June 11, 1957 A. H. MACISZEWSKI ET AL 2,795,672

FREQUENCY SELECTIVE VIBRATING REED RELAY

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Fig. 1.

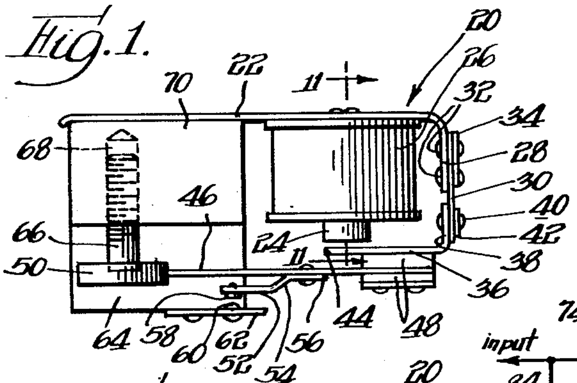


Fig. 2.

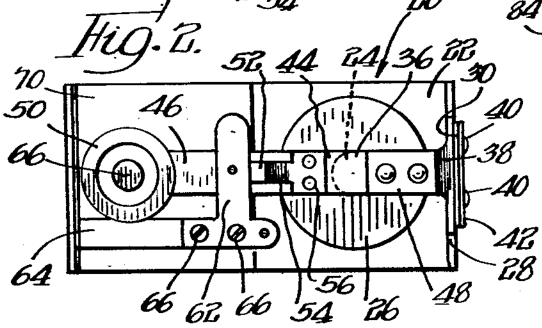


Fig. 3.

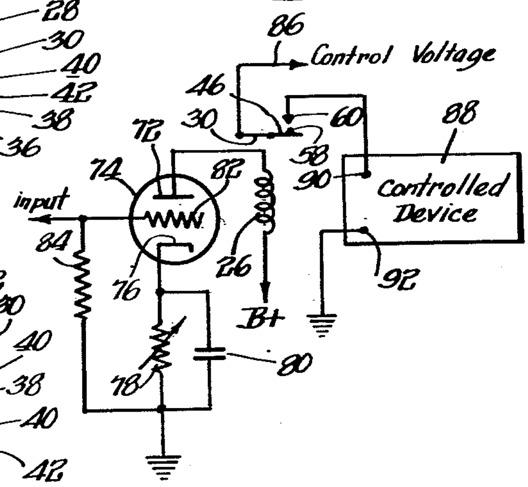


Fig. 4.

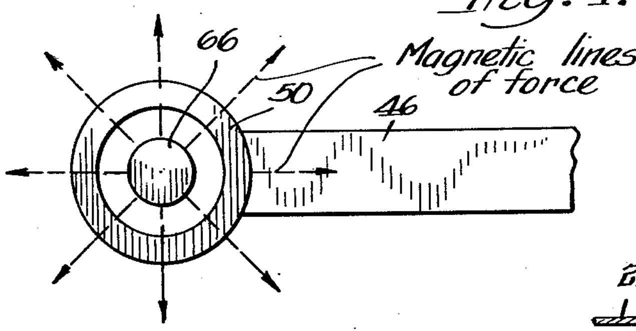


Fig. 11.

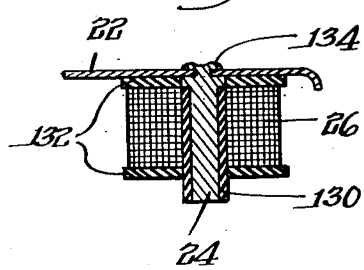
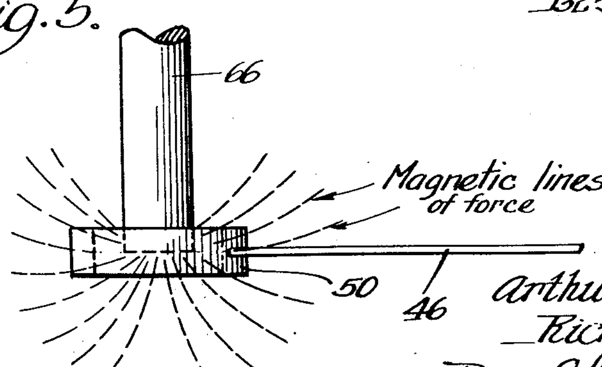


Fig. 5.



