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[45] Patented **May 4, 1971**
[73] Assignee **Industrial Research Products, Inc.**
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Continuation of application Ser. No. 550829, May 17, 1966, now abandoned.

[54] **ACCELERATION INSENSITIVE TRANSDUCER**
10 Claims, 12 Drawing Figs.

[52] **U.S. Cl.** **310/8.2,** 310/8.3, 310/8.5, 310/9.4, 179/110.1
[51] **Int. Cl.** **H04r 17/00**
[50] **Field of Search** 310/9.1, 9.4, 8.5, 8.6; 179/110.1, 114, 119

[56] **References Cited**
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Assistant Examiner—Mark O. Budd
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ABSTRACT: A transducer which includes a conductive case and an apertured cover mounted on the case. A baffle plate is mounted adjacent to the aperture. A diaphragm is mounted on the case. A piezoelectric element is mounted within the case and is held in position by a resilient conductive clip which is stressed beyond its elastic limit. A lever attached to a fixed pivot connects the piezoelectric element with the diaphragm and has balanced effective moments due to inertia on opposite sides of the pivot.

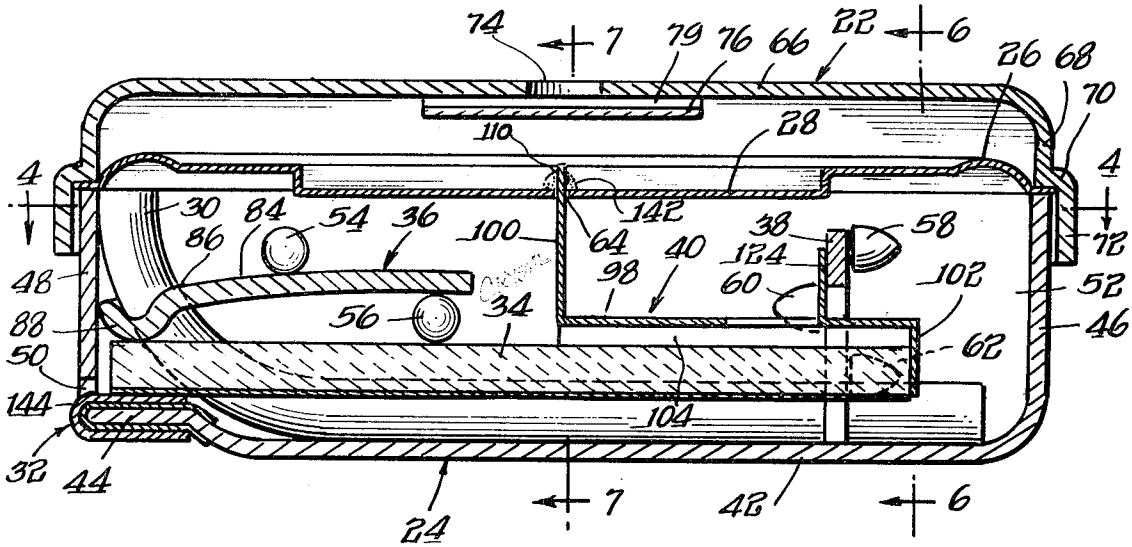


Fig. 1.

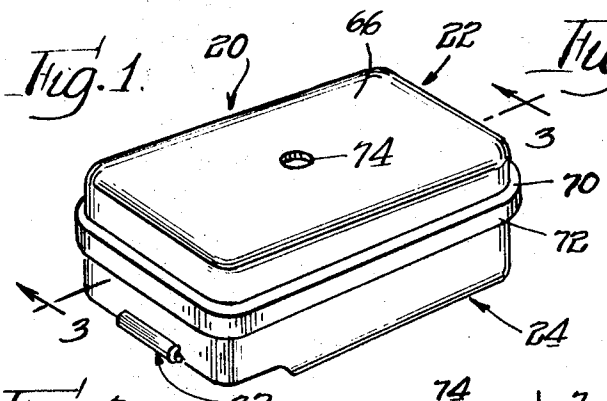


Fig. 2.

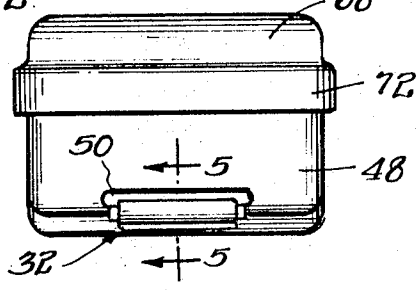


Fig. 3.

