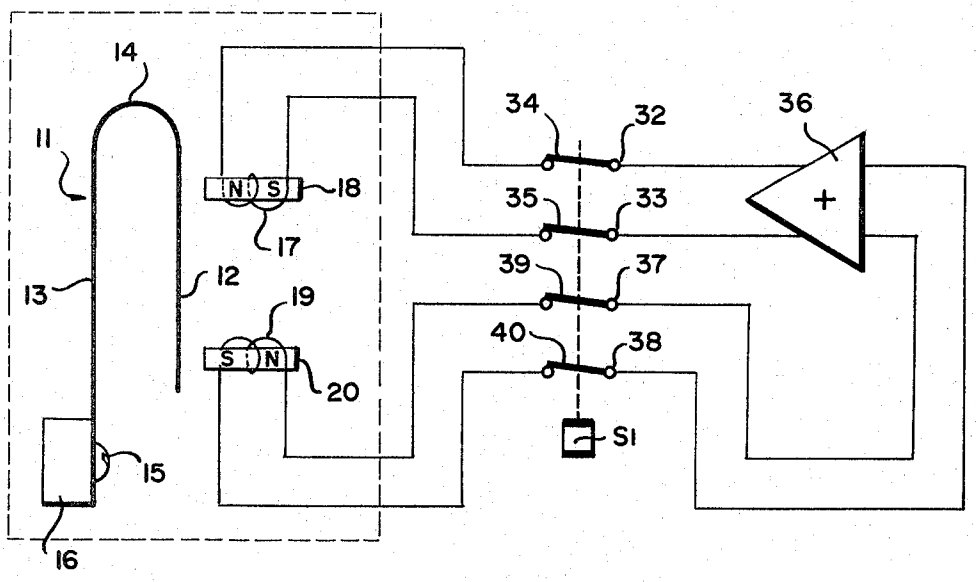
May 7, 1968 W. P. ASTEN 3,382,459

RESONATOR

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FIG.1



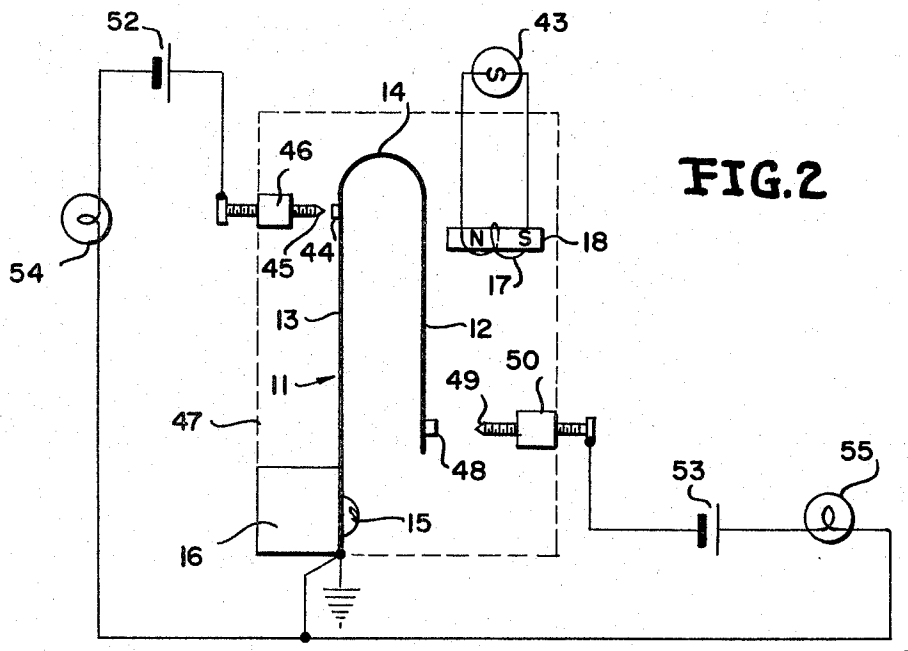


FIG.2

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FIG. 3

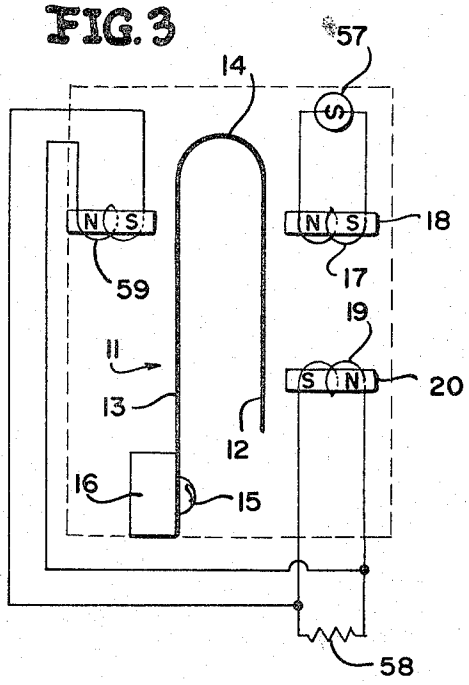


FIG. 4

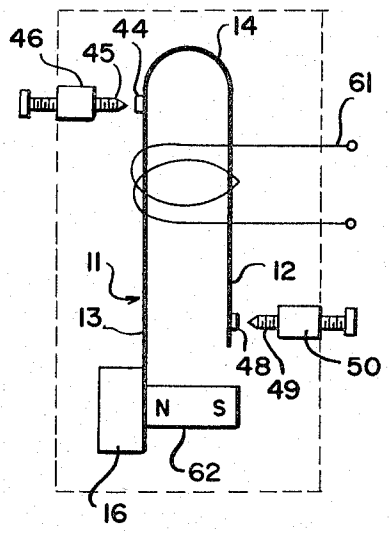


FIG. 5

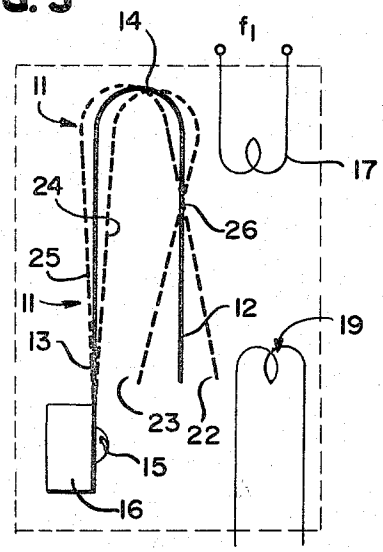
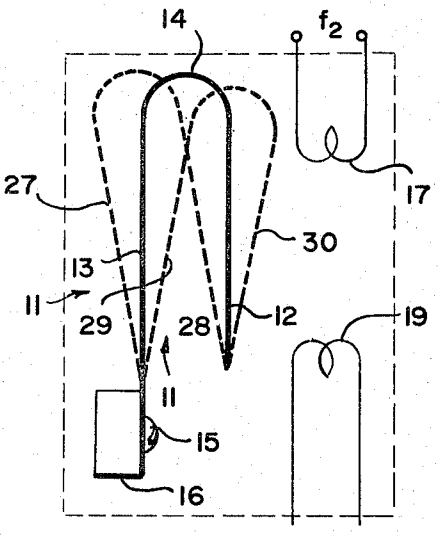


FIG. 6



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3,382,459

RESONATOR

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Filed May 10, 1965, Ser. No. 454,311
29 Claims. (Cl. 331—156)

ABSTRACT OF THE DISCLOSURE

An electromechanical resonator includes a tuning fork having a U-shaped configuration in which normally parallel tines are connected by a bridging portion, the fork supported along one of the tines only, to permit freedom of vibration of that tine along its unrestricted length and of the other tine and the bridging portion along their entire lengths. The fork is driven in either of the tuning fork (opposite movement of the tines) and reed (common movement of the tines) modes of vibration at the disparate natural frequencies of those vibrational modes, and separate and distinct detectors are utilized for sensing the vibrations of the fork in the respective modes.

The present invention relates generally to resonators of the tuning fork type, and more particularly, to a tuning fork type resonator wherein one tine is anchored so a second tine and a leg joining the tines together are free to vibrate so that substantial vibrations in two different modes, at distinct frequencies, are established.

Resonators of the tuning fork type are capable of vibrating in two separate modes, generally at different natural frequencies, namely in the reed mode and the tuning fork mode. In the latter vibration mode, the tines generally have equal, but opposite velocities relative to their rest position, i.e., during one half cycle of oscillation, both tines are directed toward their rest position, while during the other half cycle of oscillation they are directed away from the rest position. When a tuning fork vibrates as a reed, in contrast, one tine vibrates toward its rest position while the other tine moves away from the rest position.

In prior art tuning fork assemblies in which the leg joining the two tines together is fixedly mounted, the Q of the resonator when it vibrates as a fork is generally on the order of two magnitudes greater than the Q of the vibrations of the fork assembly when it vibrates as a reed. The disparity between the Q's in the two different oscillating modes has caused tuning fork designers considerable difficulty.