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FREQUENCY SELECTIVE VIBRATING REED RELAY

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Fig. 6.

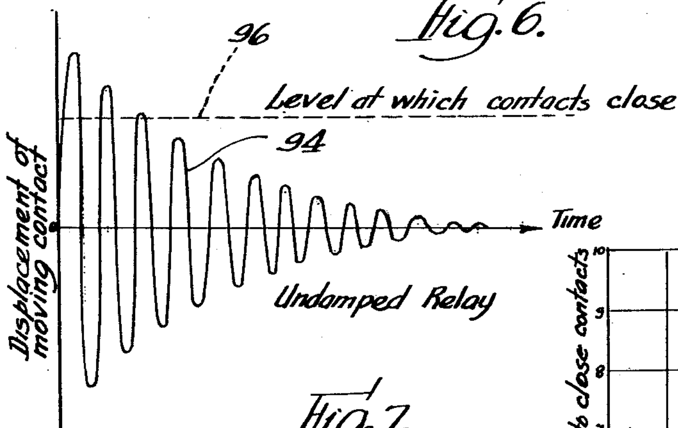


Fig. 7.

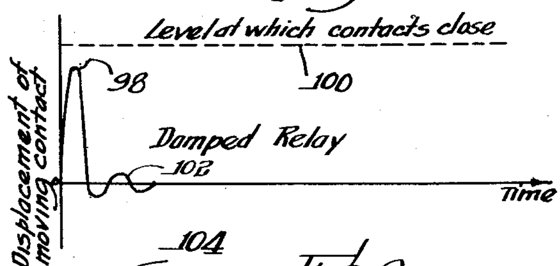


Fig. 8.

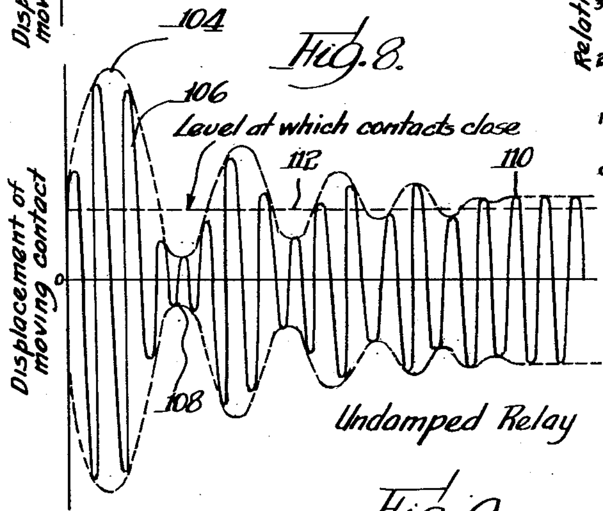


Fig. 10.