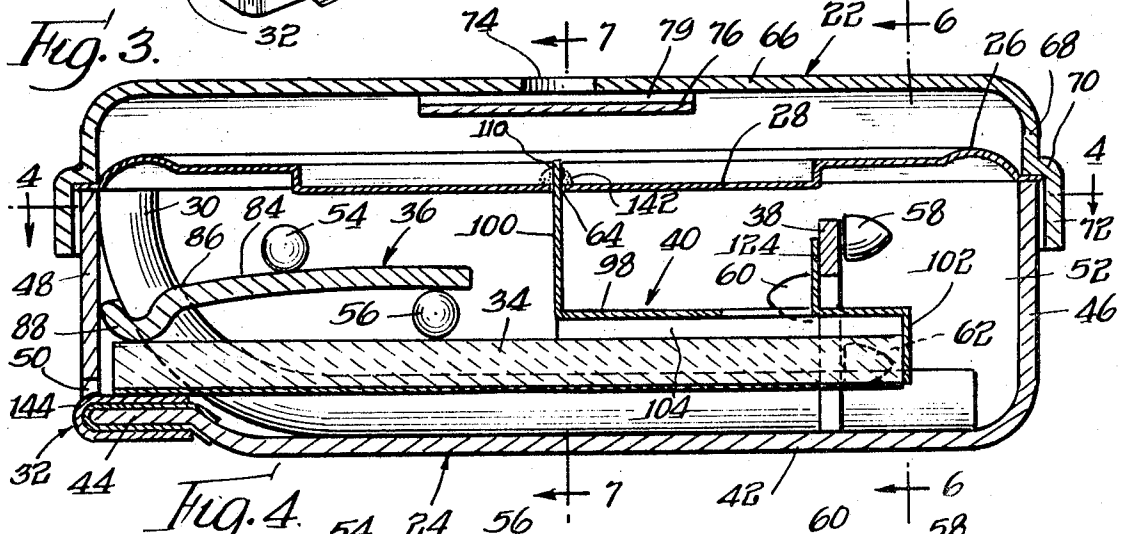
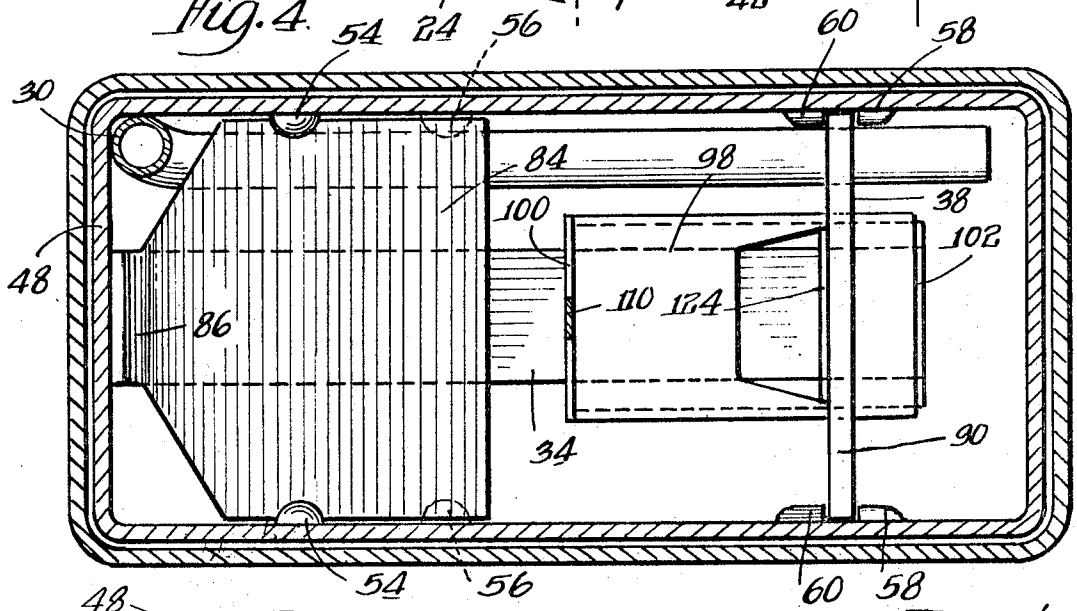


Fig. 4.



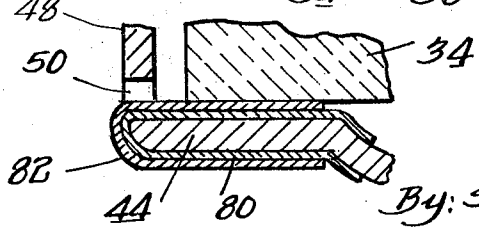


Fig. 5.

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Fig. 6.

