June 23, 1970 D. E. LEWIS ET AL 3,517,230

INTEGRAL REED TUNING FORK

Filed Aug. 16, 1968

FIG.1

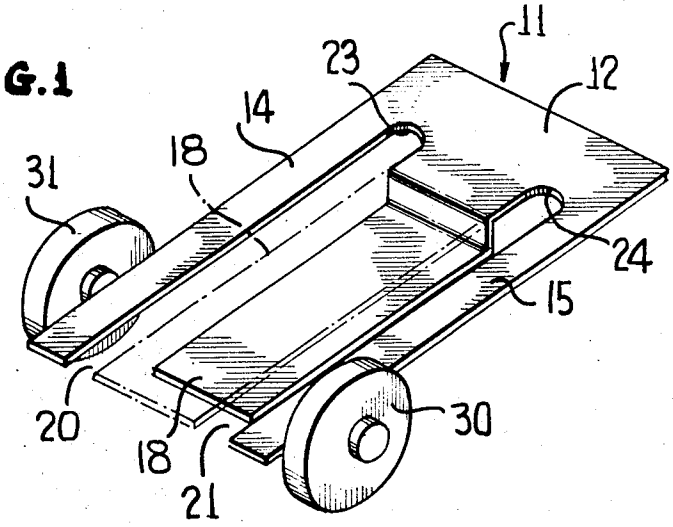


FIG.2

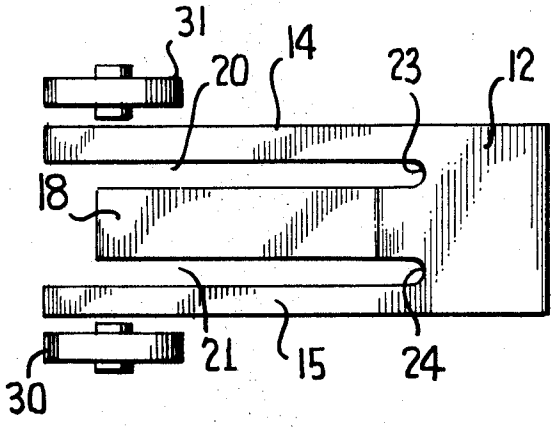
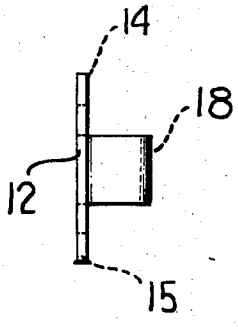


FIG.3



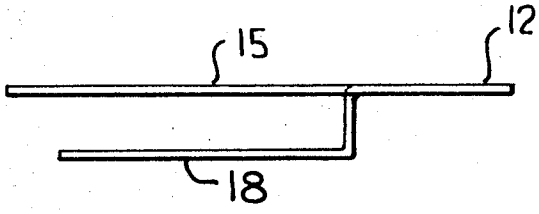


FIG.4

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INTEGRAL REED TUNING FORK

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ABSTRACT OF THE DISCLOSURE

A sheet metal tuning fork has a reed integral therewith. The tuning fork is in the plane of the sheet metal, and the reed constitutes a portion of the sheet metal projecting from the bridging portion of the fork between the tines and lies in a plane offset from that of the fork.

BACKGROUND OF THE INVENTION

The present invention relates generally to sheet metal tuning forks, and more particularly to a tuning fork having its tines mounted for primary vibration in the plane of the sheet, and having a reed formed integrally therewith.

In the past, sheet metal tuning forks have generally been constructed by bending a narrow strip of the sheet metal into a U-shaped configuration, in which the tines of the fork lie in displaced planes as a result of the deformation of the sheet metal from its original plane. The entire width of the strip of sheet metal is thereby positioned for subjection to driving forces obtained from a source of oscillatory energy. Examples of prior art tuning forks of this general type may be found in U.S. Pat. 3,106,124 issued to William P. Asten, and in U.S. Pat. 2,994,241, to Gibbs.

