chamber **43** of the repeater **41** and is converted into a corresponding low impedance output to the signal nozzle **52** of the transverse impact modulator ***41a***. Once again, loading of the sensing means or circuit is eliminated and the impacting modulator sees the finite and relatively low output impedance of the repeater **41** which, as previously noted, can be controlled by selection of the supply resistance **46** and/or the construction of the repeater exhaust nozzle assembly **47 – 49**.

A somewhat more complicated resistance dividing network for comparing a plurality of signals is illustrated in FIG. **4** wherein the invention is shown applied to a fluidic bridge network similar to that shown in the U.S. Pat. No. 3,382,883. Generally, the illustrated embodiment of the invention shows a first signal pressure source **56** which is connected to the corresponding ends of a pair of temperature sensitive resistances **57** and **58** which are subjected to variable or fixed temperature conditions or the like to be sensed, as shown by suitable dotted line enclosures **59**. The resistances **57** and **58** form two legs of the bridge. A third leg of the bridge is formed by a sensing resistance **60** which is connected to a separate signal source **61** in the illustrated embodiment of the invention. A fourth resistance **62** is connected between the second sensing leg including resistance **58** and a third signal source **63** to define a complete bridge network. The resistances **60** and **62** can be separately coupled to any temperature sensing condition to be determined or can be fixed resistances as shown inserted into the circuit to establish a balanced network at a predetermined condition at one or more of the other legs of resistances **57** and **58**. In addition, the signal pressures **61** and **63** can be a common pressure, either variable or fixed, to define a set point, a summing impact modulator **64** is connected across the output junction of the bridge network and in particular includes a first signal nozzle **65** connected by a repeater **66** to a signal line **67**. The signal line **67** in turn is connected to the junction **68** of the resistances **57** and **60** and thus provides one input to the summing impact modulator **64**. The second opposing nozzle **69** of the second summing impact modulator **64** is similarly connected to a signal line **70** through a repeater **71**. The signal line **70** in turn is similarly connected to the junction of a resistances **58** and **62** in accordance with the usual output bridge type interconnections. The repeaters **66** and **71** may be diaphragm units such as illustrated in FIGS. **1** or **3**, or alternatively may be any other suitable high input impedance device such as the fluidic device shown in the Korta et al. U.S. Pat. No. 3,499,458.

The bridge circuit operates generally in accordance with general bridge theory with the output signal pressures being proportional to the unbalanced condition of the several legs. This, in turn, is related directly to the relative resistances of the condition sensitive resistances **57** and **58** as well as that of the resistances **60** and **62**. The output in turn is controlled by the relative strength of the input signals to the summing impact nozzles **65** and **69**, with the output appearing at the output collector of the summing modulator **64**. As in the previous embodiment the repeaters **66** and **71**, however, isolate the sensing resistance network from the relatively low input impedance of the summing impact modulator and thus prevents loading of the bridge network. The output of the repeaters **66** and **71**, however, with its finite and relatively low output impedance permits highly satisfactory operation of the summing impact modulator as a high gain device. In fact, the pressure gain of a bridge network as illustrated in FIG. **4** is on the order of 100 times as great as the same bridge network with the repeaters removed.

Further, where a plurality of repeaters are employed such as shown in FIG. **4** the relative sensitivity of the sensing legs can be controlled by varying of the output impedance characteristics of the two repeaters. Thus, the supply resistances and/or the exhaust orifice restrictions can be varied to produce a desired sensitivity. The summing impact modulator **64** provides a highly satisfactory summing device for a bridge network as a result of the direct nozzle connection. The summing device could, however, be any other suitable summing means such as a summing transverse modulator such as shown in FIG. **5**.