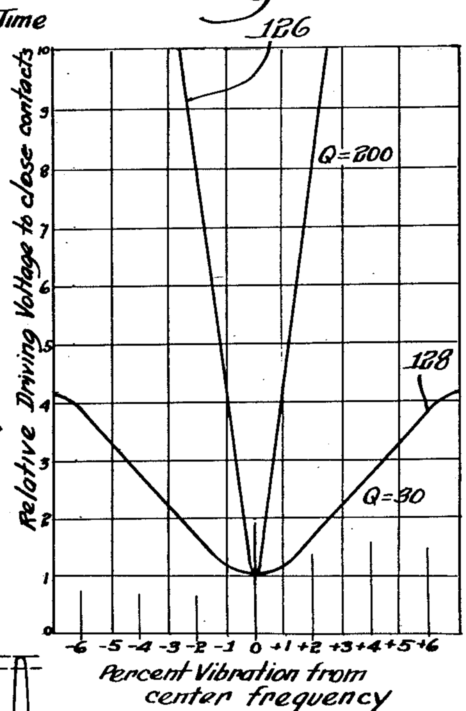
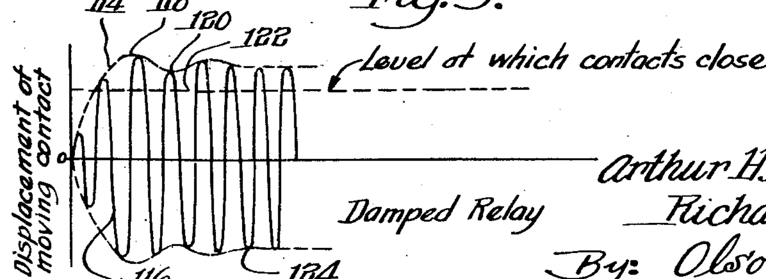


Fig. 9.



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FREQUENCY SELECTIVE VIBRATING REED RELAY

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Application August 10, 1953, Serial No. 373,346

12 Claims. (Cl. 200—91)

This invention is concerned generally with a resonant or frequency selective vibrating reed relay, and more particularly with a damped relay of this character.

Resonant or frequency selective vibrating reed relays often are used in remote control apparatus, such as garage door openers, for controlling the operation of an apparatus or device in accordance with a signal generated at a remote location.

Resonant or frequency selective vibrating reed relays utilize a vibrating reed usually of metallic construction, having a predetermined fixed frequency of vibration. When such a reed is excited, generally magnetically, by a wave corresponding in frequency to the natural period of vibration of the reed, the reed vibrates. Suitable contacts are arranged for intermittent closing by the vibrating reed, and the intermittently closed contacts are utilized to control a further apparatus or device such as a conventional relay or a vacuum tube. Simple, undamped, resonant or frequency selective vibrating relays are subject to certain drawbacks.

In operating garage door openers and other types of apparatus, resonant relays are remotely controlled by radio or magnetic waves. Random impulses due to atmospheric discharges or man-made electrical "noise" frequently cause false tripping of such relays. The transient response of such relays is generally poor. Furthermore, the actuating wave has to be held to very close limits in order properly to actuate a simple resonant relay. This calls for relatively complicated and expensive signaling devices.

It is an object of this invention to provide a resonant relay or frequency selective vibrating reed relay which is relatively insensitive to random impulses.

Another object of this invention is to provide a resonant relay having superior transient response.

A further object of this invention is to provide a resonant relay of increased band width, i. e. a resonant relay that is responsive to signals varying from the selected frequency by a greater percentage than has been possible heretofore.

This invention contemplates achieving the above and other objects by providing an improved damped resonant relay.

Damping of various devices for diverse purposes has been accomplished heretofore. Viscous damping frequently is resorted to. In this type of damping the moving member is immersed in a fluid, usually oil. The retarding force of the fluid is proportional to the velocity of the moving body and linear mechanical resistance is established. Linear resistance is necessary for proper control of the mechanical application factor or "Q" of a vibrating system. Energy is imparted to the fluid with each cycle of vibration, and appears as heat generated by the internal frictional forces of the fluid. This change in temperature varies the viscosity of the fluid if the vibrations are continued for any substantial length of time, and leads to wide variations in performance. This renders viscous damping highly undesirable for a

resonant reed, and the necessary physical structure for viscous damping is obviously impractical for a resonant reed relay.

Vibration damping also is often achieved by means of a "dash-pot" consisting essentially of a cylinder and piston, one of which is fixed and the other of which is attached to the moving body. One or the other of the cylinder and piston is usually provided with an opening, which may be adjustable, to allow air or some other gas to escape at a controlled rate. The damping due to air passage to and from the cylinder is proportional to velocity and produces a linear mechanical resistance. Dash-pots lack uniformity in operation unless they are held to extremely close and expensive manufacturing tolerances. Furthermore, there are rather great frictional forces associated with the piston and cylinder, and these frictional forces generally are larger than the damping force required with a resonant relay. Such frictional forces do not represent linear mechanical resistance and would cause extremely erratic performance of a resonant relay.