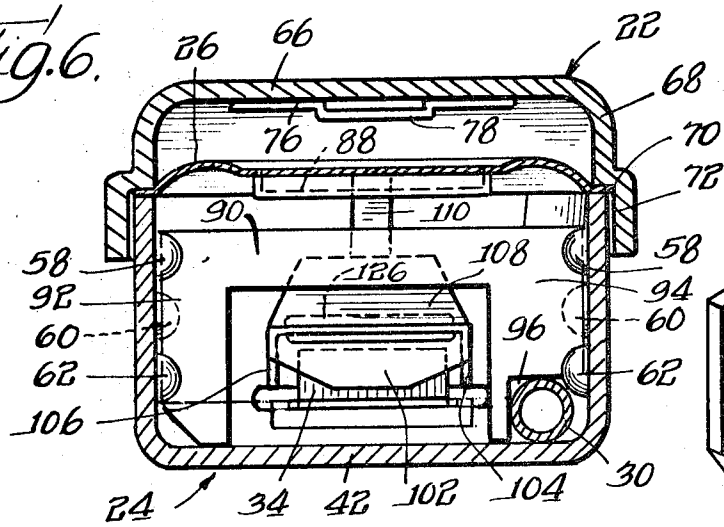


Fig. 8.

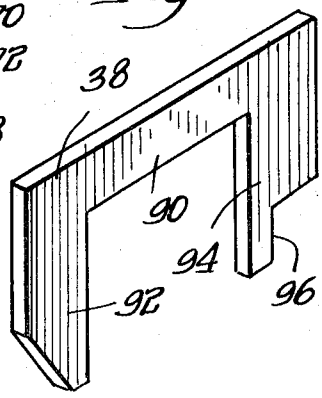


Fig. 7.

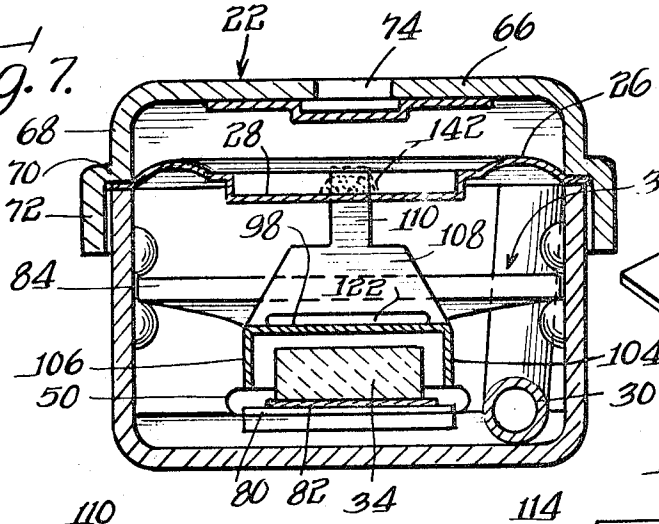


Fig. 9.

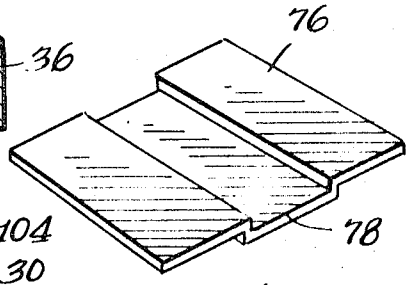


Fig. 10.

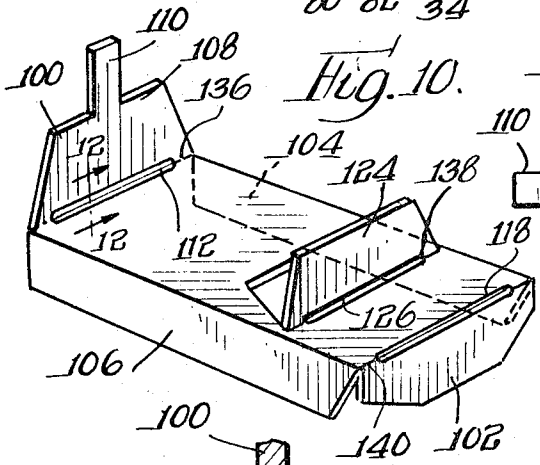


Fig. 11.

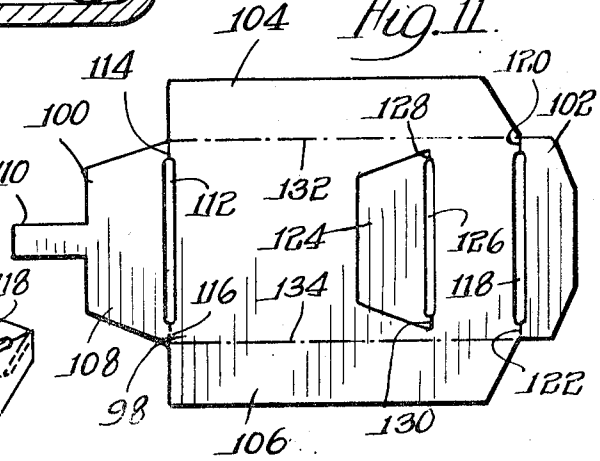
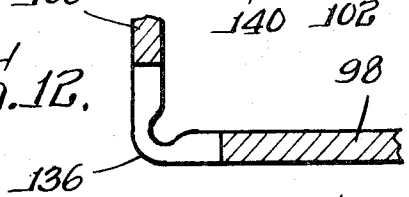


Fig. 12.



