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C. N. CHALLACOMBE ET AL

2,959,747

ELECTROMOTIVE VIBRATOR AND OSCILLATOR SYSTEMS

Filed Oct. 11, 1957

3 Sheets-Sheet 1

FIG. 1.

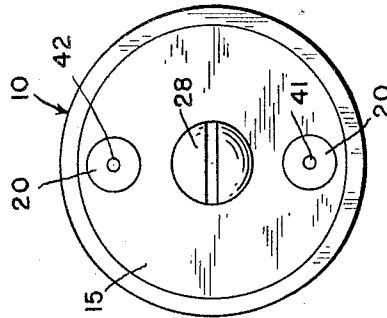
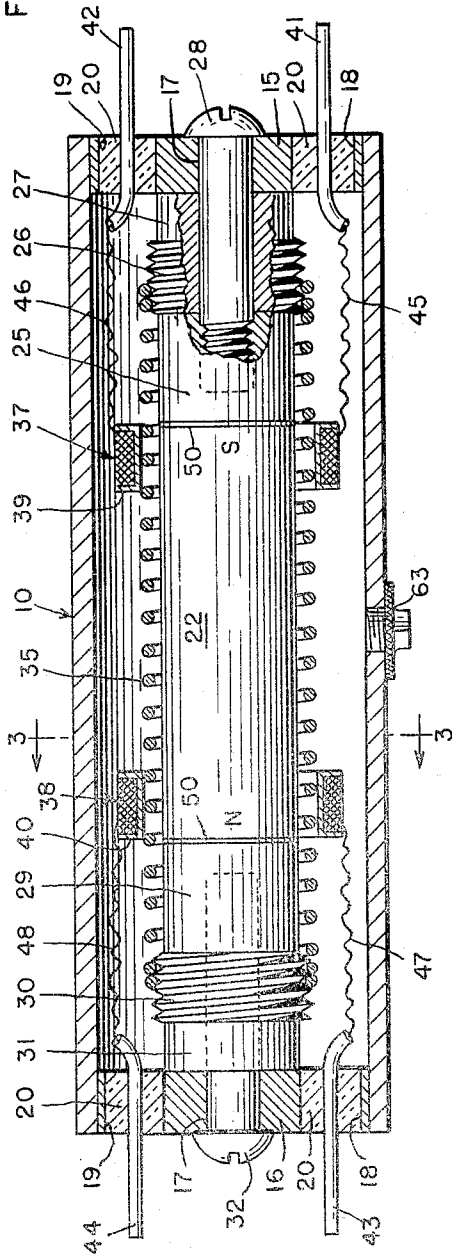


FIG. 4.

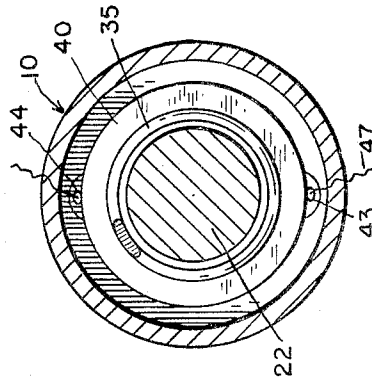
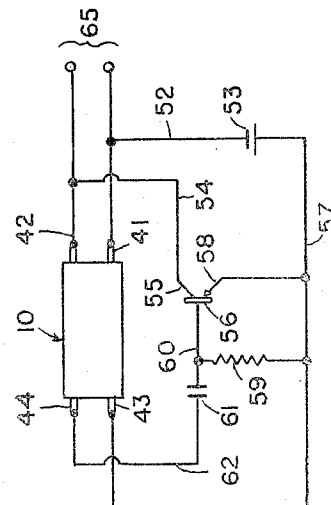


FIG. 3.

FIG. 2.