One basic problem present in such a fork configuration is the existence of severe stresses in the metal from which the fork is formed, at the bend constituting the bridging portion between the tines. Because of the criticality of the bend area to the operation of the fork, the presence of these stresses in the metal, i.e., compression along the interior surface of the bend and tension along the exterior surface of the bend, tends to create serious difficulty in controlling the frequency of the fork and the vibration of the tines in a tuning fork mode, in contrast to a reed mode.

It has been suggested in the prior art to mount a reed as a base to the sheet metal tuning fork, attaching it to the base of the U (i.e. the base of the bend) in which the fork is formed, or at the interior surface of the bend. In the aforementioned Asten patent the reed is attached to the base of the U by such methods as silver soldering or spot welding. When one is dealing with miniaturized tuning forks, however, as is generally the case with sheet metal forks, difficulties are experienced in maintaining a symmetrical configuration of fork and reed with such methods of attachment, as well as in obtaining integrity and reliability of the mechanical bond. While the fork disclosed by Asten in the aforementioned patent is admirably suited for many purposes, it has been found to suffer fractures at the joint between fork and reed where the nature of the overall device permits extremely limited acessibility to the area in which the weld or solder join is to be made. In the fork disclosed in the aforementioned Gibbs patent, a pair of mounting ears project from either side of the bend area, in the plane of the original sheet metal, but in the final configuration in a plane orthogonal to the planes of the tines. The major difficulty here, aside from the problems noted above with respect to the fork configuration itself, is that the mounting ears are located precisely at the bend and, as a result

of the manner in which they are formed, tend to set up further stresses in an already stressed region. In addition, the ears project backward relative to the tines of the fork and thus have a significant effect on the dynamic stability of the fork, since they vary the dynamic center of the overall configuration.

Stability of the oscillation frequency of the sheet metal tuning fork assembly depends to a great extent upon the mass ratio of the fork to the base assembly. Specifically, a relatively high ratio of mass of fork to mass of base assembly can result in oscillations at a frequency deviating substantially from the designed natural fork frequency. To achieve frequency stability, it is incumbent upon tuning fork designers to provide a support or base whose mass is at least equal to, and is preferably greater than, the mass of the fork. The most often-used method of achieving this result in present-day miniaturized devices is to reduce the mass of the fork until a compromise is reached between the weight and dimensions of the fork and the fork frequency, the former being a function of the latter.

In U.S. Pat. 3,269,249 issued to Donald R. Dailey, this problem is to a great extent overcome by stamping the fork from flat sheet metal stock to provide it with a planar U-shaped configuration, and mounting the resulting structure such that the tines vibrate in the plane of the sheet. In this manner, the actual frequency of the fork is determined primarily by the tine length and width, the thickness of the sheet having only a trifling effect thereon. In practice, the sheet thickness need only be sufficiently great to provide as much rigidity of tines as will preclude fork vibrations and/or bending in a plane other than that in which the fork normally lies. Since, according to the Dailey invention, the width of the stamped tines may be substantial, the absolute values of fork mass and base mass may be reduced and the ratio of tuning fork mass to base assembly mass may also be reduced, without degrading stability. Moreover, since the fork may be stamped from sheet metal stock in a shape which does not require further bending of the tines, the cost of fabrication is reduced considerably from that required for the prior art type of sheet metal fork. It follows also that the concurrent stamping of numerous forks can be accomplished in an expeditious manner when compared to the rather tedious and individual bending operations required in the formation of prior art sheet metal forks.

Despite these improvements stemming from the Dailey tuning fork, severe limitations were still imposed upon frequency range and frequency stability, in part because of the manner of assembly of the fork and/or the fork tines to the base or mounting assembly, and further, because of the special machining requirements for the fork itself and for any components to be attached thereto.

It is, accordingly, a principal object of the present invention to provide a tuning fork of simple construction and of high accuracy of oscillation frequency, and which is capable of operation over a frequency range extending from at least 3,000 cycles per second to at least 25,000 cycles per second.