Referring particularly to FIG. **5**, the present invention is shown applied to a controlling receiver having a summing transverse impact modulator **72** defining a summing point to a high gain summing amplifying stage **73** which may be any suitable high positive gain fluidic amplifying device such as a diaphragm amplifier and/or a pneumatic relay. In the illustrated embodiment of the invention, a pair of positive forward signal sources **74** and **75** and a pair of negative signal sources **76** and **77** are shown connected to correspondingly signal the summing transverse impact modulator **72**.

The summing transverse impact modulator **72** is constructed in accordance with the teaching of U.S. Pat. No. 3,469,592 and is diagrammatically illustrated including the pair of opposing nozzles **78** and **79** connected respectively to a pair of preset or signal pressure sources **80** and **81**. The nozzles **78** and **79** as in the previous embodiment establish opposing impacting streams adjacent a collector **83** the output of which is connected as the input to the high positive gain amplifier **73**. The nozzles and collector are mounted within a housing **84** defining a reference enclosure with respect to the collector **83**. A transverse nozzle **85** is mounted adjacent to and laterally spaced from the nozzle **78** and is adapted to establish a deflection control stream interengaging with the output of the nozzle **78** and in particular to variably deflect the stream and thereby the impact position with respect to the collector **83**. In addition, a second signal port or nozzle **86** terminates in the housing **84**. The nozzle **86**, however, is constructed to merely control and vary the pressure within the housing **84** and thus the downstream pressure presented to the deflection control nozzle **85**. The strength of the deflection control stream is, therefore, determined by the pressure differential across the orifice of nozzle **85**, in accordance with the teaching of the above patent.

In the illustrated embodiment of the present invention, the positive signal sources are connected to the nozzle **85**. In particular, a first repeater **87** in series with an output or coupling resistor **88** connects the first positive signal source **74** to the nozzle **85**. A repeater **89** in combination with a coupling resistor **90** connects the second positive signal source **75** to the nozzle **85** in parallel with the connection of signal source **74** via a common input line **91**.

A common input line **92** to the secondary pressure port **86** is similarly connected through a coupling repeater-resistor **93** to the reverse acting or negative signal source **76** and in parallel through a coupling repeater-resistor **94** to the third signal source **77**. The amplifier **73** includes a forward loop reference line **95** interconnecting the amplifier to the common secondary port signal line **92** as a reference in accordance with the teaching of the Kuczkowski patent. In addition, an adjustable feedback resistance **96** interconnects the output of the amplifier **73** appearing at the output line **97** to the common referencing line **92** to thereby provide a negative feedback signal which is summed with the outputs of the negative signals sources **76** and **77**.

The repeaters **87**, **89**, **93** and **94** may be mounted adjacent to the summing transverse impact modulator **72** with signal lines of the necessary length coupled to the respective sources. The repeaters can be readily formed with a low output impedance compared to the impedance of the signalling means and will thus minimize loading of sensing or signalling means with a resulting substantial increase in the sensitivity.

The reverse negative acting repeaters **93** and **94** should be constructed with a relatively low exhaust resistance and thus a substantial exhaust nozzle flow. This is true so that the exhaust fluid of the summing transverse impact modulator **72** and any exhaust fluid of the forward loop can readily be exhausted through the repeaters **93** and **94** and thus perform the additional function of eliminating the need of exhausting the supply air to the reverse acting signal sources **76** and **77**.

The output impedance characteristics of the several repeaters can of course be varied by varying the supply resistances and/or the exhaust restrictors to further control the relative sensitivity of the several sensing channels.

Thus, the repeaters in FIG. 5 as in the previous embodiments provide the desired isolation and impedance control characteristics.

These characteristics can also be used advantageously as a coupling between a pair of fluidic amplifying stages such as shown in FIG. 6 where an input summing impact modulator 98 similar to that shown in FIG. 1 has its output collector 99 connected by repeater 100 to the deflection control nozzle 101 of a transverse impact modulator 102. This type of coupling is particularly useful where the first stage has insufficient power to drive the second stage or when the two are operating on different fluids which cannot be mixed because of safety reasons or, because possible contamination of a relatively expensive fluid in one stage.