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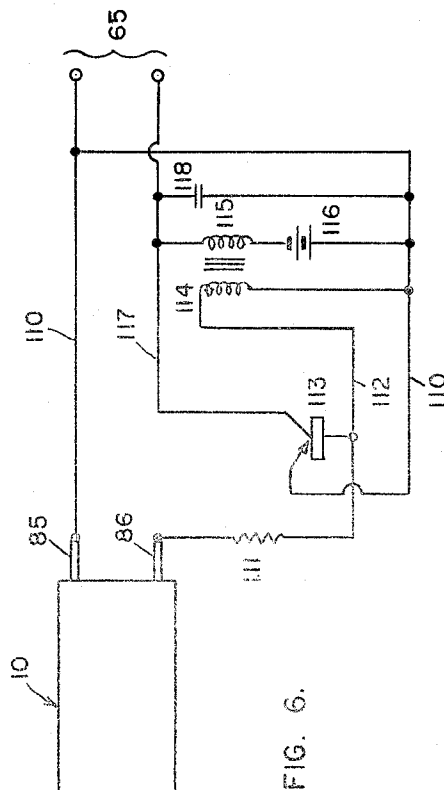
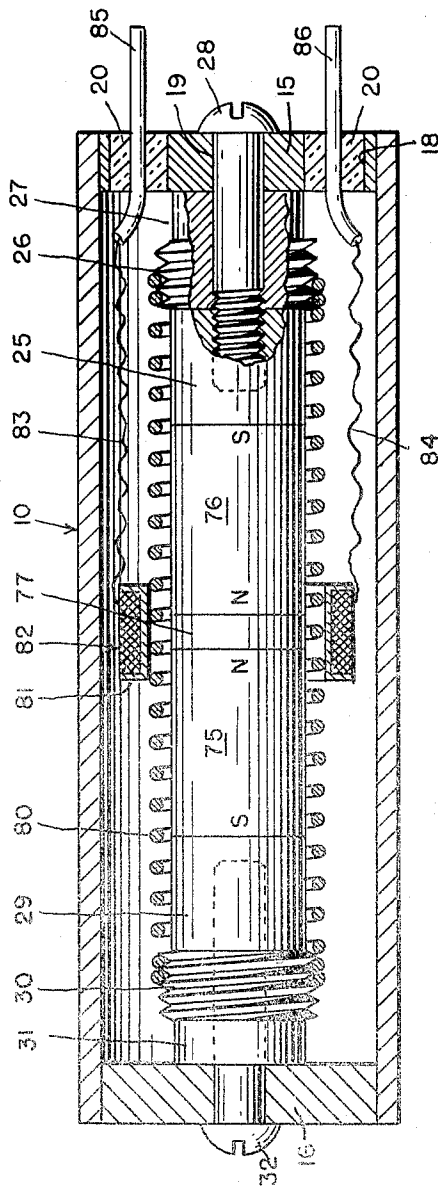
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3 Sheets-Sheet 2



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3 Sheets-Sheet 3

FIG. 8.

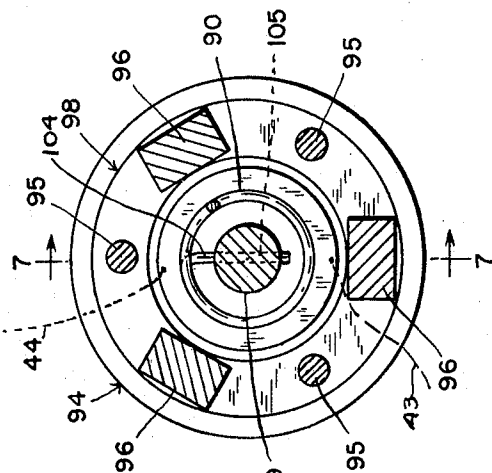
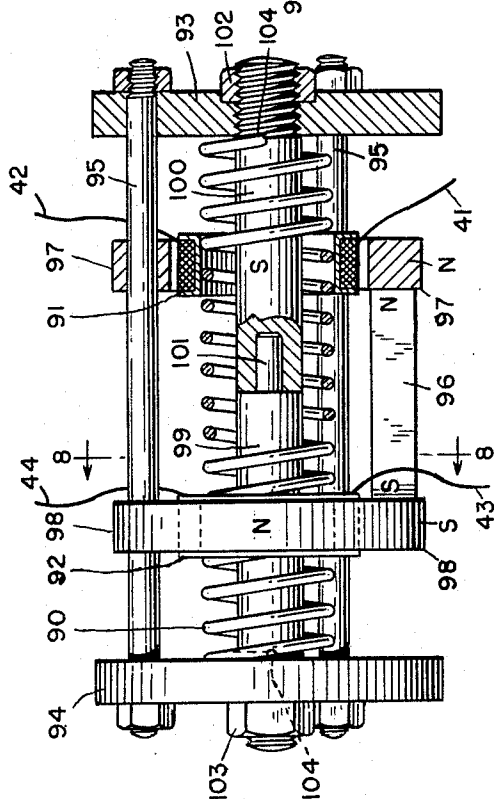