The difficulty arises if the tuning fork is utilized as a frequency sensitive relay or as a filter, because low amplitude signals are coupled through the fork at the reed frequency. Because only a single pickup device is employed for both fork and reed vibration modes in all prior art devices, it is frequently impossible to distinguish between filter outputs at the two frequencies associated with the different modes. Another problem associated with prior art electromechanical tuning fork resonators, when employed as filters, is that fork mode vibrations result in the output pickup element deriving a signal 180° out of phase from oscillations occurring at the reed frequency relative to the input. In consequence, even if it were desired to pass both the reed and fork natural frequencies, the pickup voltages are of reversed relative polarity so that for phase detection applications, the information coupled through the filter is of little value.

According to the present invention, there is provided an electromechanical resonator of the tuning fork type, wherein one tine of the fork is anchored. By anchoring one tine of the fork, the other tine is free to vibrate as is the leg that connects the two tines together. Since the leg connecting the two tines together is free to vibrate, the fork oscillates in both the reed and tuning fork modes. The Q's of oscillations in the two modes are separated from each other only by a factor on the order of 10 Thereby, the amplitude of the signals derived from pick ups for the two different modes of operation can be made approximately the same.

Because one tine of the tuning fork is anchored, separate pickup members can be employed for detecting the reed and tuning fork vibrations. The use of two different output sensors is ideally adapted for use as a dual frequency sensitive relay wherein one of two outputs is activated depending upon the excitation frequency applied to the tuning fork. Also, the use of two separate and distinct pickup devices enables the tuning fork to be employed as a dual frequency band pass filter in which signals at both frequencies are of substantially the same phase and relative amplitude.

A further feature of the present invention resides in its use as a very stable oscillator at two different frequencies. I have found that oscillations at both the reed and fork frequencies can be attained with the present invention by reversing drive and pickup transducers, disposed in proximity to the free tine and the leg joining the tines together. A single high-gain positive feedback amplifier has its input and output selectively connected to the transducers. It is merely necessary, when using the present invention as a dual frequency oscillator, to reverse the polarity of the signals coupled to the amplifier to derive one or the other of the two frequencies.

It is, accordingly, an object of the present invention to provide a new and improved tuning fork configuration.

Another object of the present invention is to provide a tuning fork configuration wherein reed and fork modes of vibration are at Q's on an order of magnitude different from each by approximately one.

It is another object of the present invention to provide a new and improved resonator of the tuning fork type wherein two separate and distinct frequencies can be detected with approximately the same capability.

An additional object of the present invention is to provide an electromagnetic resonator of the tuning fork type wherein one tine of the fork is anchored, while the other tine and the leg joining the two tines are free to oscillate so that substantial vibrations in both the tuning fork and reed modes are attained.

Still another object of the present invention is to provide a tuning fork configuration in which separate pickup elements are employed for detecting the reed and fork modes of vibration.

A further object of the present invention is to provide a new and improved oscillator having an electromagnetic resonant element that is susceptible to oscillation at two different frequencies and wherein the oscillator derives two distinct output frequencies dependent upon the resonator oscillation mode.

Still a further object of the present invention is to provide a new and improved dual frequency oscillator employing a tuning fork that is susceptible to vibration both in the tuning fork and reed modes wherein the vibrations are approximately on the same order of magnitude, so that the same amplifier can be employed for the dual frequency output and only switching is necessary to change from one frequency to another.

Still another object of the present invention is to provide a new and improved relay that is capable of deriving a pair of separate outputs in response to two different frequencies applied thereto.

Still a further object of the present invention is to provide a dual frequency responsive relay employing a resonator that is capable of oscillating in both the reed and tuning fork modes and wherein contact is made at two

different points depending upon the frequency applied to the relay.

Still a further object of the present invention is to provide a new and improved filter employing an electromechanical resonant element from which can be derived outputs at two different frequencies, both having the same phase relative to the input signal.

Still an additional object of the present invention is to provide a new and improved dual frequency filter employing a relatively high Q electromechanical resonating element that oscillates at two different frequencies with amplitudes approaching the same order of magnitude.

Yet an additional object of the present invention is to provide a dual frequency filter employing an electromechanical resonator which is free to vibrate both in the reed and fork modes and wherein outputs are derived from distinct pickup elements for the two oscillation modes.