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ACCELERATION INSENSITIVE TRANSDUCER

This invention is a continuation application of copending application Ser. No. 550,829, filed May 17, 1966 for "Transducer", now abandoned.

This invention relates to an improved construction for a transducer and more particularly to that type of transducer which is of a miniature size particularly adapted for use in converting acoustic energy to electrical energy and vice verse.

The construction of miniature transducers is generally well known; however, if the size of a given transducer is reduced, it is imperative that the construction of the transducer be simplified and improved to provide a transducer which has a high degree of reliability and fidelity. One class of transducers which is well-known is that type of transducer which utilizes a piezoelectric element in connection with a diaphragm to convert acoustic energy to electrical energy and vice verse. One of the problems which is encountered in the construction of such a transducer utilizing piezoelectric transducing material is that the force required to distort practical sizes of piezoelectric material is ordinarily greater than the force which is readily generated by acoustic energy. To this end, a force multiplication arrangement is provided. However, a force multiplication arrangement in a transducer provides another problem in that mechanical vibration and shock may more readily distort the piezoelectric element because of the inertia of the diaphragm and connecting linkage. It is, therefore, a principal object of this particular invention to provide an improved construction for a transducer utilizing a piezoelectric element in which there is a compensating arrangement to reduce possible unwanted signal and damage to movable parts due to vibration and shock.

In view of the fact that the forces which are generated by acoustic energy are minute, it is another object of the subject invention to provide an improved force multiplier which absorbs a minimum amount of energy.

It is a further object of the herein disclosed invention to provide an improved construction of a transducer having a piezoelectric element in which the mounting for the piezoelectric element engages a minumum area of the element to allow the maximum electromotive force to be generated in the piezoelectric element.

It is a still further object of the instant invention to provide an improved construction for a transducer which has high fidelity.

It is a still further object of this invention to reduce the number of parts in the transducer thereby providing an improved construction for a transducer which allows the transducer to be manufactured more simply and economically.

Other objects and uses of the herein disclosed invention will become readily apparent to those skilled in the art upon a perusal of the following specification in light of the accompanying drawings, in which:

FIG. 1 is a perspective view of a transducer embodying the herein disclosed invention;

FIG. 2 is an end view of the transducer shown in FIG. 1 showing a slot aperture in one end of the transducer;

FIG. 3 is a cross-sectional view taken on line 3–3 of FIG. 1 showing in elevation the interior construction of the instant transducer;

FIG. 4 is a cross-sectional view taken on line 4–4 of FIG. 3 showing in plan view the interior construction of the subject transducer.

FIG. 5 is an enlarged cross-sectional view taken on line 5–5 of FIG. 2 showing the details of construction of a contact terminal or clip which provides a means for electrical contact with one side of a piezoelectric element which constitutes a portion of the instant transducer;

FIG. 6 is a cross-sectional view taken on line 6–6 of FIG. 3 showing an end-elevational view of the interior construction of the present invention;

FIG. 7 is a cross-sectional view taken on line 7–7 of FIG. 3 also showing the details of construction of the interior of the instant transducer;

FIG. 8 is a perspective view of a yoke which constitutes a portion of the instant transducer;

FIG. 9 is a perspective view of a baffle plate which constitutes a portion of the instant transducer;

FIG. 10 is a perspective view of a lever which constitutes a portion of the instant transducer;

FIG. 11 is a plan view of the lever shown in FIG. 10, but the lever is shown in a flat attitude prior to folding to the attitude shown in FIG. 10; and

FIG. 12 is an enlarged cross-sectional view taken on line 12–12 of FIG. 10 showing a portion of a diaphragm tab fold.

Referring now to the drawings and especially to FIG. 1, a transducer embodying the herein disclosed invention and generally indicated by numeral 20 is shown therein. The transducer 20 generally includes a cover 22 sealingly mounted on a case 24 which case has a generally rectangular outline and one side open. The case was mounted on its open side a surround 26 with a diaphragm 28 fixed to the surround. A conventional Thuras or inertance tube 30 is passed through the diaphragm and positioned in the interior of the casing. A contact 32 is mounted on the case, and an elongated conventional ceramic piezoelectric element 34 is positioned in the case in engagement with contact 32. The element is held in position by a resilient electrically conductive clip 36 which is also in electrical contact with case 24. A yoke 38 is mounted within the case, and a lever 40 is connected to the diaphragm 28, the yoke 38 and the element 34 to act as a force multiplier between the diaphragm and the element.