FIG. 7.



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ELECTROMOTIVE VIBRATOR AND OSCILLATOR SYSTEMS

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14 Claims. (Cl. 331-156)

This invention relates to an oscillator device and its mode of operation by which alternating electric currents may be generated. Such apparatus and methods are described and claimed in the copending application Ser. No. 500,771 of David E. Wiegand, filed April 12, 1955, now Patent No. 2,926,313; and reference is made thereto for the general principle of operation and the associated circuit arrangements.

An object of this invention is the provision of a structure and operation in which a helical spring mechanically vibrates in a magnetic field and supports a coil by which energy may be delivered to or taken from the spring, such energy being effective as a second magnetic component interactive with said magnetic field.

Another object is the provision of a structure and operation in which the mass of an electrical coil secured at an intermediate point of a helical spring forms therewith a mechanically vibrating system, and the coil itself permits electrical energy to be delivered to or taken from the system, wherein the spring moves in a magnetic field and the coil is effective for determining a second magnetic component interactive with said field.

Another feature of the invention is the provision of a structure and operation in which a helical spring of relatively movable or free turns acts as an elastic member, and one or more coils secured to the spring at antinodal points act as mass members, for providing a mechanically resonant system, together with means for producing a magnetic field directed radially from the axis of and in the same plane as the coil or coils and with conductors for delivering electrical energy to or taking electrical energy from the coil or coils.

Another object is the provision of a structure in which commercially available materials and parts are shaped and assembled to provide a rugged structure of a desirable small size.

A further feature is the provision of a structure in which a coil spring with relatively movable or free turns acts as an elastic member, and one or more electrical coils secured to the spring act as mass members movable in a magnetic field for providing a mechanically resonant system in association with circuit means for deriving an alternating current effect from the mechanically resonant movements and for applying an impulsing or maintaining current effect to movable parts.

A further object is the provision of a structure in which the mechanically moving helical spring supports a pair of coils insulated therefrom and movable therewith in a magnetic field, in association with circuit means for deriving an alternating current effect from one coil and for applying an impulsing or maintaining current effect to the other coil.

A further object is the provision of a vibrator and oscillator structure in which a mechanically moving helical spring supports a pair of coils with the coils coordinated in impedance with an external circuit whereby no special circuit devices are required for coordinating cir-

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cuit impedances, and the spring can be selected for its mechanical characteristics without regard to its electrical behavior.

With these and other objects as features in view, illustrative examples of structure and operation are shown on the accompanying drawings, in which:

Fig. 1 is a diametrical section through a structure according to this invention, with an associated circuit;

Fig. 2 is a circuit diagram of a form of electrical connections for the device of Fig. 1.

Fig. 3 is a transverse section on line 3-3 of Fig. 1;

Fig. 4 is an end elevation;

Fig. 5 is a diametrical section of another form of the device;

Fig. 6 is a circuit diagram for the device of Fig. 5;

Fig. 7 is a diametrical section of a third form of the device, with parts in section on line 7-7 of Fig. 8;

Fig. 8 is a section on line 8-8 of Fig. 7.