The most commonly used means or method employed in vibration damping devices lies in the use of rubber. As rubber is compressed and allowed to expand, it goes through a mechanical hysteresis curve, the area of which represents the energy per cycle required to travel the curve. The degree of damping cannot be controlled very closely with rubber, and such vibration dampers are used whenever the actual degree of damping is not very important as long as sufficient damping is achieved. The degree of damping cannot be controlled anywhere near closely enough for use in a resonant relay. Additionally, the characteristics of rubber change with temperature (and the energy required to travel the hysteresis curve is converted into heat in the rubber) and rubber deteriorates with time to such an extent as to make the use of rubber inacceptable in a precision device.

It is an object of this invention to provide a new or improved damped resonant relay. More specifically, it is an object of this invention to provide an electromagnetically damped resonant relay.

Other and further objects and advantages of the present invention will be apparent from the following description when taken in connection with the accompanying drawings wherein:

Fig. 1 is a side view of a resonant or frequency selective vibrating reed relay constructed in accordance with the principles of the invention;

Fig. 2 is a bottom plan view of the relay;

Fig. 3 is a schematic diagram illustrating an application of the relay;

Fig. 4 is a bottom view illustrating the magnetic damping action;

Fig. 5 is a side view illustrating the same;

Fig. 6 illustrates the D. C. transient characteristics of an undamped relay;

Fig. 7 illustrates the D. C. transient characteristics of the damped relay disclosed herein;

Fig. 8 illustrates the A. C. transient characteristics of an undamped relay;

Fig. 9 illustrates the A. C. transient characteristics of the damped relay disclosed herein;

Fig. 10 illustrates the "Q" or mechanical amplification factor of an undamped resonant relay and of the damped relay disclosed herein; and

Fig. 11 is a sectional view through the magnet core and winding showing the means for preventing operation at harmonic frequencies or higher mode resonances.

Referring now in greater particularity to the drawings, wherein like numerals are used to identify similar parts throughout, there may be seen in Figs. 1 and 2 a relay **20** constructed in accordance with the principles of the invention. The specific illustrative relay constructed in accordance with the principles of this invention is capable of responding to a predetermined sub-audio frequency signal in the range of 10 to 32 C. P. S., although the principles are applicable to frequency selective relays operable at other frequencies. Ten separate channels or frequency bands are available in the 10 to 32 C. P. S. range, and a relay adjusted to one of the channels will not respond to signals in any other channels nor to signals of any other frequency whatsoever.

The relay **20** includes a frame **22** supporting a pole piece **24** on which is placed the actuating coil **26**. The frame **22** is provided with a right angularly disposed end or flange **28** to which is secured a spring hinge **30** by means such as rivets **32** and back up plate **34**. An armature **36** is provided with a right angularly disposed end or flange **38** which is secured to the spring **30** by means such as rivets **40** and a back up plate **42**. The free end **44** of the armature is aligned with and spaced from the pole piece **24** for magnetic attraction and repulsion thereby, it being understood that the pole piece, armature, frame, and spring hinge all are constructed of magnetic material.

A flat primary spring reed **46** is carried by the armature **36** and is electrically insulated therefrom by insulating spacers **48**. A ring **50** is affixed to the outer end of the spring **46**, and the mass of the ring is determined in accordance with the compliance of the primary spring reed **46** to obtain the desired frequency of mechanical resonance.

A secondary flat spring reed **52** having an offset at **54** is secured to the primary reed intermediate the ends thereof as at **56** and carries a contact **58** of suitable electrically conducting material which is not readily damaged by frequent opening and closing of contacts. A second contact **60** is carried by a flat spring **62** in opposition to the first contact for contacting engagement therewith. The spring **62** is substantially T-shaped and the cross bar or arm of the T is supported by means such as an insulating block **64** mounted on the frame **22**. The spring **62** is adjustable for proper positioning of the contact **60**, and such adjustment may be effected by mounting the spring by means such as screws **66** threaded into the block **64** and passing through slots or over-sized holes in the spring **62**. It will be understood that a pair of opposed fixed contacts could be provided for alternate engagement by the movable contact, although this is not illustrated.