The present invention's greatest application, however, is in connection with fluid controlling receivers or operational amplifying type circuits for producing an output in accordance with a plurality of input signals. Thus, in FIG. 7, the invention is shown incorporated in a controlling receiver of the master-submaster controlled variety and in particular such as a receiver providing a direct action or response in combination with a direct readjustment. In particular, the embodiment of the invention shown in FIG. 7, employs a summing impact modulator 103 as the summing point for summing a plurality of signals as hereinafter The the output of the summing impact modulator 103 is connected to drive a diaphragm amplifier 104 such as that disclosed in the Atkinson et al application. The output of the diaphragm amplifier 104 is shown connected to a fluid relay 105 to establish a relatively high power output signal at an output line 106. Thus, the combination of a diaphragm amplifier 104 and the relay 105 can produce an exceptionally high gain in a simple and reliable circuitry for increasing relatively small output signals to a level suitable for directly driving the various loads. Thus, the diaphragm amplifier produces a very high pressure gain with minimum consumption of air. The relay output provides a desired pneumatic power for directly driving of the load. A feedback resistance 107 of a variable construction interconnects the output of the relay 105 to a nozzle 108 of a pair of opposing nozzles 108 and 109 of the summing impact modulator 103, to establish a negative feedback signal to the summing point of the forward loop of the circuit. The negative feedback resistance 107 is variable to allow adjustment of the gain by varying the negative feedback. The resistance is selected to be essentially linear over the given range for which the circuit is generally designed.

The nozzles 108 and 109 are further connected to sum the master and submaster signals. In particular, a master signal source 110 is connected via a coupling resistance 111 as an input to a repeater 112 and in particular to the input chamber of the repeater. Coupling resistor 113 interconnects the output of the repeater to a first summing line 114 to the nozzle 108 to signal the nozzle in accordance with the master signal in common with the feedback signal via the feedback resistance 107. In addition, a set point signal source 115 is connected through a coupling resistor 116 to the summing line 114. The set point signal source 115 may be of any suitable construction and thus may be a pressure regulator, a variable resistance element connected to a suitable supply or a completely external pressure signal source. It is therefore shown in an appropriately labeled block.

The opposite or opposing signal nozzle 109 of the summing impact modulator 103 is signaled from the submaster or controlled signal source 117. The source 117 is coupled to the input chamber of a repeater 118, the output or low impedance side of which is connected through a coupling resistor 119 to the nozzle 109.

In the illustrated embodiment of the invention, the relative effect of the master signal 110 and the set point signal 115 is controlled through a referencing dividing network including a pressure regulating valve 120 which is connected through a variable "Ratio" resistance 121 to the input side of the master signal repeater 112 and to the master signal resistance 111. Thus, the master signal source 110 is connected to one end of the divider and the pressure regulating valve 120 is connected to the opposite end. The Ratio of the change in the repeater input to the master signal varies continuously between zero to one, with the Ratio resistance at zero, to a Ratio of one-to-one with the Ratio resistance infinite. The output of the master signal repeater 112 and the set point signal repeater 115 are summed through the linear coupling resistors 113 and 116 and applied as a single input pressure via line 114 to the nozzle 108. As the resistors 113 and 116 are linear, the signal pressure is equal to the sum of the respective output pressures individually divided by the coupling resistors.

Since adjustment of variable resistance 121 varies the proportion of the master signal 110 applied to the master repeater 112 and therethrough to summing impact modulator nozzle 108, it therefore varies the relative effect of the submaster and master signals on the summing impact modulator output and the circuit output 106. The Ratio of the submaster signal pressure change to the master signal pressure change required to maintain a constant instrument output pressure is called Ratio in the control industry. This Ratio can be varied from zero to approximately the Ratio of resistors 116 to 119.