Referring now to FIGS. 3 and 4, it may be seen that the case 24 is a unitary construction, and the case 24 is made of an electrically conductive metal. The case includes a bottom 42 which has a ledge or step 44 formed integral therewith or may be formed by inserting a block in the bottom of the case. An end wall 46 is formed integral with one end of the bottom, and an end wall 48 is formed integral with the ledge 44 at the other end of bottom 42. The end wall 48 includes a slot aperture 50 adjacent to ledge 44. The case also includes a pair of mirror-image sidewalls 52, which are formed integral with the sides of the bottom 42. Each of the sidewalls includes a pair of generally hemispherical clip retaining protuberances 54 and 56 and three generally tear-shaped yoke retaining protuberances 58, 60 and 62. As was mentioned above, the surround 26 is fixed to the case 24. The surround is adhesively secured to the end walls 46 and 48 and sidewalls 52 to seal closed the open end of the case. The diaphragm 28 which is mounted on the case has a tab receiving aperture 64 in its surface to receive a portion of the lever 40 as will be described in detail hereinafter.

As was mentioned above, the cover 22 is mounted on the casing 24. The cover includes a substantially flat portion 66, and it has four cover sidewalls 68 formed integral with the outer periphery thereof. A cover offset 70 is formed integral with the sidewalls and a retaining edge 72 is formed integral with the cover offset. The offset 70 is placed into engagement with the surround and is adhesively secured thereto to seal closed the casing. The cover plate contains a sound aperture 74 in this flat portion as may be best seen in FIGS. 1 and 3.

Fixed to the interior surface of cover plate 66 adjacent to the diaphragm is a baffle plate 76. The baffle plate 76 includes a recess 78 which extends along the length of the cover plate. In this instance, when the baffle plate is secured to the cover plate the distance between the surface of the cover plate and the recess portion is of the order of 0.002 inch to 0.006 inch. The small overall height of this baffle plate facilitates its mounting between the cover plate 66 and the diaphragm 28. However, mounting the baffle plate inside of the case 24 is not essential to the effective function of the baffle. The recess portion in the baffle provides a shallow passage 79 which communicates with the sound aperture to provide damping of vibrations because of energy loss in the viscosity of the air passing between the channel walls and thus improving the operation of the transducer.

Looking now to FIGS. 3 and 5, construction of the electrical contact 32 are shown therein. The contact includes an electrically insulating sheet 80 which is fixed to the ledge 44 and is coated with a conductor such as copper which provides a con-

ductive surface for the contact and terminal. Thereby, the conductive surface is insulated from the ledge **44**, and the case **24**. As is evident in FIGS. **3** and **5**, the contact extends through slot **50** so that the contact **32** is positioned interiorly and exteriorly of the casing. The element **34** is conventional in construction in that it is made of a laminated piezoelectric material sensitive to bending of the composite element and has one side in engagement with the contact **32** so that the electric potential on one side of the element **34** is electrically conducted to the contact. The element is held in position by the resilient clip **36** which is in electrical contact with the other side of the element.

As may be seen in FIGS. **3** and **4**, the resilient clip or clamp **36** holds the element in secure engagement with the contact **32** on the ledge **44**. The resilient clip is made of a metal such as steel or brass having a high modulus of elasticity and having a ductile range when the yield point is exceeded and includes a base **84** which is substantially equal to the interior width of the case **24**. The base is positioned beneath the protuberances **54** and above the protuberances **56**. In its normal or unstressed condition, the resilient clip is bowed for reasons which will become apparent hereinafter. An arm **86** is formed integral with base **84**, and the arm has an arc **88** formed therein which arc engages the upper surface of the element **34** in a narrow region forming substantially line contact which is substantially perpendicular to the longitudinal axis of the element. As was mentioned above, the resilient clip **36** is between the protuberances **54** and **56** and with the element against the arc **88**. As the arc **88** is caused to slide along the surface of the element during insertion, the resilient clip **36** is made to bend and is stressed beyond its yield point into its ductile region so that substantially the same force is applied by the clip to the element irrespective of the thickness of the element within commercially allowable tolerances. A curvature or bow in the base portion **84** of the clip is useful in obtaining sufficient bending of the part on insertion but it is not essential to achieve the desired operation. By using this particular construction in each transducer, an adequate clamping force by the arc **88** against the element is assured without risk of crushing the element. Furthermore, there is an assurance that the element will be held by the clip if the element is made within commercial manufacturing tolerances so that shimming is eliminated and assembly and manufacture is simplified. It should be noted also that inasmuch as the resilient clip is made of metal, the side of the element which is in contact with the clip through arc **88** is electrically connected to the casing. Thus, the electric potential between opposite sides of the element is carried to the casing and the conductor surface of contact **32**. Lead tabs which are not shown in this instance may then be attached to the case and to clip **32** to accommodate leads to the instant transducer.