A bar magnet **66** is supported concentrically with the ring **50** and is axially adjustable so that it may project into the ring a predetermined distance. By way of example, the bar magnet preferably is cylindrical in configuration and may be threaded into a suitable tapped bore **68** in an insulating block **70** carried by the frame **22**. The block **70** may be, and preferably is, integral with the aforementioned block **64**.

An illustrative means for operating the relay is shown in Fig. 3. The relay coil **26** is connected at one end to a source of B+ voltage, and is connected at the other end to the plate **72** of an electron tube **74** which is illustrated simply as a vacuum triode, although it will be understood that other types of tubes or electronic valves could be used. The cathode **76** is shown as grounded through a resistor **78** and parallel capacitor **80**. The grid **82** is shown as being grounded through a conventional grid resistor **84**. The normal conduction of the tube **74** and hence the biasing current applied to the relay coil **26** is adjusted by any suitable means, for instance by providing an adjustable resistor in the cathode circuit of the tube. The biasing current is adjusted so as to pull the reed **46** and the contact **58** carried thereby toward the pole **24** and away from the contact **60**, deflecting the spring hinge **30** in so doing. The reed **46** and the contacts and connections have been shown somewhat simplified in Fig. 3 for illustrative purposes. It will be seen that a suitable control voltage is applied at **86** to the movable contact **58** and that the fixed contact **60** is connected to a controlled device **88** as at **90**, said device being grounded or otherwise connected to a return line as at **92**.

The actuating signal for the resonant relay is suitably applied to the grid **82** of the tube **74** as indicated at "Input," and this signal causes the potential applied to the coil **26** to vary in magnitude above and below the average value as established by the biasing current. This causes the reed to move toward and from the pole piece **24**, and hence causes the contacts **58** and **60** to close intermittently. Of course, if the input signal is not of substantially the frequency of resonance of the reed **46** and weight **50**, the reed will remain quiescent and the contacts will remain open.

Intermittent closing of the contacts causes the control voltage to be applied to the control device **88** and thereby to effect the desired operation. Important advantages are obtained by the mounting of the movable contact **58** on the second flexible reed **54**. The contacts can close before the primary reed **46** reaches its maximum swing, and the secondary reed **54** thereafter flexes to maintain the contacts in engagement. This increases the "duty cycle" or total time during a complete cycle that the contacts are closed. Furthermore, it reduces the physical reaction of the suddenly closed contacts back on the resonant system, thus avoiding an appreciable change in resonant frequency during the portion of the cycle that the contacts are closed. This tends to minimize "hunting" action and other erratic behavior of the relay.

As earlier noted, simple vibrating reed relays have a high "Q" or amplification factor, and consequently have relatively narrow band widths in which they will respond. Simple resonant reeds are easily constructed having "Q's" of several hundred, but cannot be constructed to have low "Q's" when of suitable size for resonant relays. A low "Q" is attained according to the principles of this invention by means of the magnet **66** and ring **50**.