The set point signal source 115 and the submaster signal source 117 are connected to the opposite sides of the summing impact modulator 103. The opposite positioning of these two signals simplifies the installation of the circuit and the calibration because the set point signal is always changed in the same direction as the desired submaster change. Further, this arrangement minimizes the number of summing resistors on any one side of the summing impact modulator. As each additional resistor attenuates the gain of each other in the network repeater-resistor combination (such as repeater 112 - resistor 113) the number of summing resistors is, of course, advantageously reduced.

The input is further calibrated by a variable calibrating resistance 122 connected directly between the output of the pressure regulating valve 120 and the nozzle 109 of the summing impact modulator. This sets the inputs and the outputs to a corresponding calibrated pressure usually in the middle of the input and/or output operating range. This will maintain a fixed set point even though the feedback resistance 107 or the Ratio resistance 121 are adjusted at mid-range input and output. This result follows as there is essentially no pressure drop across the feedback and/or variable Ratio resistance and consequently no flow through them. Even at other than the midrange setting, the structure minimizes set point changes with adjustment of the resistances by minimizing the flow and therefore the pressure drop across the resistance elements.

In the illustrated embodiment of the invention, a direct readjustment is employed wherein the master signal and the submaster signal change in the same direction to maintain a constant instrument output. Thus, the one signal provides a direct acting or positive gain while the other signal provides a reverse acting or negative gain. A reverse readjustment can of course also be employed wherein the master and submaster signal changes are in opposite directions, to maintain a constant instrument output or have a corresponding gain characteristic, which is either direct or reverse acting. Thus, in the illustrated embodiment of the invention the master signal and the submaster signal are applied through the summing resistors to opposite sides of summing impact modulator **103** and change in a corresponding direction to maintain the circuit output. If either the submaster or master signal source are changed to the other side of the summing impact modulator as the master is in FIG. **8**, the circuit provides a reversed readjustment. The master signal control is then connected into the circuit to the common nozzle **130** with the submaster signal source **129**.

In FIG. **8** as in FIG. **7**, a summing impact modulator **123** constitutes the summing point to the input of a closed loop amplifying network **124** having the corresponding elements of FIG. **7**. A set point signal source **125** is coupled through a coupling resistor **126** to the nozzle **127** of the summing impact modulator **123**. The master signal source **128** and the submaster signal source **129** are connected in parallel in a similar manner to the opposing nozzle **130** of the summing impact modulator **123**. The collector **131** is associated with the first nozzle **127** such that the input to the nozzle **130** increases the output and a reduction in the strength of the stream from nozzle **130** reduces the output and thus provides a direct action response. The signal sources **128** and **129** are connected into the circuit generally through coupling repeaters as heretofore described. Thus, the master signal source **128** is connected through an input resistance to the input chamber of a repeater **132**. A linear summing resistor **133** connects the output chamber and port of the repeater **132** to the nozzle **130**. A Ratio resistance **134** interconnects the input chamber of the repeater **132** to a pressure regulating valve **135**. A calibrating resistance **136** connects the output of the valve **135** to the opposing nozzle **127** and thus inserts a Ratio and calibration resistance into the circuit corresponding to that shown in FIG. **7**. In FIG. **8** the submaster signal source **129** is connected to the same nozzle as the master signal source **128** and more particularly to the nozzle **130** opposite that of the set point signal source **125**. In particular, the submaster signal source is connected to the input chamber of a repeater **137**. A linear summing resistor **138** connects the output chamber of the repeater of the second nozzle **130** in common with the output of the master summing resistor **133**. The circuit operates in essentially the same manner as shown in FIG. **7** with the exception that the master signal source **128** and the submaster signal source **129** are now applied in parallel to the nozzle **130** rather than to opposing nozzles (as in FIG. **7**). Consequently, the variation in the master and submaster signal sources operate in the same direction with respect to the output. Both circuits are direct action, which is defined with respect to the submaster signal, with FIG. **7** providing a direct readjustment and the modification of FIG. **8** a reverse readjustment.