The above and still further objects, features and advantages of the present invention will become apparent upon consideration of the following detailed description of one specific embodiment thereof, especially when taken in conjunction with the accompanying drawing, wherein:

FIGURE 1 is a schematic representation of the tuning fork according to the present invention in combination with an amplifier so that oscillations at two distinct frequencies can be derived;

FIGURE 2 is a schematic diagram of the manner in which the present invention is employed as a dual frequency sensitive relay;

FIGURE 3 is a schematic diagram illustrating the manner in which the tuning fork configuration of the present invention is employed as a dual frequency bandpass filter;

FIGURE 4 is a schematic representation of a further embodiment of the present invention;

FIGURE 5 is a schematic representation to illustrate the manner in which the electromechanical resonator of the present invention vibrates in the tuning fork mode; and

FIGURE 6 is a schematic illustration to show the manner in which the electromechanical resonator of the present invention vibrates as a reed.

Reference is now made to FIGURE 1 of the drawings wherein electromechanical resonator **11**, shaped as a sheet metal tuning fork and preferably made of a highly magnetically permeable material such as Ni-Span-C, has first and second tines **12** and **13**, joined together by leg **14**. Tine **13** is somewhat longer than tine **12** and is anchored at its end remote from leg **14** by means of bolt **15** that extends into stationary housing **16**. A circular aperture or slot, neither of which is shown, is provided in tine **13** at its end so that bolt **15** can anchor tuning fork **11** at only one position or a plurality of different positions. If it is desired to change the frequencies derived from the unit by other than conventional means, that is by varying the fork mass and/or dimensions, a slot is provided in tine **13** and fork **11** is moved relative to bolt **15** and housing **16**.

Positioned in proximity to leg **14** is a first coil or velocity-electric signal transducer **17** having extending through it bar magnet **18**. At the end of tine **12** remote from leg **14** is a second coil or velocity-electric signal transducer **19** having bar magnet **20** extending through it. Bar magnets **18** and **20** are arranged to have their opposite poles in closest proximity with tine **12** so tine **12** is provided with a DC magnetic bias to provide low reluctance for the AC signals coupled between coils **17** and **19**.

Before considering the manner in which the network of FIGURE 1 functions as a dual frequency oscillator, consideration will be given to the manner in which electromechanical resonator **11** vibrates both in the reed and fork modes, by referring to FIGURES 5 and 6. In FIGURE 5, it is assumed that a frequency F_1, coincident with the natural resonant frequency of the resonator in its fork mode of vibration, is applied to coil **17**. The force applied to fork **11** by the electromagnetic field deriving from coil **17** causes vibration of the fork substantially in the tuning fork mode wherein leg **14** that joins tines **12** and **13** together remains substantially at the same position throughout an entire period of oscillation. The free end of tine **12**, however, oscillates with substantial excursions between its rest position and its maximum extent of travel, as indicated by dotted lines **22** and **23**.

Since the end of tine **13** is anchored to mounting post **16**, no substantial movement of tine **13** occurs as tine **12** oscillates. What movement there is of tine **13** at points in proximity to leg **14**, is always oppositely directed relative to the center line between tines **12** and **13** from the movement of tine **12** at its free end. Thus, at an instant of time when the free end of tine **12** extends most inwardly, as indicated by dotted line **23**, the portion of tine **13** from bolt **15** to leg **14** extends inwardly, as indicated by dotted line **24**, towards the center line joining the tines together, Similarly, during the other half cycle of tuning fork vibration, tines **12** and **13** both move away from the center line, as indicated by dotted lines **22** and **25**.

It is noted that there exists a substantially stationary point **26** between driving coil **17** and the free end of tine **12**. Stationary point **26** is a point about which the oscillations are derived, similarly to anchoring leg **14** in a conventional tuning fork. Because there are unequal masses of fork **11** relative to stationary point **26**, the Q of the oscillations derived in the tuning fork mode with the present invention are substantially lower than those obtained with the conventional prior art work. If it is desired to increase the Q of the resonator of the present invention, the fork is designed so that stationary point **26** is moved closer to leg **14**, and oppositely, decreasing Q's are obtained by arranging fork **11** so stationary point **26** is closer to the free end of tine **12**.

To provide an understanding of the manner in which the fork of the present invention vibrates in the reed mode, reference is made to FIGURE 6 wherein a frequency F_2, different from frequency F_1 and coincident with the natural resonant frequency of resonator **11** in the reed mode of oscillation, is applied to coil **17**. In response to the electromagnetic energy at frequency F_2 deriving from coil **17**, fork **11** is caused to vibrate as a reed wherein the ends of tines **12** and **13** remote from leg **14** remain in substantially the same position throughout a cycle of oscillation while leg **14** joining the tines together vibrates substantially. Thus, during one half cycle of oscillation at frequency F_2, both tines **12** and **13** move to the left of their rest position as depicted by dotted lines **27** and **28**, while during the other half cycle, the tines move to the right of their rest position, as indicated by dotted lines **29** and **30**.