The yoke **38** is generally U-shaped as may be best seen in FIG. **8**. The yoke includes an arm **90** with a leg **92** at one end of the arm and a leg **94** at the other end of the arm. Leg **94** includes a recess **96** to receive the inertance tube **30**. As may be seen in FIGS. **3** and **4**, the yoke **38** is positioned in the case **24** between the yoke protuberances **58**, **60** and **62**. A suitable adhesive is used to fix the yoke in position. As may be clearly seen in FIG. **6**, the inertance tube **30** is positioned in the recess **96**.

The construction of the lever **40** may be best seen in FIGS. **10** and **11**. In FIG. **11**, the lever **40** is shown in its flattened attitude, that is, prior to bending to its shape which may be best seen in FIG. **10**. The lever **40** includes a flat elongated arm **98** which has a diaphragm tab **100** formed integral with one end of the arm and an element tab **102** which is formed integral with the other end of the arm. Formed integral with opposite sides of the arm are stiffeners **104** and **106**. The diaphragm tab includes an enlarged base portion **108** with a finger **110** extending therefrom adapted for insertion into aperture **64** of the diaphragm. At the junction of the diaphragm tab and arm **98**, there is an elongated slot **112** which extends over the major portion of the width of the junction. The remainder of the junction is etched to provide a pair of grooves **114** and **116** so that there is a minimum amount of material at the junction of the tab and the arm **98**. A slot **118** is formed at the junction of the other end of arm **98** and element tab **102**. Grooves **120** and **122** are formed at ends of the slot **118**. Grooves **120** and **122** are similar to grooves **114** and **116**. A pivot or yoke tab **124** is cut out of the arm **98**, and a slot **126** is formed at the end of the tab **124** as may be seen in FIGS. **10** and **11**. A pair of grooves **128** and **130** are formed at opposite ends of slot **126** to the edges of the pivot tab **124**. A groove **132** is formed at the junction of the stiffener **104** and one side of arm **98** and a similar groove **134** formed between stiffener **106** and the other side of the arm. All of the grooves, that is, grooves **114**, **116**, **120**, **122**, **128**, **130**, **132**, and **134** are formed in the lever by etching or mechanically coining. They facilitate the forming of the bonds and also reduce the stiffness to foldedly flexing the tabs.

After the lever **40** has been formed in its flattened attitude as shown in FIG. **11**, it is bent to the shape shown in FIG. **10**. The diaphragm tab **100** is bent upward so that it is substantially perpendicular to the arm **98**, and a folded region **138** is formed at the junction of tab and arm **98**. The element tab **102** is folded downward so that it is substantially perpendicular to the arm **98**, and a folded region **140** is formed between the element tab and the arm. It is apparent that in each of the folded regions **136**, **138**, and **140**, there is a slot and the flexural stiffness is reduced in these portions of the lever. FIG. **12** which is an enlarged cross-sectional view showing a portion of the folded region between the diaphragm tab and the arm clearly shows how the slot and the grooves cooperate to provide a minimum of material between the tab and the arm. The stiffeners **104** and **106** are also folded downward so that they are also substantially perpendicular to the arm and to the tabs.

The lever **40** is secured to the yoke by means of pivot tab **124** using suitable means, such as, welds or an adhesive. The element tab **102** is secured to the vibratable end of the element **34** as may be best seen in FIG. **3**. The finger **110** of the diaphragm tab is positioned in aperture **64** of the diaphragm and an adhesive **142** is used to secure the tab to the diaphragm.

The subject transducer may be readily assembled by first placing into position the electrical contact **32** and insulator **80** on ledge **44**. The element **34** which is of a conventional and well-known construction is positioned on the contact **32**. The resilient clip **36** is forced over the protuberances **56** and under the protuberances **54** against the top surface of the element **34**. The arced end **80** slides along the surface of the element causing bending in the clip. As was mentioned above, the resilient clip **36** is bowed to a point where the stress is raised beyond the yield point and into the ductile region of the material used for the clip. Thus, the element is held securely between the arc **88** and contact **32**. It is important to note that by using the clip and ledge construction disclosed herein, a high clamping action is obtained over a minimum length of the element, and the major portion of the element is utilized to develop an electromotive force between opposite sides of the actuator as a result of deformation.

The lever **40** is then secured to the yoke. The yoke is placed into position. The protuberances form a convenient locating method. The tab on the lever is fastened to the vibratable end of the element. The diaphragm **28** is mounted so that the finger **110** of the lever is positioned in aperture **64** of the diaphragm, and adhesive **142** is placed on the diaphragm and finger to connect the lever to diaphragm **28**. The cover with the baffle plate in position is then placed on the case and is secured thereto. An adhesive **144** is then placed in the slot **50** to seal closed the slot and to attach the fixed end of the element to the case in order to further secure the element to the case. The adhesive **144** serves the dual function of providing a seal and a means for fixing the element more firmly to the case and clip.

In operation, sound waves enter the sound aperture **74**, the baffle plate **76** serves to prevent undamped resonances of the

vibratable parts. When the diaphragm 28 is forced down, as viewed in FIG. 3, by a pressure increase outside the microphone, the diaphragm tab 100 is also forced down as is the end of arm 98. The arm pivoting about the pivot tab then raises the element tab 102 to raise the vibratable end of the element 34, thus causing a strain in the element which develops an electric potential between opposite sides of the element as is conventional and is well known. The case 24 then has the potential of the upper side of the element, and the conductive surface 82 has the potential of the lower side of the element.

It is important to note that the forces which are generated by a sound wave are very small, and the lever arrangement is used to multiply the force available from the diaphragm. But, the need for a force transmittal system which is efficiently minute and inexpensive to manufacture requires that the lever construction be simple but effective. It should be noted that at each of the folded regions where the tabs are connected to the arm there is a minimum of material. In each fold where flexing is desired, there is a slot and grooves so that the force from the diaphragm is not resisted by overcoming a large bending torque. Rather the force is transmitted axially along the diaphragm tab to the arm and the arm substantially freely pivots about the pivot tab at the yoke and the force is then transmitted to the element tab with a minimum of loss as an axial force applied to the element. By utilizing the lever construction, where stiffeners are formed integral with arm 98, the arm has a maximum of stiffness for its weight so that the displacement of the diaphragm is not dissipated by bending the arm 98. Obviously, when the sound pressure tends to move the diaphragm upward, the transducer element operates in the opposite direction. It should also be noted that when the instant transducer is used as a speaker or receiver, the amount of power required to operate the diaphragm is also reduced.

In this construction, the distance from the point where the diaphragm tab is connected to the arm 98 to the point where the pivot tab is connected to the arm 98 is about three times the distance from the point where the pivot tab is connected to the arm to the point where the element tab is connected to the arm. In this particular arrangement the diaphragm, diaphragm tab and that portion of the arm and stiffener from the point where the pivot tab is connected to the arm to the end of the arm adjacent to the diaphragm tab is inertially balanced relative to the remainder of the lever and the element, that is, the effective moment due to the inertia of the parts on one side of pivot tab is balanced relative to the effective moment due to the inertia of the parts on the other side of the pivot tab. This particular construction provides a transducer which has high fidelity where the effects of extraneous vibrations and mechanical shock applied to the casing of the transducer are minimized.

From the foregoing description, it is readily apparent that the transducer 20 may be simply and economically manufactured and assembled. The transducer parts are interconnected to provide an optimum utilization of each of the parts.

Although a specific embodiment of the herein disclosed invention has been shown and described in detail above, it is evident that those skilled in the art may make various modifications or changes without departing from the spirit and scope of the instant invention. It is to be expressly understood that the instant invention is limited only by the appended claims.

We claim:

1. A transducer comprising, in combination, a case, a transducer element having one end fixed relative to said case and the other end being vibratable, a lever having one end fixed to the vibratable end of said element, a diaphragm connected to said case and being connected to said lever, and a pivot connected to said lever between the ends thereof to hold pivotally the lever relative to the case, the distance from the pivot to the connection of said lever to said diaphragm and the distance from said pivot to the connection of the lever to said element being proportional such that the effective moments due to the inertia of the lever and parts connected to the lever, on one side of the pivot are equal to the effective moments due to the inertia of the lever and parts connected to the lever on the other side of the pivot, whereby the effects of extraneous vibrations and mechanical shock applied to the case are minimized.

2. A transducer comprising, in combination, an electrically conductive case, an elongated ceramic piezoelectric element mounted in said case with one end vibratable relative to said case, a resilient electrically conductive clip mounted in electrical contact with the case and in electrical contact with one side of the element to hold the element in position within the case, said resilient clip having a ridge substantially perpendicular to the longitudinal axis of the element to provide contact between the element and the clip, said case having an aperture contained therein adjacent to the fixed end of the element, an electrical conductor connected to the other side of the element and insulated from the case extending through said aperture, a diaphragm mounted on the case, a cover mounted on said case adjacent to said diaphragm, said cover having an aperture contained therein, a baffle plate mounted on the cover adjacent to the aperture and the diaphragm to provide shallow passageway communicating with said aperture, a diaphragm tab fixed to the diaphragm, an elongated arm formed integral with the diaphragm tab and having a diaphragm fold at the junction of the arm and the diaphragm tab, an end tab formed integral with the other end of the arm and having an end fold at the junction of the end tab and the arm, said end tab being connected to the vibratable end of the element, a pivot tab secured relative to the case at one end and the other end formed integral with the arm and between the ends of the arm, a pivot fold formed at the junction of the pivot tab and the arm, said pivot tab being positioned between the ends of the arm so that the effective moments of the diaphragm, diaphragm tab and the arm on one side of the pivot tab are equal to the effective moments of the element, the end tab and the arm on the other side of the pivot, and each of said folds having a slot substantially parallel to the fold and reduced portion to reduce the torque resistance between the adjacent parts.

3. In a transducer having a case, a transducer element having one end fixed relative to said case and the other end vibratable, and a diaphragm connected to the case, the improvement comprising a lever connected to the diaphragm and to the other end of the element; said lever having an arm, a diaphragm tab formed at one end of the arm at a folded portion thereof and connected to the diaphragm, said diaphragm tab being substantially perpendicular to the arm at the folded portion and extending upwardly therefrom, and end tab formed integral with the other end of the arm at a second folded portion and connected to the other end of the element, said end tab being substantially perpendicular to the arm at the folded portion and extending downwardly therefrom, and each of said folded portions having a slot and a reduced portion at opposite ends of the slot to reduce torque resistance between parts of the lever.

4. In a transducer as defined in claim 3, the improvement comprising a pivot tab formed at a third folded portion between the ends of the arm and extending upwardly therefrom, said pivot tab being substantially perpendicular to the arm and being connected to the case.

5. In a transducer as defined in claim 3, the improvement comprising a pair of stiffeners formed at opposed edges of the arm and being substantially perpendicular to the arm.

6. A transducer comprising, in combination, an electrically conductive case, an elongated transducer element mounted in said case, a resilient electrically conductive clip mounted in electrical contact with the case and in electrical contact with one side of the element to hold the element in position within the case, means for electrically contacting the other side of the element, a diaphragm mounted on said case, a lever having one end fixed to the vibratable end of said element and the other end fixed to the diaphragm, and said lever having a pivot connected to the case and said pivot being between the ends

of said lever to hold the lever relative to the case so that the effective moments due to the inertia of the lever and the parts connected to the lever on one side of the pivot are equal to the effective moments due to the inertia of the lever and parts on the other side of the pivot.

7. A transducer comprising, in combination, a case, said case including a substantially flat mounting ledge with an aperture in one wall of the case adjacent to the ledge, an electrical conductor positioned on the ledge through said aperture and being insulated from the ledge and the case, a piezoelectric element having one end in contact with the electrical conductor, a clip having a mounting ridge positioned in the case with the mounting ridge in engagement with the element to secure one end of the element to the case and to provide an electrical contact to one surface of the element while the opposite surface of the element is in contact with the electrical conductor, a plurality of protuberances in said casing in engagement with the clip to hold the clip in a deformed state beyond the elastic limit of the clip to hold the clip in engagement with the element, a yoke mounted in the casing, a diaphragm mounted on one side of said case, and a lever connected to the element and the diaphragm and pivoting about the yoke.

8. In a transducer having a case, a transducer element having one end fixed in said case and the other end vibratable and a diaphragm connected to the case, the improvement comprising, a diaphragm tab fixed to the diaphragm, an elongated arm having one end connecting with the diaphragm tab and having a diaphragm fold at the juncture of the arm and the diaphragm tab, an end tab formed at the other end of the arm and having an end fold at the juncture of the end tab and the arm, said end tab being connected to the vibratable end of the element, a pivot tab connected to the case at one end and the other end connected to the arm between the ends of the arm, a pivot fold formed at the juncture of the pivot tab and the arm, each of said folds having a slot substantially parallel to the fold and a reduced portion at opposite ends of the slot to reduce the torque resistance between the parts, and a pair of the sidewalls formed at opposite sides of the arm and being substantially perpendicular to the arm.

9. A transducer comprising, in combination, a case, an elongated piezoelectric element mounted in said case, a clip having a mounting ridge positioned in the case with the mounting ridge in engagement with the element to secure one end of the element to the case, a plurality of the protuberances in said casing in engagement with the clip to hold the clip in a deformed state beyond the elastic limit of the clip to hold the clip in engagement with the element, a diaphragm mounted on one side of said case, a lever pivotally connected to the element, the diaphragm and the case, a cover mounted on said case, said cover having an aperture, and an aperture baffle mounted on the cover adjacent to said aperture, said baffle having a shallow passage extending along the length of the baffle and communicating with the aperture.

10. A transducer as defined in claim 9 further comprising a plurality of second protuberances in said case and being spaced from the first mentioned protuberances, a yoke mounted in the case between the second protuberances to be held in position thereby, a diaphragm connected to one side of said case, and a lever connected to the element and the diaphragm and pivoting about the yoke.