PRESSURE RESPONSIVE SWITCH WITH LIQUID CONTACT MEANS

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This invention relates to transducers, and more particularly relates to a transducer switch for controlling electrical circuits in accordance with gas pressure input signals.

Transducers for modulating or switching an electric current by means of a gas pressure input are known. An example of an air to electrical transducer wherein modulation is achieved is a common diaphragm microphone. An example of gas operated electrical switches is the use of a domed snap-action diaphragm linked to a standard electrical switch.

While gas pressure to electrical signal transducers are known as aforesaid, they are often relatively large in size, insensitive or unreliable sensitive, relatively complex, or subject to deleterious aging phenomena which lowers reliability, often without warning. What is needed in miniaturized applications is a transducer for gas to electrical signals that is super-sensitive, extremely simple with virtually no moving parts, and virtually oblivious to aging phenomena such as oxidation and the like. While the prior art gas to electrical signal transducers perform the general function, they do not meet these needed qualities.

Accordingly it is a principal object of the present invention to provide a gas pressure to electrical signal transducer that is super-sensitive, and virtually immune to aging phenomena such as wear and oxidation and the like.

Another object of the invention is to provide a device of the character described having extremely high reliability.

Another object of the invention is to provide a device of the character described that may be made in a greatly miniaturized form without any sacrifice of its other beneficial qualities.

Another object of the invention is to provide a device of the character described which is extremely simple and economical to manufacture.

These and other objects and advantages of the invention will be more fully appreciated and understood upon examination of the hereinbelow contained detailed description of a physical embodiment thereof, when taken with the illustrative figures wherein like reference characters denote like parts in all views thereof, and wherein:

FIGURE 1 is a plan view of a cylindrical embodiment of a transducer switch device according to the principles of the present invention,

FIGURE 2 is a section view of the device of FIGURE 1 taken along line 2—2 therein and showing internal details of construction,

FIGURE 3 is a detail view of a portion of the internal details of FIGURE 2,

FIGURE 4 is another view of the detail of FIGURE 3 showing an internal change therein, and

FIGURE 5 is a second embodiment detail element employed in place of the detail element shown in FIGURES 3 and 4.

Referring now to the figures, wherein are shown presently preferred but merely illustrative embodiments of the inventive principles, a transducer for gas to electrical signals according to the invention comprises an envelope indicated generally at 10 in FIGURE 1, which may conveniently be of a cylindrical outline, although other configurations may be employed. As is shown in FIGURE 2, envelope 10 includes a first portion 11 constituting a gas input inlet 11 which may conveniently be fabricated in a non-metallic substance such as for example hard plastic, and may be internally threaded at 12. Inlet 11 defines an inner passageway 13 a portion of which may be internally threaded at 12 as aforesaid.

As may be seen in FIGURE 2, at the inner end of passageway 13 is a diaphragm 13a, which is relatively flexible, but totally impervious to gas flow. Diaphragm 13a may advantageously be fabricated in, for example, a flexible plastic such as Mylar polyester, and is firmly attached in a gas-tight manner to the walls of passageway 13. Diaphragm 13a defines a chamber 13b which is in gas input inlet 11, which chamber 13b communicates with an open end 14a of capillary tube 14. While it is preferred to employ a diaphragm such as 13a in the manner shown and for reasons to be explained hereinbelow, it is also possible to omit diaphragm 13a altogether and observe certain precautions in operation, as will also be described hereinbelow.

At the opposite end of envelope 10 is located a gas chamber 15, which also may be conveniently fabricated in a suitable non-metallic substance, or in other durable and stress resistant substances. The outer shell of gas chamber 15 defines a gas-tight inner volume 16 which communicates with the second open end of capillary tube 14, that is with end 14b. Sealed in gas-tight manner into one end of chamber 15 is a diaphragm 15a, to be further described hereinbelow.

Cylindrical shell 18 interconnects portions 11 and 15 and completes the outer envelope 10. In the embodiment shown, shell 18 is approximately concentric and co-extensive with capillary tube 14, and is primarily intended to perform the function of protecting said capillary tube from physical damage. Filling the annular space between capillary tube 14 and outer shell 18 is insulting material 17, which may be any of the well known electrical and thermal insulating materials. Attached at the outer surface of shell 18 are a plurality of insulated electrical terminals 19a, 19b and 19c. Each of terminals 19a, 19b and 19c is electrically connected to a wire 20a, 20b and 20c respectively, which wire leads in through shell 18 and insulating material 17 to and through the wall of capillary tube 14 into the interior of the fine bore 14c of capillary tube 14, where the ends of the said wires, or means at the ends thereof, form contacts within fine bore 14c.