In the arrangement shown in Figs. 1 to 4, an outer cylindrical jacket 10 is made of a magnetizable material of low remanence (such as soft iron or the material available commercially under the name "Mu Metal"). Two plugs 15, 16 of material such as steel or brass are prepared for closely fitting in the ends of the jacket 10; each plug has a central hole 17 and diametrically opposed holes 18, 19 into which are fitted glass insulating beads 20.

A cylindrical piece 22 of permanently magnetizable metal (such as high carbon steel or the material available commercially under the name "ALNICO No. 2") is provided of a length slightly more than half the computed effective length of the spring to be used therewith. A first end support of non-magnetizable material (such as brass) has a cylindrical portion 25 at its inner end; a coarsely threaded portion 26 of greater external diameter; and a spacing portion 27 which can bear at its outer end face against the plug 15. A brass screw 28 has a cylindrical shank closely fitting the hole 17 in the plug 15 and a like coaxial bore in the pieces 27, 26, 25; and at its inner end is threadedly engaged with the latter piece. A second end support of like material has an inner cylindrical portion 29; a coarsely threaded portion 30 of greater external diameter; and a spacing portion 31; with internal screw threads in the portion 29. A brass screw 32 has a cylindrical shank closely fitting the hole 17 in the plug 16 and at its inner end is threadedly engaged with the portion 29. The end supports may be made identical and as single pieces, but it is preferred to make the support adjacent the plug 15 with the cylindrical portion 25 separate from the threaded portion 26; as this permits making the portion 26, 27 with a simple bore hole, and the portion 25 with an internally threaded bore hole, and securing portion 25 to the magnet 22 while leaving the piece 26, 27 to rotate on the shank of its screw.

A helical spring 35 is formed of a wire of material having strength and elasticity, and preferably having low thermal factors of change of elasticity and dimensions. In diameter, the spring fits in the grooves of the threaded portions 26, 30 and its ends are supported thereby, noting that the spacing or pitch of turns of the helical spring and the pitch of the threaded portions can be conformed during assembly. The internal diameter of the spring is greater than that of the magnet piece 22 so that the spring operates normally without engagement with the magnet piece or the portions 25, 29; and the external diameter of the spring is less than the internal diameter of the jacket 10 by an amount for receiving the electrical coils described hereinafter and permitting these coils to move freely within the jacket. The length of the spring 35 is determined roughly by the prescribed

frequency to be attained, noting that end turns are immobilized on the threaded portions 26, 30, and that a group or groups of intermediate turns are to be secured to the electrical coils and hence held against motion relative to other turns of the group. In practice, the lengths of the magnet 22 and of the cylindrical portions 25, 29 are correspondingly selected, so that the spring 35 while in service is under tension.

Two electrical coils 37, 38 are made, each being wound of insulated conductive wire into a supporting ring 39, or 40 having an internal diameter slightly less than the external diameter of the spring 35 when the latter is free, and having an external diameter less than that of the interior of the jacket 10, with the ring having an outward groove for receiving the wire. The wire is of appropriate size and an appropriate number of turns are provided, e.g. 500 to 1500, for providing an impedance, e.g. of 1000 ohms, of the correct value for circuit employment.

External leads 41, 42, 43, 44 are tightly fixed in the glass beads 20 and project at the faces of the plugs 15, 16. Flexible conductors 45, 46 extend from the ends of the coil 37 to the leads 41, 42 and are soldered to the latter. Flexible and extensible conductors 47, 48 extend from the ends of the coil 38 to the leads 43, 44 and are soldered to the latter.