The reed **46** is constructed of non-magnetic material such as beryllium copper. In a specific example constructed in accordance with the principles of this invention, the reed is 5⁄16" wide, 1¼" long and .008 inch thick. The ring **50** is constructed of pure copper and in the specific embodiment has an outside diameter of ⅝" and a hole diameter of 7⁄16". The ring is replaceable and has a thickness which varies in discrete steps from one ring to another to determine the operating or resonant frequency of the ring and reed. This frequency may be 10, 11, 13, 15, 17, 19, etc. cycles per second. The magnet **66** is a permanent magnet, and in the specific example is constructed of Alnico V and is ¼" in diameter and 1" long. The magnet **66** normally is positioned as shown in Fig. 5 so that the end of the magnet projects approximately half way through the ring. The flux lines associated with the bar magnet thus cross the body of the ring in a direction outward from the center of the ring as shown in Figs. 4 and 5. As the ring is displaced by vibration of the reed **46**, the ring cuts the lines of flux at all points on the periphery of the ring. A voltage thus is induced in the ring, and this voltage (E) is proportional to the velocity (v) of the ring, the flux density (B) of the field, and the mean circumference of the ring (l). Expressed mathematically, $E=Bvl$. Since the ring is made of copper, it comprises a closed electrical circuit of very low resistance. The small voltage induced thus causes appreciable current to flow around the ring. The direction of the current, by Lenz's law, is such that the magnetic field it produces is of opposite polarity to the field which causes it. The action of these opposing fields exerts a restraining force upon the moving ring. Since the flux density produced by the magnet, and the circumference of the ring are constant, the velocity of the ring is the only variable. The restraining force is therefore proportional to the velocity and is thus a linear mechanical resistance. The energy loss is converted to heat dissipated in the resistance of the ring, and the power so dissipated is so minute, being on the order of several hundred millionths of a watt, that no significant temperature rise of the ring can be detected. This extremely low order of magnitude illustrates the impracticability of damping a resonant reed relay by conventional damping means. The degree of damping required can be set by adjusting the amount of projection of the magnet rod **66** through the ring **50**. Withdrawing the magnet (i. e. threading it further into the bore **68**) reduces the damping. When the magnet is withdrawn to the point where the ring no longer intersects any of the magnetic lines of force, the vibrating system is undamped.

The electromagnetically damped resonant relay disclosed herein is substantially insensitive to random impulses. The response of a simple undamped relay to a random impulse is shown in Fig. 6. A sudden D. C. pulse applied to the relay, which is to be expected in radio remote control systems from atmospheric discharges or man-made noise, causes the reed to be displaced a substantial distance. The reed then vibrates due to its own inertia, and this vibration takes a substantial time to decay as illustrated by the curve **94** in Fig. 6. During part of this vibrating period, the amount of displacement is equal to or greater than the amount needed for the contacts to close, as indicated by the dashed line **96**. Accordingly, spurious operation will be effected.

As shown in Fig. 7, the maximum amplitude of vibration as indicated at **98** is less than the level at which the contacts close, the latter being indicated by the dashed line **100**, and the vibrations die out very quickly as illustrated by the curve **102**. Thus, the contacts of the damped relay disclosed herein do not close in response to random impulses, and there is no spurious operation.

When a transient voltage of the proper frequency is applied to an undamped resonant relay, the undamped reed suddenly swings to a maximum displacement as indicated at **104** (Fig. 8) of the envelope of the curve **106**, representing the vibration of the reed. This large swing is followed by a minimum displacement swing as indicated at **108**, and it is not until some time is passed as indicated at **110** before the reed settles down to a steady state of resonant vibration. The dashed line **112** indicates the vibration amplitude necessary for the closing of the contacts, and it will be apparent that the contacts will close only intermittently until the steady state of operation is reached at **110**. This is a most objectionable feature as it is likely to bring about improper operation of the controlled device. Furthermore, if the applied signal is of sufficiently short duration, the desired control action may not be effected. Correction cannot be made by increasing the driving voltage or reducing the spacing of the contacts as this would render the relay more likely to be tripped by noise pulses.

On the other hand, the vibrating reed of the damped relay herein disclosed increases in amplitude of vibration relatively slowly as illustrated by the envelope **114** (Fig. 9) of the vibration curve **116**. Following the first maximum amplitude of vibration as indicated at **118**, the minimum amplitude as shown at **120** still lies above the line **122** illustrating the level of amplitude at which the contacts close. Steady state operation is quickly reached as illustrated at **124**.