Within the fine bore 14e of capillary tube 14 is also located a small volume of mercury or other conductive material indicated at 21. The amount of mercury or other material involved will be extremely small, so that temperature effects on the length of mercury itself within fine bore 14e will be negligible. In general the length will be of the order of magnitude of diameters of fine bore 14e, for example 10 diameters. Of course materials other than mercury may be employed, and larger volumes of the substance forming portion 21 may be employed, but it is advantageous to use mercury because of its low vapor pressure, and it is advantageous to use a short or small segment for portion 21 because of the aforesaid temperature effects thereon.

The wires 20a, 20b and 20c for terminals 19a, 19b and 19c are arranged so that the liquid drop or portion or segment 21 is sufficient to interconnect two or more of the wires at the contact points where they enter fine bore 14c in capillary tube 14. Specifically in the embodiment...
shown, terminals 19a and 19b have wires 20a and 20b entering fine bore 14c a distance apart somewhat greater than the length within fine bore 14c of mercury drop or segment 21. Intermediate the points of entry of wires 20a and 20b is the point of entry into fine bore 14c of wire 20c connected to terminal 19c. It will be seen from the example relationship just described that movement of segment 21 within fine bore 14c is effective to interconnect wire 20c with either of wires 20a or 20b individually, but not to connect wire 20c with wires 20a and 20b at the same time. Thus three possible conditions can be attained dependent upon the position of segment 21 within fine bore 14c in the example embodiment shown. First, segment 21 may be positioned so as to connect no two of wires 20a, 20b and 20c. Second, segment 21 may be positioned so as to connect wire 20c to wire 20a. Third, segment 21 may be positioned so as to connect wire 20c to 20b. In effect then segment 21 cooperates with wires 20a, 20b and 20c to effectuate a single pole double throw (SPDT) switch.

By arranging other and further wires entering at the same or other points within fine bore 14c, and by choosing other lengths for segment 21, single pole single throw (SPST), double pole double throw (DPDT), and multiple contact switching functions may be effectuated. By multiple contact switching functions is meant a situation, for example, where a plurality of contacts may alternatively be connected to a single contact. Other switching variations than those already mentioned, may also clearly be effectuated by appropriately placing the wires entering fine bore 14c. Switches may be arranged to be normally open, or normally closed, depending upon where segment 21 normally is. Normality will in this sense imply either the condition of normal gas pressure at gas input inlet 12, or the condition of a normal gas pressure differential between diaphragms 13a and 15a, as explained hereinbelow.

The illustrated is fully illustrative and atmospheric pressure compensated. If segment 21 is chosen to be of a length of the order of several diameters of bore 14c, the effect of temperature on segment 21 itself can be ignored altogether. Segment 21 can also be longer of course, but then care must be taken in locating the wires 20a, 20b, 20c, etc., in regard to their points of contact within bore 14c so as to account for all the reasonable range of expansion in segment 21 due to ambient temperature changes, and yet perform the same switching functions.

The device is also compensated against changes more likely to occur under functioning. Ambient pressure differentials are compensated most conveniently by making diaphragms 13a and 15a of the same diameter, thickness, and material, and arranging to have equal gas spaces behind the diaphragms. Thus under those circumstances the pressure added or subtracted on one end of segment 21 by an ambient pressure change is matched by an equal and opposite change on the other end thereof. The diaphragms 13a and 15a need not be the same to effect this, it is only necessary that the pressure change within the total volume between diaphragm 13a and segment 21 be equal to the pressure change within the total volume between diaphragm 15a and segment 21.

For example, when the volumes are equal, the diaphragms may be equal, and equal changes in volume due to diaphragm action will produce equal changes in pressure at segment 21. Application of Boyles and Charles' law will easily allow design of proper diaphragms when the volumes are unequal. The fact that diaphragm 15a may be moved away from its normal position when an ambient pressure change occurs does not matter significantly, since the volume of bore 14c is negligible compared to the other internal volumes concerned.

The device is also best compensated for ambient temperature changes by again arranging to have the volumes already described be equal. They thus exert equal pressure changes, under given temperature changes, and the position of segment 21 is again not affected. Of course the volumes do not have to be equal to attain this, it is merely essential that the change in pressure on one end of segment 21 due to temperature change be equal to the change in pressure on the other end. However, if the volumes are not equal, the diaphragm must be unequal in a way which satisfies the effect of unequal volumes on pressure as regards both ambient pressure and temperature change. It is simplest to have the volumes and diaphragms equal.