In assembly, the magnet 22 and the portions 25, 29 are of the same diameter, and the portions 25, 29 are bonded end-to-end coaxially with the magnet 22 e.g. by solder or plastic cement films 50. When the external diameters of the portions 25, 26 are greater than the insides of the rings 39, 40, the latter may be placed loosely around the magnet 22 during this phase of assembly; and the helical spring 35 passed through them during a later step. If the rings 39, 40 are larger internally than radial projections at one end of the core system, the coils 37, 38 may be placed on the helical spring 35 before the spring is passed around the magnet 22 and over the portions 26, 30. In either case, the spring 35 is engaged into place on the threaded portions 26, 30, under a slight tension. The positions of the coils are adjusted so that they will come approximately at the $\frac{1}{4}$ and $\frac{3}{4}$ positions of the effective length of the spring between the threaded portions. The plugs 15, 16 are aligned and the screw 32 is tightened: the screw 28 is engaged but not tightened so that the parts 26, 27 and 15 can be rotated relative to the magnet 22 and the piece 25. The solder connections of the conductors 45, 46, 47, 48 are made. The unit is connected in circuit. A rough tuning is then accomplished by screwing end turns of the spring 35 from groove to groove on the portions 26, 30, thus changing the active length of the spring. The coils 37, 38 are adjusted more accurately to the $\frac{1}{4}$ and $\frac{3}{4}$ positions; and are then rigidly cemented to the turns of the spring 35 in contact therewith. One spring end, e.g. the one adjacent the end plug 16 in Fig. 1, can be fixedly cemented or soldered to the threaded portion 30. The other end of the spring is likewise secured to the threaded portion 26; and this portion and the end plug 15 rotated relative to the magnet 22 and the piece 25 for causing torsion in the spring to increase or decrease its diameter and thereby change the frequency of vibration of the spring, until it has been tuned to the desired periodicity of mechanical resonance. This adjustment is then fixed by tightening the screw 23, and by use of solder or cement to secure the parts against accidental or intentional shifting: thus the end plugs 15, 16 can be soldered to the spacers 27, 31 and the screw 28, 32. The assembly is then slipped into the jacket 10, and the plugs 15, 16 are secured, as by soldering.

The case 10 with its end plugs 15, 16, and other external parts may be sealed gas-tight, with an opening in the casing closable by the plug 53, Fig. 1. Prior to use, the air can be evacuated from the interior so that the air friction effects, and decrement therefrom, is reduced. It has been found that the Q value of a device can thus be

doubled. It is also feasible to replace the air by a gas, such as hydrogen, which has a lesser viscosity and lesser friction effect, under atmospheric or other pressure.

The structure will operate with circuits as described in the aforesaid Wiegand patent application. In Fig. 2, an illustrative circuit is shown, for use with a transistor. The lead 41 is connected by a conductor 52 with a battery 53; and lead 42 is connected by conductor 54 to an electrode 55 of the transistor body 56. The other battery terminal is joined to a common conductor 57 which is connected to a second electrode 58 of the transistor, and to a resistance 59 which at its other end is connected to the base conductor 60 from the transistor. This conductor 60 also is joined by a condenser 61, which at its other terminal is connected by conductor 62 to the lead 44. The common conductor 57 is connected to the lead 43. The electrical oscillations also appear at the terminals 65, and conductors connected thereto can lead to the device for employing the alternating current.

In operation, when the circuit is connected, a pulse from the battery 53 is delivered to the coil 37, and the magnetic effect induced by coil 37 acts to cause the coil, and therewith the engaged turns of the spring 35, to move axially, that is, longitudinally along the axis of the spring, in the magnetic field gap defined by the casing 10 and the right-hand end of the magnet 22; and the magnetic flux establishes a path through the magnet and the jacket 10, with passage at the gap between the casing 10 and the other end of the magnet. This causes the turns of the spring to move relative to the fixed structure including the magnet 22, the end plugs 15, 16, and the jacket 10, in a direction determined by the direction of current flow in the coil 37 which illustratively is opposite the south pole of the magnet 22 as indicated by the letter S. This movement of the free turns of the spring causes the coil 38 to move in the magnetic field and an electrical pulse is generated therein. This current pulse is delivered by the conductors back to the transistor, at which the effect is amplified, and a further pulse delivered to the coil 37. Upon cessation of the transient pulse, the turns of the spring 35 move back by the elasticity of the material. Therewith the coils 37 and 38 return to their initial rest positions, and beyond as the kinetic energies of the masses are converted to potential energy in the spring; and therewith the coil 38 delivers a reverse pulse to the conductors, which is amplified and fed to the coil 37 to increase its action. This action continues until a balance is established between the acceptance of energy by the mechanical system and the impulsing energy delivered from the circuit system. The helical spring has a characteristic frequency of harmonic mechanical vibration; and the electrical circuit constants can easily be chosen so that the electrical amplification is not highly selective or critical as to frequency, and the mechanical frequency is determinative in the system, with the amplitude of mechanical vibration increasing by the electrical impulsing effect, where-with a device having coil impedances of 1000 ohms can generate alternating current voltages of the order of 0.1 to 0.4 volts; and an impedance change of the order of 10,000 or more.