While the excursions in the vicinity of leg **14** when resonator **11** is excited to the reed mode of vibration are not as great as the excursions of the free end of tine **12** during the fork mode of vibration, they are approximately on the same order of magnitude. The relative amplitudes of these vibrations are such that when resonator **11** oscillates in the tuning fork mode, Q's on the order of 100 to 150 are obtained. This is not too different from the Q's of approximately 50 for reed mode vibrations.

Because substantial movement occurs at two distinct points for the different modes of vibration of the present invention, namely at the free end of tine **12** and in the vicinity of leg **14**, it is possible with the present invention to provide two separate and distinct output detecting means. One of the detecting means is located in proximity to the free end of tine **12** and provides an output only when fork **11** is driven in the tuning fork mode at fre-

quency F_1. In contrast, a pickup element in proximity to leg **14** is responsive only to reed vibration of fork **11** and provides an output when the fork is driven at frequency F_2. Movement of leg **14** in response to fork mode vibrations is generally insufficient to provide a large amplitude output from coil **17** at frequency F_2 while displacement of the free end of tine **12** in response to reed vibrations is generally insufficient to provide a large amplitude signal from transducer **19**. Since the resonator outputs for the two different vibration modes are on the approximately same order of magnitude and are derived from different transducers **17** and **19**, the structure of the present invention is ideally adapted for use as a dual frequency oscillator, dual frequency filter, or dual frequency relay.

In use as an oscillator for deriving a pair of frequencies, the circuit diagram of FIGURE 1 is employed. In FIGURE 1, coil **17** is connected via stationary contacts **32** and **33** and movable contacts **34** and **35** to the output of amplifier **36**. In an opposite manner, coil **19** is connected to the input of amplifier **36** through stationary contacts **37**, **38** and movable contacts **39**, **40**. Switch contacts **34**, **35**, **39** and **40** are arranged so that coil **17** can be connected to the input of amplifier **36** while coil **19** is connected to the amplifier output.

By reversing the connection of switch contacts **34**, **35**, **39** and **40**, the polarity of the signal coupled between the amplifier output and coil **19** is reversed from the polarity when the amplifier output is connected to coil **17**. Thereby, a positive feedback loop is maintained for both connection situations, regardless of which coil is used for driver and pickup functions. Amplifier **36** is provided with sufficient gain in both connection modes to be driven into saturation during every half cycle of its operation, whereby square waves are derived, in a manner well known to those skilled in the art. Thereby, stability of the oscillations derived from fork **11** is insured at both operating frequencies.

When it is desired to provide oscillations at frequency F_1, coincident with the natural resonant frequency of fork **11** in its fork mode of vibration, amplifier **36** is connected to coils **17** and **19** as illustrated in FIGURE 1. Any vibrations imparted to fork **11** at frequency F_1 are picked up by coil **19**, increased in magnitude by amplifier **36** and regeneratively coupled back to coil **17**, which serves as a drive coil. The F_1 oscillations imparted by coil **17** to fork **11** result in regenerative oscillations for the fork at frequency F_1 so that stable oscillation as indicated by FIGURE 5 are quickly derived.

Activating the switch so that contacts **34** and **35** engage fixed contacts **37** and **38**, respectively, while contacts **39** and **40** alight on contacts **32** and **33**, respectively, changes the freqency at which fork **11** vibrates to frequency F_2. This is because coil **19** now serves as a driver while coil **17** is utilized as a pickup whereby a regenerative path is provided through amplifier **36** at frequency F_2. Oscillations of resonator **11** at frequency F_2, result in that frequency being supplied to the input of amplifier **36**. The F_2 signal deriving from amplifier **36** is coupled to coil **19** in phase with the signal applied to the amplifier. Since the oscillations applied to coil **19** are regenerative, fork **11** continues to oscillate at frequency F_2.

Any tendency for fork **11** to vibrate at frequency F_1 is degenerate with the switch reversely connected from the manner illustrated, and vice versa. Degeneration occurs because of the reversed phase with which the F_1 and F_2 signals are applied to coils **17** and **19** for the reversed and illustrated switch positions. An inspection of FIGURE 5 indicates that frequency oscillations at frequency F_1 as picked up in coil **17** are reversed in phase relative to those of frequency F_2. When the fork is vibrating in the fork mode, leg **14** is closest to coil **17** when the free end of tine **12** is the farthest from coil **19**. In contrast, an inspection of FIGURE 6 shows that tine **12** is closest to both coils **17** and **19** during the same portion of an oscillating cycle. Thus, the network of FIGURE 1 can regeneratively oscillate at only one frequency, F_1 or F_2, at a time, and the other frequency is degeneratively fed back to preclude oscillation.