It will be clear then, that if volumes 13b and 16 (the volume of bore 14c is negligible) are made equal, the device is functionally identical, and is pressure compensated if diaphragms 13a and 15a are equal in kind. If for some reason unequal volumes are wanted, Boyles and Charles' laws will be applied to select the proper volume changes which must be effectuated in each of chambers 13b and 16 to keep the pressure change equal at each end of segment 21, and appropriate diaphragms 13a and 15a will be installed so as to effect such proper changes in the respective volumes.

In those situations where compensation is not needed or desired, the diaphragms 15a may be replaced by a combination of the inflexible volume 15. Moreover, in some situations of use, the gas pressure through gas input inlet 12 will be so controlled or restrained in variation that diaphragm 13a may be omitted. Even without such a restrained variation, diaphragm 13a may be omitted if capillary tube 14 is made long enough to contain segment 21 despite the pressure changes at end 12. In general however, it will be preferred to employ diaphragm 13a as a safety feature to diminish the degree of volume change in response to pressure change at end 12, and it will also be preferred to temperature and ambient pressure compensate the device by the proper arrangement of volumes 13b and 16, and diaphragms 13a and 15a, as aforesaid.

It will be clear that when diaphragm 15a is not employed, "normal" pressure (resulting in the "normal" position of segment 21 for those conditions) will be determined by the pressure at end 12, even if that pressure includes ambient variations. When diaphragm 15a is employed, the "normal" position of segment 21 is determined by the differential between the pressure in chambers 13b and 16, and this can be arranged aforesaid to cancel out ambient changes. These considerations are relevant to design of a SPST switch that is "normally" open or "normally" closed, and designed to throw under a given pressure change at end 12, and therefore a given change in location of segment 21. The same considerations will enter into design of SPDT and the other switches already mentioned.

The gas within each of chambers 13b and 16 is preferably inert, so that the contacts within capillary 14c are not oxidized. Also preferably the same gas fills each chamber, so as to standardize thermodynamic and other effects. Any gas may be used, but nitrogen is excellent, and is inert. The segment 21 within bore 14c is not gravity sensitive, that is it will not freely move in response to the normal gravity acceleration vector, because capillary attraction of the walls in such space on the preponderant force compared to gravity induced force thereon. However, the segment will move in response to great accelerations, such as shocks or impacts.

In operation, end 12 is connected to a pressure source which is to be monitored by the device. It will be assumed first that diaphragms 15a and 15b are not present, the chamber 15b being completely closed off by diaphragm 15a. It may be assumed that the volume within chamber 16 is sufficient to position segment 21 as is shown in FIGURE 2, when end 12 is open. It may be, however, that when end 10 is attached to the pressure source which it monitors, the "normal" pressure therein is sufficiently greater than atmospheric so that segment 21 is moved to the position shown in FIG-
ure 3 wherein it connects the contact ends of wires 20a and 20c. This move has been against the volume in chamber 16 which had to contract to accommodate the movement. When a greater pressure appears at end 12, the segment moves to the right as in FIGURE 4, and the contact ends of wires 20b and 20c are now connected through the conductive mercury. Again the volume 16 had to contract (under the increase in pressure behind segment 16 on the end 12 side) to accommodate the move. Thus release of the increase in pressure at 12 allows the chamber 16 to push the segment 21 back out to the position of FIGURE 3. Thus a SPDT switch action is achieved.

It will be realized that the switch so operated is extremely sensitive. It is also virtually without moving parts, and consequently without mechanical wear. The only chemically critical parts, the contact ends of wires 20a, 20b, 20c, are protected by the inert gas. In the figures the various wires are closely spaced for illustration. If the device is too sensitive, or if compensation is not used, the wires 20a and 20b may be widely spaced, and dual parallel wires 20c may be used, as is shown in FIGURE 5. The sensitivity (and accuracy) of the device can thus be varied, where necessary or desired, by spacing the contact wires. It can also be varied by changing the volumes of the chambers involved, or by other means. The operation of the device will now be considered where compensation, either by diaphragms 13a and 15a, or otherwise, is employed. Illustrating such operation by compensation with diaphragms as shown, the end 12 is attached to the monitored pressure source as before. It may be assumed that the static pressure thus monitored moves the segment 21 from its position shown in FIGURE 2 to that of FIGURE 3, also as aforesaid. Now, if an increase in ambient pressure occurs, and it is reflected at end 12 as an increase in the pressure there, the segment 21 will not move to the position of FIGURE 4 in response thereto and give a false throw to the switch. Instead, the diaphragm 15a will also monitor that ambient pressure increase, and decrease the volume of chamber 16 sufficient to cause an increase in the pressure at segment 21 equal to the increase in the pressure at 21 due to the same ambient pressure felt by diaphragm 13a. This will be true whether or not the volumes 13b, 16 are equal, and whether or not the diaphragms 13a, 15a are of equal structural, so long as the aforesaid compensation effect is the same. As aforesaid this is best done by equal volumes and equal diaphragms.