Another form of practice is shown in Fig. 5, in which a half-wave type of operation occurs, as compared with the full-wave operation of the device of Figs. 1 to 4.

In this form, the outer jacket 10 of soft iron has end plugs 15, 16 as before. These plugs have apertures for receiving the brass screws 28, 32 for holding the portions 27, 26, 25 and 31, 30, 29 as before. Two permanent magnets 75, 76 are employed in lieu of the single magnet, and are mounted end-to-end with an intervening spacer 77 of magnetizable but not permanently magnetizable material, e.g. soft iron-like poles, e.g. the north poles, N, N are adjacent one another so that the spacer 77 is effective as a north pole at the mid-point of the assembly. A helical spring 80 has its ends mounted on

the threaded portions 26, 30 as before. The mid-point of the spring 80 supports a bobbin ring 81 which has the electrical coil 82 wound therein. Flexible and extensible conductors 83, 84 lead from the ends of the coil 82 to the terminal leads 85, 86 which pass through the glass beads 20 in the end plug 15.

This device may be assembled by connecting the magnets 75, 76, the spacer 77, and the end pieces 29, 30, 31 and 25 together as before, by cement or hard solder. The end structure of threaded portion 29 and its spacer portion 31 can also be connected to the magnet assembly, likewise by cement or hard solder. At this time, also, the spacer 27 and threaded portion 26 can be loosely assembled to the end plug 15 by engaging a screw 28 through them and into the member 25 for alignment. The end spacer 31 can be similarly secured to the end plug 16. The spring 80, with the bobbin 81 left movable therealong, is mounted on the threaded portions 26, 30 and secured thereto by cement. The coil 82 is adjusted roughly to the center of effective length of the spring 80; and its end conductors 83, 84 are connected to the leads 85, 86 and thence in a circuit as shown in the copending Wiegand application, such as that shown in Fig. 6 of the present drawings. In this circuit, a device terminal 85 is connected to a conductor 110, and the other terminal 86 is connected through a resistor 111 by conductor 112 to a transistor body 113 and to a winding 114 of a transformer, the other end of the winding 114 being joined to the conductor 110. Another winding 115 of the transformer is connected at one end through the battery 116 to the conductor 110, and at its other end to a conductor 117 leading to the third terminal of the transistor. A condenser 118 is connected between conductors 110 and 117. Pulses for external employment can be derived at the terminals 65 respectively joined to the conductors 110, 117. In operation, upon connection to the circuit a pulse from the battery 116 is delivered to the coil 82 and initiates longitudinal vibration of the spring 80. This spring movement with the coil 82 causes current to be generated therein, and this current pulse acts at the transistor to cause an amplified current effect to be produced whereby the spring receives vibration-maintaining energy, and the spring continues in vibration at a frequency determined by the spring constants and the mass of the coil 82 and its bobbin ring 81.

Spring vibration is started as with Fig. 1 and the movement of the coil 82 in the magnetic field between the mid-spacer 77 and the jacket 10 causes an alternating current to be generated which is amplified in the external circuit and a part returned to the coil 82 for maintaining the vibration. Another part of the amplified current is available externally at terminals 65 with the device functioning as a source of alternating current and operating at a frequency determined by the mechanical vibration of the spring 80.