By completely reversing the nozzle connections in either one of the above circuits, a reverse action with the same readjustment as described above is established. For example, in FIG. **7**, if the set point signal source **115** and the master signal source **110** are connected to nozzle **109** and the submaster source **117** is connected to nozzle **108**, the circuit will provide a reverse action with direct readjustment.

The illustrated embodiments of the invention have been given with a single submaster source and a signal set point source for purposes of simplicity and clarity of explanation. However, any one source could in fact include a multiplicity of sources which could be summed prior to the illustrated receivers through suitable resistance networks and applied to the input chambers of the individual receivers, or interconnected through individual repeaters or connected to the appropriate nozzle through the proper linear summing resistors such as shown.

Applicants have found that the basic circuit shown in the drawings produces an exceptionally versatile and reliable controlling receiver which can be readily adapted to various master and submaster circuit combinations.

The controlling receiver can, of course, be employed as a basic input summing device as shown in FIG. **9** wherein a summing impact modulator **140** is connected in a closed loop network **141** similar to that shown in the previous embodiment. The first signal source **142** is connected through a repeater **143** and a coupling resistor **144** to one side of the summing impact modulator **140**. The opposite or second signal source **145** is connected through a repeater **146** and a coupling resistor **147** to the opposite or opposing nozzle of the summing impact modulator **140**. Pressure regulating valve **148** and a calibrating resistance **149** are connected to the nozzle in common with the second signal source resistor **147**. This simple circuit is essentially that shown for the more sophisticated master-sub-master control with the master set point adjustment capability eliminated, through the removal of the input connections to the controlling receiver.

The basic controlling receiver such as shown in FIG. **8** is particularly adapted to integration of fluid signals for example as shown in FIG. **10** where the corresponding elements of FIGS. **10** and **8** are similarly numbered for simplicity and clarity of explanation. Thus, in the embodiment of the invention shown in FIG. **10**, the controlling receiver of FIG. **8** is provided with an integrating module **150** connected to the controlling receiver **151** and particularly to the master and submaster coupling repeaters **132** and **137** of FIG. **8**. In particular, the input signal source **152** is connected directly through an input resistor **132a** to the master signal repeater **132**. The input signal source **152** is also connected through a resistor **153** to the submaster signal repeater **137**. An integrating fluid capacitor **154** interconnects the resistor **153** and the input chamber of the repeater **137** to a reference or ground. A positive feedback loop includes a line **155** interconnecting the circuit output and the input to the repeater **137** and the topside of capacitor **154**. The line **155** includes a linear feedback resistor **156**. Thus without any internal change to the controlling receiver **151** the integrating unit accessory module **150** is connected to permit fluid integration.

The Ratio resistance **134** of the controlling receiver now serves as a proportional gain change. This circuit provides a substantial simplification in the forward loop of the amplification circuit and permits the construction of a basic controlling receiver which can be readily adapted to integration. The output circuit will deliver any desired output, below the primary supply, which is required to maintain a constant input. The Ratio resistance **134** functions as a proportional gain control to adjust the internal negative feedback in a manner to balance the positive feedback. This adjustment establishes system stability as well as the overall speed of response and the wave shape of the output signal.

The fluid repeaters inserted into the circuit connection prevents loading of the input by the fluidic summing point and produces maximum circuit sensitivity. The concept of employing a diaphragm amplifier after the summing junction in place of the more conventional multiple fluidic stage amplifier is desirable where air consumption and number of components must be minimized. Thus, where maximum circuit sensitivity is not required the diaphragm amplifier circuit of FIG. **11** may be employed.