While the illustrated connection is most advantageous because it requires a minimum of pickups, a dual frequency oscillator can also be provided if coil **17** is a driver for both modes. In such an event. an additional pickup coil is provided in proximity to leg **14**. To establish F_1 or F_2 oscillations, coil **19** and the additional coil are selectively connected to the amplifier input and its output is always connected to driver coil **17**.

Reference is now made to FIGURE 2 of the drawings, a modification of the present invention, wherein an indication is provided as to whether variable frequency source **43** is of frequency F_1 or F_2. Source **43** is coupled to driver coil **17** to cause oscillation of fork **11** in the reed or fork modes, at frequencies F_2 and F_1, respectively. Mounted in proximity to leg **14**, on tine **13**, is contact pad **44** for selectively engaging fixed contact **45**, that is mounted by insulating assembly **46** on housing **47**. Similarly, contact pad **48** is mounted at the free end of tine **12** remote from leg **14** to engage selectively fixed contact **49** that is carried on housing **47** by insulating assembly **50**. Fork **11** is grounded to metallic container **47** so that circuits can be established through the fork to contacts **45** and **49**. Because of the higher Q of resonator **11** in the fork mode of vibration than in the reed mode, contact **49** is more distantly positioned from pad **48** than is contact **45** from pad **44**.

To provide an indication as to whether source **43** is at frequency F_1 or F_2, contacts **45** and **49** are connected through separate indicating networks comprising batteries or DC sources **52** and **53**, each of which is separately connected in series with indicator lamps **54** and **55**. The activation paths for lamps **54** and **55** are completed by the connections to ground so that visual indications are derived when source **43** is at frequency F_1 or F_2.

In response to source **43** being of frequency F_1, resonator **11** vibrates in the fork mode and contact is made between contacts **48** and **49** at frequency F_1. The motion of the end of fork **11** where tines **12** and **13** are joined by leg **14** is insufficient, however, to provide engagement between contacts **44** and **45**. Thereby, lamp **55** is activated to the exclusion of lamp **54** when fork **11** is driven at frequency F_1. Similarly, but in an opposite manner, a frequency F_2 deriving from source **43** results in resonator **11** vibrating in the reed mode whereby substantial movement of contact **48** does not occur, but engagement between contacts **44** and **45** occurs at frequency F_2. Thus, lamp **54** is energized to the exclusion of lamp **55** in response to source **43** being of frequency F_2.

Reference is now made to FIGURE 3 of the drawings wherein a variable frequency source **57** is coupled through electromechanical resonator **11** to load **58** at frequencies F_1 and F_2. At frequency F_1, tuning fork **11** is vibrated in the fork mode and oscillations from source **57** are coupled directly to load **58** through coil **19** with a predetermined polarity and phase relative to the phase of the source **57**. At frequency F_2, resonator **11** is caused to vibrate in the reed mode, which vibrations are detected by auxiliary pickup coil **59**, positioned to be responsive to movement of tine **13** in proximity to leg **14**.

Coil **59** is wound so that the relative phase of the signal it picks up is the same as the signal picked up by coil **19** relative to source **57**. Thus, if the signal deriving from coil **19** is positive when source **57** is positive, the signal derived from coil **59** is positive at the same time as when source **57** is positive. Because no phase inversion occurs in the filter between frequencies F_1 and F_2, the configuration of FIGURE 3 can be employed in phase detecting applications.

A further feature of filter construction according to FIGURE 3 is that the responses of the filter at both frequencies F_1 and F_2 can be adjusted to be substantially con-

stant, despite the disparity of the Q for the reed and fork modes of vibration. This is accomplished by adjusting the number of turns in pickup coil **59** to be considerably greater than the number of turns in coil **19** so that the voltages generated across both coils are approximately equal in response to signals of frequency F_1 and F_2 being of the same amplitude.

Of course, in utilizing the tuning fork of the present invention as a filter, adequate shielding must be provided between coils **17**, **19** and **59** to prevent magnetic coupling between them through other than tuning fork **11**. If shielding is not provided, there will frequently be sufficient electromagnetic coupling between the various coils to bypass the effect of the electromechanical resonator. Sufficient shielding, for many purposes, can be obtained by enclosing each of coils **17**, **19** and **59** and their associated bar magnets in cylindrical magnetic shields made of Mu metal, wherein the shields have their end pieces removed. In the alternative, for many purposes, a shield can be placed around only coil **17** and its bar magnet.