The frequency and wave pattern of this current can be accurately determined. The bobbin 81 is adjusted to the mid-point of the spring 80 and there secured by cement. If the frequency is not precisely that intended, the threaded portion 26 can be rotated relative to the member 25 for increasing or decreasing the vibration frequency: when the desired frequency is attained, the parts 25, 26 are fixed relative to one another by tightening the screw 28 in the member 25 and securing as before by cement or solder. The assembly is then slid into the jacket 10, and the end plugs 15, 16 are secured by cement or soft solder.

The form shown in Figs. 7 and 8 likewise has a helical spring 90, and a pair of electrical coils 91, 92 are secured thereto at one-fourth and three-fourths of the length of the spring, that is, at the anti-nodes of longitudinal vibration of the spring. The spring 90 has spaced turns, and extends between the end headers 93, 94 of insulating material, which are held fixedly relative to one another

by the through-bolts 95 with end nuts. Three equispaced permanent magnets 96 extend between concentrator rings 97, 98, e.g. of soft iron, which are apertured for the bolts 95, and may be secured to the magnets by cement or solder. Coaxially of the spring 90, at the center of the device, a core of soft iron is provided by the two rods 99, 100 which are held aligned by the reduced inner end 101 of one rod which fits in an end hole of the other rod. The outer ends of the rods are threaded and extend through holes in the headers 93, 94 and are secured by nuts 102, 103. Diametrical holes in the rods receive the radially in-turned ends 104, 105 of the spring 90, so that these ends bear against the inner faces of the headers 93, 94. The ends of the coils can be connected by conductors 41, 42 and 43, 44 in a circuit as in Fig. 2, and the spring 90 vibrates in its second mode of vibration.

The systems can be operated on a "full wave" basis by so connecting the amplifier and electrical coils that they are 180 degrees out of phase. Thus, in Fig. 1, when the coil 37 moves toward the right, the impulse delivered from the amplifier to coil 38 causes it to move toward the left concurrently, so that there is stretching of the free turns between the coils, and a release of tension in the free turns between the coils and the respective secured ends of the spring. Therewith, if the masses of the coils 37 and 38 are the same, there are essentially equal but opposite forces being exerted between the coils and the external casing 10 and its parts and no reaction between the casing and surrounding structures which might vibrate the latter or cause mechanical noise.

In each form, a coil spring is mounted to perform mechanical vibrations lengthwise, with this spring having one or more electrical coils connected to spring turns to act as masses which in conjunction with the spring determine the frequency of the vibrations. A magnetic field is concentrated in a radial zone or zones intersecting the coil or coils so that there is interaction between the field and the coil whereby mechanical movement of the spring is induced or such movement is employed to generate current pulses in the coil.

It is obvious that the invention is not limited to the illustrative forms shown, but may be embodied in many forms within the scope of the appended claims.

We claim:

1. A magnetomotive oscillator for employment with an external device responsive to alternating voltage effects comprising a rigid support having rigid end members located at a fixed distance apart, means thereon for providing a magnetic field, a coil spring of resilient material fixed at its ends to the said end members of said support, and having free turns between its ends which can oscillate longitudinally along the spring axis toward and from one another, an electrical coil fixed to the coil spring between its ends for providing an oscillating mass movable longitudinally along the spring axis in the magnetic field and with the coil axis in the direction of the spring axis, and electrical connections to the electrical coil whereby the said longitudinal movement thereof is effective to produce an alternating voltage effect at said connections.

2. A magnetomotive oscillator for employment with an external device for amplifying electrical pulses comprising a rigid support having rigid end members located at a fixed distance apart, means thereon for providing a magnetic field, a coil spring of resilient material fixed at its ends to the said end members of said support, and having free turns between its ends which can oscillate longitudinally along the spring axis toward and from one another, an electrical coil fixed to the coil spring between its ends for providing an oscillating mass movable longitudinally along the spring axis in the magnetic field and with the coil axis in the direction of the spring axis, and electrical connections to the electrical coil whereby electrical pulses generated by longitudinal

movement of the electrical coil in the magnetic field are delivered to the external device and amplified pulses from the external device are delivered to the electrical coil.