Also, if an ambient temperature change occurs, the position of segment 21 will not falsely change. If the volumes 13b and 16 are equal, this result follows directly. If unequal, the diaphragms will be designed to compensate for the effect on pressure at segment 21 due to both ambient pressure and temperature change.

Since, in the compensated form, as shown, the segment 21 is not moved, or at least not moved appreciably, by changes in ambient conditions, the wires 20a, 20b, 20c may be relatively close as shown in FIGURES 2-4 inclusive. The device is thus not only sensitive, but accurate, since it discriminates between intended pressure changes and environmental "noise," that is, ambient-change-caused pressure changes. Thus in the compensated case, to complete the illustration, the segment 21 will move to the position of FIGURE 3 only upon the intended change in the monitored source as reflected at end 12. It will be realized that a capillary tube 14 has been shown with three internal contacts as in FIGURES 2-4 inclusive, and four internal contacts as in FIGURE 5. No further illustration is needed to cover all switching possibilities, since the same device can be used however one wishes merely by changing the number of contacts and the external connections at terminals 20a, 20b, 20c, etc. Thus essentially a spaced plurality of contacts is shown, and in practice a great number may be employed.

To calibrate the device it is only necessary to test terminals until the right combination for given conditions is found. Such terminals, of course, need not relate to contiguous contacts in bore 14c. It also follows, that a device with such a plurality of contacts can be used as SPST, DPDT, DPDT, etc., switches, since all that has to be done is to select the proper external terminals. The pressure conditions under which switching occurs are also changeable by changing the choice of external terminals. In other words, a single device can serve any of a great variety of uses, and is fully interchangeable.

In such a line of contacts, many external possibilities other than straightforward switching may thus be effected. For example, a moving segment 21 may make and break a whole series of contacts, which performs any desired external function (depending only on the way the external terminals are attached, and to what). Thus a function fed into end 12 in the form of a pressure variation can control any other function programmed into the contacts alone bore 14c. One example would be a linear function in pressure (resulting in linear motion) which linearly causes contacting of circuits controlling successive values approximating a sinusoidal function. Other relations are of course a matter of choice. The device allows minute pressure changes to switch electric signals, and in the logical extension, to create a dependent electrical function which has been arranged with regard to the external terminals 19a, 19b, 19c, etc., of the contact wires 20a, 20b, 20c, etc.

While the invention has been described with reference to certain specific embodiments, this has been for purposes of illustration only. The invention is not limited by the embodiments shown.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. Apparatus comprising an open-ended capillary tube; at least two spaced electrical contacts within the bore of said capillary tube; a free segment of conductive liquid enclosed within the bore of said capillary tube and intermediate the ends thereof; means defining a first closed chamber communicating with one open-end of said capillary tube, said first chamber including a first diaphragm portion having an outer face thereof adapted to communicate with the ambient atmosphere; means defining a second closed chamber communicating with the other open-end of said capillary tube, said second closed chamber including a second diaphragm portion having an outer face; and means communicating with said second diaphragm outer face for monitoring gas pressure.

2. Apparatus comprising an open-ended capillary tube; at least two spaced electrical contacts within the bore of said capillary tube; a free segment of conductive liquid enclosed within the bore of said capillary tube and intermediate the ends thereof; means defining a first closed chamber communicating with one open-end of said capillary tube, said first chamber including a first diaphragm portion having an outer face thereof adapted to communicate with the ambient atmosphere, and further adapted to vary the pressure within said first chamber as a given function of said ambient pressure change; means defining a second closed chamber communicating with the other open-end of said capillary tube, said second closed chamber including a second diaphragm portion having an outer face; and monitoring means communicating with said second diaphragm outer face for monitoring gas pressure.

3. Apparatus according to claim 1 wherein said first and second chambers are approximately equal in volume, and said first and second diaphragms are adapted to vary each volume approximately equally in response to an ambient pressure change.
4. Apparatus according to claim 1 wherein each said chamber contains an inert gas.

5. Apparatus according to claim 1 wherein each said chamber contains an inert gas, and said segment comprises liquid mercury.

6. Apparatus according to claim 1 wherein each said chamber contains an inert gas, said segment comprises liquid mercury, and said capillary tube is insulated against ambient temperature changes along the length thereof.

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