A further modification of the present invention is illustrated in FIGURE 4 wherein the input power necessary to drive tuning fork **11** is reduced by encircling both tines **12** and **13** about drive coil **61**. Coil **61** is wound about tines **12** and **13** towards their end where leg **14** is located so that engagement can be made between contacts **44** and **45** as well as between contacts **48** and **49**. DC permanent magnet bias is provided in the configuration of FIGURE 4 by fixedly mounting bar magnets **62** on housing **16** to which tine **13** is anchored. Bar magnet **62** can be provided with a bolt at its end so that it can serve as a magnetic bias for the fork as well as means for securing fork **11** in situ.

In response to a signal at frequency F_1 or F_2 applied to drive coil **61**, fork **11** of FIGURE 4 oscillates in the fork or reed mode of vibration, respectively, to establish an electric circuit between either one of contacts **44**, **45** or contacts **48**, **49**. To provide maximum efficiency in the fork of FIGURE 4, coil **61** should be positioned between point **26**, FIGURE 5, and leg **14**. Thereby, opposing forces are not established in tine **12** on either side of point **26** by the magnetic force from coil **61** when resonator **11** vibrates in the fork mode.

While I have described and illustrated one specific embodiment of my invention, it will be clear that variation of the details of construction which are specifically illustrated and described may be resorted to without departing from the true spirit and scope of the invention as defined in the appended claims. For example, the efficiency of coupling energy into the tuning fork assembly of the present invention can be increased if a horseshoe magnet is substituted for bar magnet **18** in the embodiment of FIGURE 2. Such a bar magnet would have its north pole as illustrated in the FIGURE and its south pole in proximity to contact pad **48**.

I claim:

1. A relay for deriving an output in response to two different predetermined frequencies F_1 and F_2 of an input signal comprising a tuning fork resonator adapted to vibrate in the tuning fork mode at frequency F_1 and in the reed mode at frequency F_2, said tuning fork including electric contact surface means, means responsive to said input signal for vibrating said tuning fork in the fork and reed modes at frequencies F_1 and F_2, respectively, and contact means for engaging said contact surface means when said fork is vibrated in each of said modes.

2. The relay of claim **1** wherein said tuning fork includes a pair of tines and a leg joining them together, and means for anchoring one of said tines while the other tine and said leg are free to vibrate.

3. The relay of claim **2** wherein said contact means includes first and second fixed contacts and said contact surface means are first and second separate areas on the tuning fork, said first area being proximate the end of the tine free to vibrate, said second area being proximate the leg on one of said tines, said first contact being positioned to engage said first area only when the fork is vibrated in the fork mode, said second contact being positioned to engage said second area only when the fork is vibrated in the reed mode.

4. An oscillator for deriving a pair of predetermined different frequencies F_1 and F_2 comprising a tuning fork resonator adapted to vibrate in the tuning fork mode at frequency F_1 and in the reed mode at frequency F_2, first velocity-position transducer means for detecting fork vibrations in the fork mode, second velocity-position transducer means for detecting fork vibrations in the reed mode, an amplifier having an input and an output, means for selectively coupling said first and second transducer means to said input and output, said first transducer means being coupled to said input when said second transducer is coupled to said output so said fork regeneratively vibrates in the reed mode, said second transducer means being coupled to said input when said first transducer means is coupled to said output so said fork regeneratively vibrates in the fork mode.

5. The oscillator of claim **4** wherein said tuning fork includes a pair of tines and a leg joining them together, and means for anchoring one of said tines while the other tine and said leg are free to vibrate.

6. The oscillator of claim **5** wherein said first transducer is positioned to be responsive to vibrations at the end of the tine free to vibrate, and said second transducer means is positioned to be responsive to vibrations of said leg.

7. An oscillator for deriving a pair of predetermined different frequencies F_1 and F_2 comprising a tuning fork resonator adapted to vibrate in the tuning fork mode at frequency F_1 and in the reed mode at frequency F_2, signal-velocity transducer means for vibrating said tuning fork in said modes, first and second signal-velocity transducer means for detecting vibrations in the fork and reed modes, respectively, an amplifier having an input and output, and means for coupling said transducer means with the input and output of said amplifier so said fork vibrates regeneratively in one or the other of said modes.

8. The oscillator of claim **7** wherein said vibrating transducer means selectively coincides with one of said detecting transducer means.