SUMMARY OF THE INVENTION

Briefly, according to the present invention, a tuning fork of sheet metal construction is formed with an integral reed, the fork and reed being stamped from flat sheet metal stock, wherein the reed has the form of an arm extending from the portion of the fork bridging or joining the tines. The stamping may be and preferably is performed together with the use of appropriate dies to produce a tuning fork with an offset integral reed in a single operation. Alternatively, stamping to provide a reed residing in the plane of the fork may be followed by bend-

ing of the reed into an offset plane. Obviously, the single operation is less costly. This configuration is advantageous for a number of reasons.

First, since the tuning fork lies entirely in a single plane, viz., that of the original sheet metal, and has been formed entirely by stamping or some other suitable process, there are none of the stresses associated with prior art forks in which the metal has been bent or deformed by elongation and contraction, or the like. While the fork configuration is generally of U-shape, we prefer that the U be "squared off." That is to say, the fork may be formed as a generally rectangular piece of sheet metal in which the tines are at the longer sides of the rectangle and the bridging portion is one of the short sides. Sufficient material is of course removed from the rectangle to define the tines and the reed extending therebetween. In the region where the tines join the bridging portion and the latter joins the reed, fillets are provided to prevent the existence of corners which, in addition to their structural weakness, might tend to degrade the control over and stability of fork frequency. However, the exterior region edges or sides of the bridging portion may or may not be "rounded off," as desired. We have found that too much smoothing of the external contour, as by "rounding off" these exterior edges of the bridging portion, has a degrading effect on fork performance.

Since the reed is an integral part of the tuning fork assembly it can readily be attached to a base or support member, or otherwise mounted to any surface by any convenient mechanical means, with little difficulty in comparison to prior art requirements regarding attachment. In addition, the offset structure of the reed permits a relatively simple base construction, better accessibility to fork tines for tuning purposes, and a more liberal selection of position of coils about the fork tines. The central position of the reed relative to the fork tines provides greater dynamic balance, and consistency of characteristics over an entire production run; and since the reed is integral with the fork, problems relating to mechanical bonding of sheet metal reed to fork, such as by welding, soldering, use of epoxy, use of threaded members, or other similar methods, are completely obviated. The integral offset reed design gives greater control over accuracy of oscillation frequency, greater stability, and less cross coupling between the fields. Reproducibility of the overall assembly is also a significant factor and is much better than has heretofore been achieved with prior art tuning fork assemblies, whether of the sheet metal variety or not, where these tuning forks have required additional machining and/or bonding processes.

Preferably, the reed extends in the same direction as the tines, to provide, among other things, greater dynamic stability in that there is greater dynamic balance in the overall configuration. However, this is not absolutely necessary. In fact, while the critical factors in the construction of forks according to the present invention are (1) that the fork lie in a plane conforming to the plane of the sheet metal, (2) that the reed lie in a plane offset or displaced from the plane of the fork, and (3) that the reed be integral with the fork; nevertheless, we experimented earlier with an integral reed tuning fork in which the fork and reed were in the same plane, i.e. the configuration was that of a sheet metal E shape. The difficulty encountered in that configuration was in mounting the reed to a base member without interfering with the fork itself, particularly the tines. This was achieved, and acceptable performance obtained, by use of an offset leg, a portion of which was attached to the reed and an offset portion of which was attached to the mounting base. Again, the offset integral reed configuration is much simpler to produce and to use, and is therefore much cheaper.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and still further objects, features and attendant advantages of the present invention will become apparent from a consideration of the following detailed description of a preferred embodiment thereof, especially when taken in conjunction with the accompanying drawings in which:

FIG. 1 is a perspective view of an integral reed tuning fork according to the invention;