3. A magnetomotive oscillator comprising a support, means thereon for providing a magnetic field, a coil spring fixed at its ends to the support and having between its ends free turns which can move longitudinally along the spring axis toward and from one another, electrical coils fixed to the coil spaced from one another along the spring substantially at its anti-nodes of longitudinal vibration and each located in the magnetic field with the axes of the coils in the direction of the spring axis, said coils providing masses for determining the said longitudinal oscillation rate of the assembly, and electrical connections to said coils.

4. A magnetomotive oscillator as in claim 3, in which the magnetic field means includes a permanent magnet located within the coil spring.

5. A magnetomotive oscillator as in claim 4, in which the permanent magnet has a length slightly greater than half the effective length of the coil spring between its fixed ends.

6. A magnetomotive oscillator as in claim 4, in which the support includes a casing of magnetically permeable material surrounding the coil spring and coils.

7. A magnetomotive oscillator as in claim 4, in which the casing has end plugs, a permanent magnet forming part of the field-providing means, and devices fixed to the end plugs for supporting the permanent magnet within the coil spring.

8. A magnetomotive oscillator comprising a casing of magnetically permeable material, and end members on the casing, support devices carried by the end members and extending toward one another within the casing, said devices including threaded portions, a coil spring having its ends fixed to the support devices and having free turns between said ends, an electrical coil secured on the spring between said fixed ends thereof whereby to provide a mass movable in longitudinal vibration with free turns between the mass and each fixed end of the spring, electrical connections to said coil, and a permanent magnet within the coil spring and supported by said devices.

9. A magnetomotive oscillator as in claim 8, in which one of the devices is movable relative to its end member whereby to adjust the period of said coil spring and mass.

10. A magnetomotive oscillator as in claim 8, in which the permanent magnet has an end adjacent an antinode of the coil spring and said electrical coil is secured to the spring adjacent the same antinode, and in which one of said threaded portions is located between the said end of the magnet and the corresponding end member whereby to determine the position of the said antinode.

11. A magnetomotive oscillator comprising a casing of magnetically permeable material, end members in said casing, a coil spring in said casing and having free turns between its ends which can oscillate longitudinally along the spring axis toward and from one another, said coil spring being secured at spaced points to said end mem-

bers, an electrical coil secured at an intermediate point of the coil spring and effective to provide a mass for determining the period of the assembly, and a permanent magnet located within the coil spring and carried on a said end member with one pole end within the said electrical coil.

12. A magnetomotive oscillator comprising a support, a coil spring fixed at its ends to said support and having free turns between its ends which can oscillate longitudinally along the spring axis toward and from one another, an electrical coil secured to the coil spring between the ends thereof and thereby providing a mass for determining the period of longitudinal oscillations of the coil spring and mass and with the axis of the coil in the direction of the axis of the spring, and means for providing a magnetic field within which said electrical coil oscillates along the longitudinal axis of the spring, said means comprising a core part within the coil spring and parts outside the electrical coil, at least one of said parts comprising a permanent magnet.

13. A magnetomotive oscillator as in claim 12, in which the support includes end members, and said core is effective to hold said end members spaced apart.

14. An electromechanical vibrator comprising, first and second spaced supports, a magnet mounted with its north and south poles spaced apart in the direction between said supports, with the north pole spaced from the first support and the south pole spaced from the second support, a mechanical spring coil means with the ends thereof attached to said supports for longitudinal vibration between the said attached ends, electrical coils connected to the spring system, with a first said coil located around the north pole of the magnet and a second of said coils located around the south pole of the magnet, one part of said spring means being connected between said first coil and the first support, another part thereof being connected between the said second coil and the second support, and a further part thereof being connected between said electrical coils, whereby said coils can move toward and from one another in the direction between the said supports, at a natural frequency, and electrical connections to a said electrical coil whereby electrical impulses may be delivered thereto for producing a magnetic field cooperative with the field of said magnet and thereby causing said electrical coil to produce a relative stretching of part of said spring means and a relative compression of another part of the spring means.

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