As heretofore noted, simple resonant reed relays have a high "Q" and relatively narrow band width. In Fig. 10 the curve **126** illustrates the "Q" of a simple resonant reed relay, the "Q" illustrated having a typical value of 200. With the electromagnetically damped relay herein disclosed a "Q" of 30 or less readily can be obtained as illustrated at **128** in Fig. 10. If the receiving device has a "Q" of 200, it will respond to frequencies to within about ±.5% with a signal level of twice that required to operate at the center frequency, as can be ascertained from the curve of **126**. The signal level must be increased to 10 times that required to operate at center frequency in order to operate the relay at frequencies of ±3% from the center frequency. If the signal level were amplified to this extent, noise signals likewise would be amplified to this extent and the response of the undamped relay to the noise signals would be almost certain to cause spurious operation.

However, with the damped relay herein disclosed having a "Q" of 30 it may be seen that a band width of ±3% is present with signal levels only about twice that required for operation at the center of the band. Accordingly, limiting circuits can be used ahead of the relay to limit random noise pulses to a magnitude on the same order as that required for steady state operation of the relay at the center of the band. Consequently, the damped relay is the only means of achieving wide band width which also permits useful limiting of random noise pulses ahead of the relay. It will be understood that the wide band width allows an inexpensive signaling device to be used. A signaling device having a frequency tolerance of ±2% can be fabricated simply and economically, but a relatively complicated and expensive signaling device would be needed to hold the frequency tolerance to ±.5%.

Spurious operation of resonant relays can be caused by signals which are multiples or harmonics of the natural resonant frequency of the reed vibrating system. Such spurious operation is avoided in the relay disclosed herein as shown in Fig. 11. The soft iron pole piece **24** is surrounded by a cylindrical copper sleeve **130** on which the coil **26** is wound. The coil is held in place according to conventional practice by insulating spool ends **132**, and the pole piece **24** is secured to the frame **22** by peening the end of the pole piece as at **134**.

Response of the mechanically resonant system to multiple or harmonic frequencies is reduced by holding the mass of the reed and parts carried thereby to a minimum and by proper proportioning of the compliance between the primary reed and the spring hinge. The further provision of the copper sleeve **130** substantially eliminates all such response to the higher frequencies. The copper sleeve has a voltage induced in it as a result of a flux variation through the soft iron pole piece. The induced voltage causes a current to flow through the sleeve, and this current sets up an opposing magnetic flux reducing the total flux. The magnitude of the induced voltage and consequently of the opposing flux is a function of frequency, increasing with frequency as an exponential function. Thus, the forces acting on the vibrating reed system are substantially less at frequencies corresponding to the spurious modes of mechanical resonance than at the desired operational frequency. This results in a relay which is substantially free from response at higher frequencies than its intended operating band.

It now should be apparent that the electromagnetically damped resonant or frequency selective vibrating reed relay herein disclosed is substantially insensitive to random impulses, has a superior transient response, and has a relatively large band width. Additionally, response at multiple or harmonic frequencies is substantially eliminated. The contact duty cycle is increased and the reaction upon contact closure is minimized by the secondary reed carrying the moving contact.

The specific example herein shown and described will be understood as illustrative only. Various changes in structure may be made without departing from the spirit and scope of this invention as set forth in the ensuing claims.

The invention is hereby claimed as follows:

1. A resonant relay comprising a frame, a vibratile reed having a predetermined natural frequency of vibration and carried from said frame, said reed having a portion of magnetic material, electrical contacts respectively carried from said frame and from said reed, said contacts being alternately open and closed upon vibration of said reed, magnet means supported from said frame and including a coil adapted to establish an alternating magnetic

field at the same frequency as the predetermined natural frequency of vibration of said reed, magnetic damping means, and conductive damping means, said damping means being carried in proximity to and movable relative to one another, one from said frame and the other from said reed, electromagnetically to damp the vibrations of said reed.

2. A resonant relay as set forth in claim 1 wherein the conductive damping means comprises a continuous ring.

3. A resonant relay as set forth in claim 1 and further including means for relatively adjusting the positions of said magnetic damping means and of said conductive damping means to adjust the damping.