Referring to FIG. **11** a simplified temperature controlling or sensing circuit is illustrated including a summing impact modulator **157** similar to that previously described having its dependent nozzle **158** connected through a restrictor **159** and a pressure regulating valve **160** to a supply through a common dropping resistance **161**. The opposite or independent nozzle **162** is connected through a calibrating or set point control resistance **163** to the downstream side of the pressure regulating valve **160**. A temperature sensitive resistance element **164** is connected in parallel with the variable resistance **163**, and subjected to the temperature condition to be sensed. The sensing resistance **164** may be any suitable flow resistance which senses the change in the viscosity of fluid as the result of the change in fluid temperature. Thus, in a gaseous fluid, the viscosity increases with temperature while in liquids, the viscosity generally decreases with increasing temperatures. The fluid resistance is preferably a capillary resistance because the rate of change in flow with temperature is the most accurately known. Although the set point resistance **163** and the independent nozzle **162** tend to attenuate the effect of viscosity change, the strength of the stream emitted by the nozzle **162** is directly controlled by the viscosity of the flow through the sensing resistance **164**. The output collector **165** of the summing impact modulator **157** is connected to signal a diaphragm amplifier **166** disclosed in the aforementioned application Serial No. 90,707 of Atkinson et al. which produces the desired controlling or signal transmitting pressure. Supply pressure is applied through a resistance **170** to the supply orifice of diaphragm amplifier **166**. A relay **167** may be inserted between the diaphragm amplifier and the output line **168** to increase the power level in accordance with the usual designed considerations. The output line **168** is also connected through a feedback resistance **169** to establish a negative feedback signal to the nozzle **158**.

Thus, when the fluid pressure decreases to the independent fluid in resistance **164**, the impacting point of the summing impact modulator **157** moves from the collector **169** and the output decreases. Conversely, when the input pressure increases, the impact position moves toward the collector **165** and the output increases to provide a corresponding input signal to the diaphragm amplifier **166**. The combination of the variable set point resistance **163** in parallel with the resistance **164** allows an adjustment so that a wide range of the different valued resistances can be employed for the sensing resistance **164** and the resistor **159** connecting the regulated supply pressure to the dependent nozzle **158**. This permits a very versatile characteristic such that the circuit can be readily adapted to the various applications by controlling the changing of the impedances.

This invention thus provides a highly improved fluidic apparatus and particularly a fluidic modulating apparatus including a summing modulator coupled to a plurality of input signals through suitable fluidic repeaters to positively prevent loading of the several sensing devices thereby maintaining sensitive detection of conditions and providing high gain in the fluidic amplifying devices. Further, by employing a diaphragm amplifier in the closed loop fluidic circuit an operational controlling receiver is provided which is reliable, has a long life and is relatively inexpensive.

Various modes of carrying out the invention are contemplated as being within the scope of the following claims, particularly pointing out and distinctly claiming the subject matter which is regarded as the invention.

We claim:

1. A fluid control apparatus comprising a fluidic means having a plurality of stream forming means establishing interacting fluid streams and including a variable signal stream forming means, fluid signal means including signal line means and establishing a pressure signal in accordance with a selected condition and having a high output impedance, a fluidic repeater connected to said signal line means and having a gain of essentially one and an essentially infinite input impedance and having a finite output impedance means, and means connecting the input of the fluidic repeater to signal line means and the output means of the fluidic repeater to said variable signal stream forming means.

2. The fluid control apparatus of claim **1** wherein said fluid sensing means includes a fluid resistance network connected between a signal pressure source and said signal line means.

3. The fluid control apparatus of claim **1** wherein said fluid sensing means includes a leak port unit, a supply restrictor connected to said leak port unit and to said signal line means, and a condition responsive member overlying said leak port unit to control the exhausting of said signal line means.

4. The fluid control apparatus of claim **1** including a fluid resistance bridge network including said fluid sensing means and including a pair of said output terminal means, a pair of said signal line means being connected one each to each of said terminal means, and a pair of said fluidic repeaters connected one each between each of said signal lines and said stream forming means.