FIG. 2 is a plan view of the tuning fork of FIG. 1; and

FIGS. 3 and 4 are respectively end and side views of the tuning fork of FIGS. 1 and 2.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawing in general, and to specific figures where clarity of description is enhanced thereby, a device according to our invention includes a sheet metal tuning fork **11** which may be seen to be of generally U-shaped construction, and which is stamped from a highly permeable magnetic material such as Ni-Span-C, and which has extending from the bridging portion **12** between tines **14** and **15** thereof, a reed **18**. As previously stated, the reed may be offset from the plane of the fork during the stamping operation, by use of appropriate dies, this being the preferred method of construction. Alternatively, the reed may initially be formed, by stamping, as an arm extending between and in the plane of the tines, as is shown by use of dotted lines in FIG. 1. Subsequently, the reed is subjected to a pair of substantially right angle bends, the first occurring at some slight distance from the main region of the bridging portion from which the arm extends. The reason for this slight projection of the arm from the bridging or joining portion **12** of the tuning fork is that there is provided some additional stability and rigidity in the mechanical construction and support of the fork, and additionally, there is no bend at the immediate junction of the extremities of the slots and the junction therewith of bridging portion **12** which, if present, would tend to set up stresses at those points and would thereby affect the oscillation frequency of the fork and of the reed. In FIG. 1, the slots are designated by reference numbers **20** and **21** and the extremities to which reference has just been made by reference numbers **23** and **24**, respectively.

In an exemplary embodiment for use in the range from approximately 3 kc. to approximately 25 kc., the integral reed fork was composed of Ni-Span-C in flat sheet metal stock. The sheet metal stock had a thickness in the range from 0.035 to 0.070 inch (with a thickness of 0.035 to 0.045 preferred), and the combined fork and reed was approximately 0.425 inch wide and approximately 1¼ inches long. The length of reed **18** depends upon the desired relationship to the length of the tines of the fork. If, for example, the arm or integral reed is to extend to precisely the free extremity of each tine, then it must, of course, be slightly longer than each tine prior to bending of that arm. The width of each tine in the constructed embodiment was approximately 0.075 inch, the width of each slot **20** and **21** was 0.0625 inch, and the width of the reed or extending arm **18** was 0.150 inch. Bridging portion **12** constituted 0.250 inch of the total length of the fork and reed combination. The slots **20** and **21** joined bridging portion **12** at a .031 inch radius, and the bend of arm **18** from the plane of the original sheet metal occurred at a distance of about 0.0625 inch from the end of either slot at the bridging portion juncture. A further substantially right angle bend is provided in arm **18** at a point between extremities of the tines to offset the plane of the arm from the plane of the original sheet metal stock by a distance of approximately ¼ inch. The bend radius for each of the two right angle bends in arm **18** is preferably approximately 1/64 inch.

The removal of the integral reed from the tine area permits easy mounting of the overall fork to any surface

by any mechanical means. For example, the reed portion may be connected to a support by means of one or more screws extending through one or more holes in the arm itself, or by spot welding.

Frequency stability of the fork is accomplished in part by use of the bridging portion area **12** to provide a predetermined mass ratio relative to the two tines **14** and **15**. That is to say, the mass of bridging portion **12** should be determined according to the desired frequency at which tines **14** and **15** are to vibrate in a tuning fork mode, and it will therefore be further dependent upon the length and thickness of the tines.

Further frequency stability is obtained by maintaining a specified dimensional relationship between reed **18** and tines **14** and **15**. In particular, it is preferred that the reed have a width equal to or greater than the combined width of both tines. The offset reed itself provides a stability and isolation which has not heretofore been obtained in other tuning fork arrangements.

The drive and pickup coils associated with the fork are placed adjacent the tines such that the core of each coil is directed at the respective tine, as shown, for example, by the location of coils **30** and **31** in FIGS. 1 and 2. If desired, all components other than tines and reed portion of the final overall package (not shown) may be encapsulated in a body of plastic material such as epoxy resin or potting compound.

Projection of the integral reed in the same direction as the tines is preferred because such a configuration provides a better dynamic balance between fork and base. Vibrations otherwise transferred from fork to base are reduced as a result of location of dynamic center of mass and there is much less tendency for the fork to vibrate in a reed resonant mode, for this configuration.