9. A filter for selectively passing frequencies F_1 and F_2 from a variable frequency source to a load comprising a tuning fork resonator adapted to vibrate in the tuning fork mode at a frequency F_1 and in the reed mode at frequency F_2, signal-velocity transducer means responsive to said source for vibrating said tuning fork in both of said modes, first and second signal-velocity transducer means for detecting vibrations in the fork and reed modes, respectively, and means for connecting both of said detecting transducer means across said load.

10. The filter of claim **9** wherein both of said detecting transducer means are connected to said load to provide the same relative phase and gain relations between the load and source voltages for both modes of tuning fork vibrations.

11. The filter of claim **9** wherein said tuning fork includes a pair of tines and a leg joining them together, and means for anchoring one of said tines while the other tine and said leg are free to vibrate.

12. The filter of claim **11** wherein said first transducer is positioned to be responsive to vibrations at the free end of the tine free to vibrate, and said second transducer means is positioned to be responsive to vibrations of said leg,

13. The filter of claim **12** wherein both of said detecting transducer means are connected to said load to provide the same relative phase and amplitude relations between the load and source voltage for both modes of tuning fork vibrations.

14. An electromechanical resonator comprising a tuning fork having a U-shaped configuration in which normally parallel tines are connected by a bridging portion, means supporting said fork only along one of said tines to permit freedom of vibration of said one tine along its unrestricted length and of the other tine and said bridging portion along their entire lengths, means for driving said fork in either of the tuning fork and reed modes of vibration, and separate and distinct detecting means for sensing the vibrations of said fork in the respective vibrational modes.

15. The invention according to claim 14 wherein said separate and distinct detecting means include means positioned adjacent the free end of said other tine for sensing the vibrations in the tuning fork mode, and means positioned adjacent said bridging portion for sensing the vibrations in the reed mode.

16. The invention according to claim 15 wherein said driving means includes at least part of one of said means for sensing.

17. The invention according to claim 14 wherein said tuning fork is composed of magnetically permeable sheet metal.

18. The invention according to claim 17 wherein said one tine is longer than said other tine, and said supporting means includes means anchoring said one tine at the segment thereof extending beyond the end of said other tine.

19. The invention according to claim 18 wherein each of said detecting means includes an electrical coil and a magnetic core extending therethrough, one of said detecting means responsive to vibrations at the free end of said other tine, and the other of said detecting means responsive to vibrations of said bridging portion, said magnetic cores providing a D-C magnetic bias for low path reluctance through at least a portion of said fork.

20. The invention according to claim 19 wherein said driving means includes at least the coil of one of said detecting means.

21. The invention according to claim 19 wherein said driving means comprises a variable frequency signal generator for supplying an output signal at either the natural frequency of said tuning fork vibrational mode or the natural frequency of said reed vibrational mode, and an electrical coil coupled to said generator and adjacent said fork between said free end of said other tine and said bridging portion.

22. The invention according to claim 14 wherein said fork is magnetically permeable and each of said detecting means comprises an electromagnetic pickup coil, one said coil responsive to vibrations at the free end of said other tine and another said coil responsive to vibrations of said bridging portion.

23. The invention according to claim 14 wherein each of said detecting means comprises an electrical contact for contacting a respective electrical contact on said fork only when the fork is driven in a respective one of said modes.

24. An electromechanical resonator including a tuning fork, said fork mounted only along one of its tines to permit freedom of movement thereof along the remainder of that tine, the remaining tine, and the bridge connecting the two tines; means for vibrating the fork at disparate frequencies corresponding to the natural frequencies of the tuning fork mode and the reed mode; means adjacent a segment of said fork vibrational in the tuning fork mode for detecting substantial movement of said fork in that mode; and means adjacent a segment of said fork vibrational in the reed mode for detecting substantial movement of said fork in that mode.

25. The invention according to claim 24 wherein said fork is composed of magnetically permeable material, and wherein each of said detecting means comprises an electromagnetic detector for generating a voltage proportional to the varying magnetic field accompanying vibrations of said fork.

26. The invention according to claim 25 wherein said vibrating means comprises an oscillator and means for electromagnetically coupling the output oscillations of said oscillator to said tuning fork.

27. The invention according to claim 26 wherein said coupling means comprises at least a portion of one of said electromagnetic detector means.

28. The invention according to claim 26 wherein is further provided means for reducing the reluctance of the magnetic path between said vibrating means and each of said detecting means.

29. An electromechanical resonator comprising a tuning fork having a pair of normally parallel tines joined by a bridging member, means for vibrating one of said tines and said bridging member over their entire lengths and the other of said tines over only a portion of its length, relative to a fixed point on the fork, and means separately responsive to vibrations of said fork in the tuning fork and reed modes for detecting the respective frequencies of said vibrations.

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