5. The fluidic apparatus of claim 1 wherein said fluidic means includes a summing modulator including a pair of impacting stream forming means and having an output means providing an output proportionate to the relative strength of said two streams, a fluid resistance bridge network including resistance means defining said fluid sensing means and including a pair of output terminal means, a pair of said signal line means being connected to said terminal means, and a pair of said fluidic repeaters connected between said signal lines and said impacting stream forming means.

6. The fluidic apparatus of claim 1 wherein said fluidic means includes a summing modulator including a pair of impacting stream forming means and having an output means providing an output proportionate to the relative strength of said two streams, said fluidic repeater being connected to one of said impacting stream forming means and to thereby control the strength of the stream from said one of said impacting stream forming means.

7. The fluid control apparatus of claim 1 wherein said fluid signal means includes a plurality of individual signal sources each establishing a pressure signal in accordance with a selected corresponding condition and each having a high output impedance, and said fluidic repeater means including individual fluidic repeaters connecting said signal sources to said variable signal stream forming means.

8. The fluid control apparatus of claim 1 wherein said fluidic means includes a summing impact modulator having a pair of impacting stream forming nozzle means producing opposing impacting streams relative to a collector, a plurality of said fluid repeaters having a diaphragm unit forming a common wall between an input chamber and an output chamber, said output chamber including an exhaust orifice means aligned with and controlled by the position of said diaphragm unit, a fluid supply resistance connected to said output chamber, a first of said repeaters connected to first of said nozzle means, a second of said repeaters connected to the second of said nozzle means, and said signal lines being connected to said corresponding input chamber.

9. The fluid control apparatus of claim 1 wherein said fluidic means includes a summing modulator including a pair of impacting stream forming means defining a pair of opposed impacting streams and having an output means providing an output proportional to the relative strength of said two streams, said variable signal stream forming means comprising a first deflection control nozzle establishing a deflection stream aligned with one of said impacting streams and a second non-deflecting control nozzle establishing a reference pressure for said streams, said fluidic repeater means including individual fluidic repeaters connected to each of said control nozzles.

10. The fluid control apparatus of claim 9 having a plurality of signal sources for at least one of said control nozzles, and wherein a separate repeater is connected between each of said sources and the corresponding control nozzle, and linear summing resistor means individually connects the outputs of the fluidic repeaters to the corresponding control nozzle.

11. The fluid control apparatus of claim 1 wherein said fluidic means includes a summing modulator including a pair of impacting stream forming means establishing a pair of opposed impacting streams and having an output collector means providing an output proportional to the relative strength of the pair of streams, said fluidic repeater being connected to control the strength of the stream from one of said impacting stream forming means, a fluid amplifier connected to the output collector means of said summing modulator, a negative feedback restrictor connected between the output of the amplifier and to the second of said impacting stream forming means of said summing modulator.

12. The fluid control apparatus of claim 11 wherein said fluid amplifier includes a diaphragm amplifier.

13. The fluid control apparatus of claim 11 wherein said fluid amplifier includes a diaphragm amplifier having a dead-ended input chamber connected to said collector, a diaphragm wall common to said input chamber and an exhaust chamber having an exhasut means, an orifice wall spaced from said diaphragm wall and defining the outer wall of the exhaust chamber and the inner wall of a load chamber having a load connection means, said orifice wall having an orifice and a supply nozzle means aligned with said orifice and establishing a stream through said orifice.

14. The fluid control apparatus of claim 1 wherein said fluidic means includes a summing impact modulator having a pair of impacting stream forming nozzles producing opposing impacting streams relative to a collector, and having a plurality of said fluid repeaters, each of said fluid repeaters having a diaphragm unit forming a common wall between a closed input chamber and an output chamber, said output chamber including an exhaust orifice means aligned with and controlled by the position of said diaphragm unit and having a fluid supply resistance connected to the corresponding output chamber, a first of said repeaters connected to the first of said nozzles and a second of said repeaters connected to the second of said nozzles, a fluid amplifying means connected to said collector and having an output signal line, a negative feedback resistance connected between said output signal line and the first of said stream forming nozzles, a pressure regulating valve, and a calibration resistance connected between said pressure regulating valve and the first of said stream forming nozzles.