4. A resonant relay comprising a frame, a vibratile reed having a predetermined natural frequency of vibration and carried from said frame, said reed having a portion of magnetic material, electrical contacts respectively carried from said frame and from said reed, said contacts being alternately open and closed upon vibration of said reed, magnet means supported from said frame and including a coil adapted to establish an alternating magnetic field at the same frequency as the predetermined natural frequency of vibration of said reed, continuous ring damping means, magnetic damping means, means for supporting said damping means adjacent to and movable relative to one another in inductive relation, one from said reed and one from said frame, and means for adjusting the magnetic field of said magnetic means acting on said ring damping means to adjust the damping.

5. A resonant relay as set forth in claim 4 wherein the magnetic damping means comprises a permanent bar magnet carried from said frame, said ring damping means is carried from said reed in axial alignment with said bar magnet, and the means for adjusting the magnetic field acting on said ring damping means comprises means for adjusting said bar magnet relatively axially of said ring damping means.

6. A resonant reed relay comprising a frame having a base and an arm disposed at an angle thereto, a magnet pole mounted on said base, an actuating coil wound on said pole, a vibrating system including an armature of magnetic material, a flexible reed mounted on said armature, and a highly conductive closed ring carried at the end of said ring, said vibrating system having a predetermined natural frequency of vibration, a spring hinge mounting said vibrating system on the arm of said frame with said armature aligned with said magnet pole for vibration of said system when said coil is energized at said predetermined frequency, a bar magnet carried from said frame in axial alignment with said ring and proximate said ring for damping the vibrations of said system, and electrical contacts carried from said frame and from said vibrating system and alternately open and closed upon vibration of said system.

7. A resonant reed relay comprising a frame having a base and an arm disposed at an angle thereto, a magnet pole mounted on said base, an actuating coil wound on said pole, a vibrating system including an armature of magnetic material, a flexible reed mounted on said armature, and a highly conductive closed ring carried at the end of said reed, said vibrating system having a predetermined natural frequency of vibration, a spring hinge mounting said vibrating system on the arm of said frame with said armature aligned with said magnet pole for vibration of said system when said coil is energized at said predetermined frequency, a bar magnet carried from said frame in axial alignment with said ring and proximate said ring for damping the vibrations of said system, a flexible reed carried by said vibrating reed, a movable electrical contact carried by said flexible reed, a fixed electrical contact carried from said frame and engageable with said movable contact upon vibration of said vibrating system, and a highly conductive sleeve interposed between said magnet pole and said coil to induce a bucking magnetic field increasing with frequency to reduce the total magnetic field progressively with frequency and thereby substantially to eliminate response at higher modes of operation.

8. A resonant relay as set forth in claim 1, and further including a resilient member on the reed, the electrical contact carried from the reed being mounted on said resilient member.

9. A resonant relay as set forth in claim 1, wherein the magnet means further includes a magnet pole and a highly conductive sleeve encircling said pole, the coil being mounted about said sleeve and pole whereby the sleeve induces a bucking magnetic field increasing with frequency to reduce the total magnetic field with increasing frequency.

10. A resonant relay comprising a frame, a vibratile reed having a predetermined natural frequency of vibration and carried from said frame, said reed having a portion of magnetic material, electrical contacts respectively carried from said frame and from said reed, said contacts being alternately open and closed upon vibration of said reed, magnet means supported from said frame and including a coil adapted to establish an alternating magnetic field at the same frequency as the predetermined natural frequency of vibration of said reed, continuous ring damping means, magnetic damping means, and means for supporting said damping means adjacent to and movable relative to one another in inductive relation, one from said reed and one from said frame.

11. A resonant relay as set forth in claim 10 and further including a resilient member mounted on said reed, the electrical contact carried from said reed being mounted on said resilient member.

12. A resonant relay as set forth in claim 10 wherein the magnet means further includes a magnetic pole and a highly conductive sleeve thereon, said coil encircling said sleeve, said sleeve inducing a bucking magnetic field increasing with frequency to reduce the total magnetic field increasing with frequency.

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