Integral reed tuning forks of the type disclosed herein have been constructed and used in an octave generator (twelve notes) for an electronic musical instrument. In one particular embodiment of the octave generator the several integral reed tuning forks were mounted on a single printed circuit board and were found to operate without interference (i.e., without crosstalk). Tuning forks according to our invention may, of course, be used in any application where conventional tuning forks have been or may be employed.

We claim:

1. An electromechanical resonator assembly comprising a magnetically permeable U-shaped planar sheet metal tuning fork having a pair of oscillatory tines joined by a bridging portion, said tines and said bridging portion lying in a first plane corresponding to the plane of the sheet metal and with respect to which said tines are oscillatory, a mounting member projecting from said bridging member symmetrically between said tines, said mounting member being offset from said first plane in a further plane parallel to said first plane, said mounting member projecting in said offset plane in the same general direction as said tines project.

2. The invention according to claim **1** wherein said mounting member is a reed having a pair of substantially right angle bends to provide said projection in said offset plane and in said general direction.

3. The invention according to claim **2** wherein said reed has a width substantially equal to or greater than the combined width of said tines.

4. The invention according to claim **1** wherein electromagnetic drive means are positioned relative to said tines to produce vibration thereof in the plane of said sheet metal.

5. A vibratory device comprising a magnetically permeable body of sheet material of generally U-shaped configuration, the legs of the U constituting the tines of a tuning fork, a reed integral with said fork projecting between said tines from the portion of said fork bridging said tines and having a width equal to or greater than the combined width of said tines, said reed offset from the plane of said sheet material within which said tines reside at a point between the extremities of said tines, and means for producing vibration of said tines in said plane.

6. The invention according to claim **5** wherein said reed projects in the same general direction as said tines.

7. The invention according to claim **5** wherein said reed projects slightly beyond said bridging portion in the plane of the tines prior to said offset portion.

8. An electromechanical resonator assembly, comprising a magnetically permeable sheet metal tuning fork having a pair of tines and a bridging portion connecting the tines, all lying in a plane conforming to the plane of the sheet metal, and a reed formed integrally with and of the same sheet of metal as said tuning fork projecting from said bridging portion in the same general direction as said tines, said reed lying at least substantially in a plane parallel to the plane of said tuning fork.

9. The invention according to claim **8** wherein the major portion of said reed is offset from the plane of said tuning fork and in a plane parallel thereto.

10. The invention according to claim **9** further including electromagnetic means positioned relative to said tines such that movement of the tines of said fork affect the electromagnetic field of said means, and vice versa.

11. A vibratory device comprising a sheet metal tuning fork comprising tines and a bridge joining said tines, and a sheet metal reed means joining said tuning fork at said bridge, said fork and said reed means lying substantially in relatively offset planes, said tines being oscillatory with respect to said planes and said reed extending in the same sense as such tines, said reed being more massive than either of said tines.

12. The invention according to claim **11** wherein said offset planes are parallel.

13. A vibratory device comprising a sheet metal tuning fork, and a sheet metal reed integral with said tuning fork at the bridging region between the tines of said fork, said fork and said reed lying in diverse planes, and having the same thickness.

14. The invention according to claim **13** wherein said fork and said reed together form an E-shaped configuration wherein the outer legs of the E constitute the tines of said fork, the central leg constitutes said reed, and the portion connecting all three legs constitutes the bridging region of the E.

15. A tuning fork, including a flat thin sheet-metal fork having two coplanar tines, said tines being separated by a base integral with said tines and said tines being relatively wide and of small thickness, a reed secured to said base and extending in the direction of said tines and being located symmetrically with respect to said tines, said reed being non-coplanar with said tines, and two electromagnets having axes in said plane and having mutually opposed pole faces located adjacent the outer edges of said tines, respectively, said tines being oscillatory with respect to said plane and magnetically coupled to said pole faces, and said reed being wider than either tine.

16. The combination according to claim **15**, wherein each tine is approximately 0.075" wide, said reed is approximately 0.150" wide, and the spacings between said reed and each of said tines is approximately 0.0625".

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U.S. Cl. X.R.

84—409, 457