15. The fluid control apparatus of claim 14 wherein said calibration resistance is adjustable.

16. The fluid control apparatus of claim 1 wherein said fluidic means includes a summing impact modulator having a pair of impacting stream forming nozzles producing opposing impacting streams relative to a collector, at least three of said fluid repeaters, each of said fluidic repeaters having a diaphragm unit forming a common wall between a closed input chamber and an output chamber, said output chamber including an exhaust orifice means aligned with and controlled by the position of said diaphragm unit and having a fluid supply restrictor connected to the corresponding output chamber, a first of said repeaters connected to first of said nozzles and a second and a third of said re-

peaters connected in parallel to the second of said nozzles, and said signal line means including a set point signal line, a master signal line and a submaster signal line, said signal lines being connected one each to an input chamber of a corresponding fluidic repeater, a positive gain fluid amplifying means connected to said collector and having an output signal line, and a negative feedback resistance connected between said output signal and line and one of said stream forming means.

17. The fluid control apparatus of claim 16 wherein said set point signal line is connected to a first of said stream forming nozzles and said master signal line and said submaster signal line are connected to the second of said stream forming nozzles, said collector being located adjacent said first of said stream forming nozzles, a fluid integration assembly having four fluid terminal means including a fluid signal input terminal means, a positive feedback terminal means and a capacitor terminal means and a proportional gain terminal means, said assembly including a fluid capacitor connected to said capacitor terminal means, an input resistor connected between said input terminal means and said capacitor terminal means, a feedback resistor connected between said capacitor terminal means and said feedback terminal means, and said apparatus having means connecting the output of said amplifying means to said feedback terminal means, said capacitor terminal means to said submaster signal line and said proportional gain terminal means to said master signal line.

18. The fluid control apparatus of claim 16 including a pressure regulating source, a ratio resistance connected between said pressure regulating source and the input chamber of the fluidic repeater connected to said master signal line.

19. The fluid control apparatus of claim 18 including a calibration resistance connected between said pressure regulating source and said stream forming means opposite from the master signal line.

20. The fluid control apparatus of claim 19 wherein said ratio resistance and said calibration resistance are adjustable.

21. A fluid temperature control apparatus comprising a summing impact modulator having a pair of impacting stream forming means producing opposing impacting streams relative to an output collector, a diaphragm amplifier having a diaphragm forming a common wall between an input chamber and an output chamber, said output chamber including an exhaust orifice means aligned with and controlled by the position of said diaphragm unit, said input chamber being connected to said collector, a fluid supply connected to said output chamber, a temperature sensitive resistance connected to a first of said stream forming means, an adjustable resistance connected in parallel with said temperature sensitive resistance, a set point restrictor connected to the second of said stream forming means, an output line connected to said output chamber of said diaphragm amplifier and a feedback resistance connected between the output line and the second of said stream forming means.

22. The fluid temperature control apparatus of claim 21 having a fluid relay connected between the output of said diaphragm amplifier and said output line.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,705,595 Dated December 12, 1972

Inventor(s) __________

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

ABSTRACT (cover page)		Line 3,	cancel "respectively" and insert --- relatively ---;
Column	11,	Line 29,	after "hereinafter" insert --- described. --- and cancel "the" (second occurrence).

Signed and sealed this 17th day of April 1973.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,705,595 Dated December 12, 1972

Inventor(s) ______________________

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

ABSTRACT (cover page)		Line 3,	cancel "respectively" and insert --- relatively ---;
Column	11,	Line 29,	after "hereinafter" insert --- described. --- and cancel "the" (second occurrence).

Signed and sealed this 17th day of April 1973.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents