

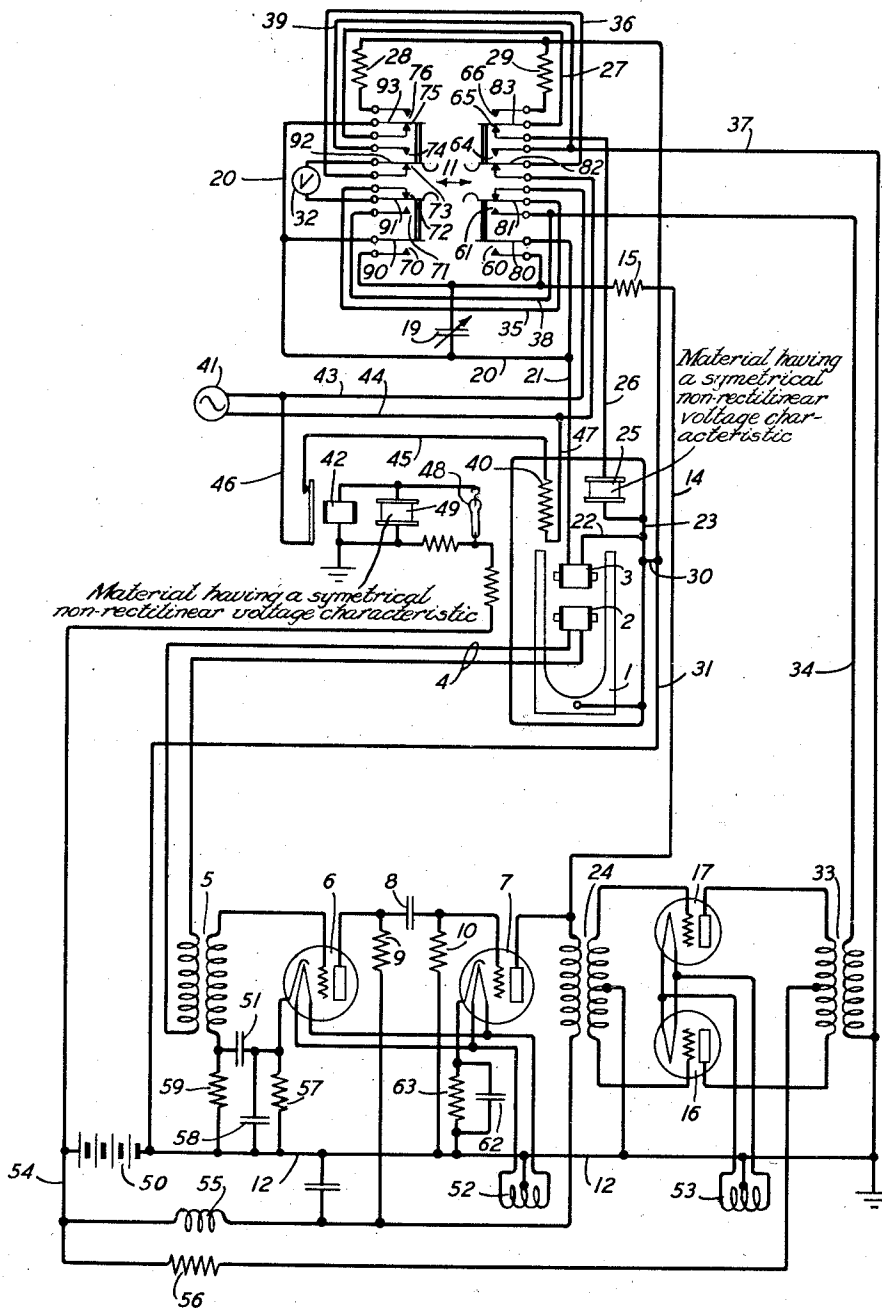
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FREQUENCY GENERATING SYSTEM

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2,049,177

FREQUENCY GENERATING SYSTEM

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This invention relates to frequency generating systems and more particularly to the stabilization of the frequency of these systems.

5 An object of this invention is the stabilization of the frequency of a frequency generator.

Another object of this invention is the regulation and control of the amplitude of vibration of mechanical resonators.

10 The increasing demand for greater accuracy in the electric timing of athletic events dictates a precise frequency supply for the systems employed for this purpose. Variations in the amplitude of vibration of the mechanical members of mechanically controlled oscillators which are especially adaptable as the frequency sources for these systems cause a pronounced change in the frequency produced by these oscillators.

Frequency generators comprise in general two circuits, a resonant circuit and a coupling circuit. 20 The resonant circuit in a well known manner oscillates or vibrates at approximately the natural frequency of the circuit while the coupling circuit supplies energy to the resonant circuit by amplifying the energy produced by the resonant circuit and returning this amplified energy to the resonant circuit. In order for oscillations of constant amplitude to be obtained, the gain through the coupling circuit must equal the loss of energy through the resonant circuit.

30 In accordance with this invention the non-rectilinear voltage current characteristics of certain materials are utilized to regulate the supply of energy to the resonant circuit of an oscillator. The preparation and properties of materials having this characteristic are described in U. S. Patent 1,822,742, granted to K. B. McEachron on September 8, 1931. The characteristics of one of these materials are such that every time the voltage is doubled the current passing through 40 the material is increased approximately twelve and a half times.

The material having this non-rectilinear voltage current characteristic is associated with the oscillation circuit. For example, in mechanically controlled oscillators the material having the non-rectilinear voltage current characteristic may be bridged across the resonant circuit. When the mechanically controlled oscillator is initially started the loss of energy through the resonant 50 circuit is relatively low in comparison to the gain of energy through the coupling circuit. Since at this stage of the operation of the oscillator, the amplitude of oscillations and the voltage across the material having the non-rectilinear voltage current characteristic is small, the material has

a relatively high resistance. Hence little energy is removed from the circuit. As the oscillations build up, however, the material acquires more and more energy until the loss of energy through the resonant circuit is equal to the gain of that 5 through the coupling circuit. The greater proportion of additional increases in energy from the coupling circuit is absorbed by the material and a relatively uniform supply of energy results in the resonant circuit. 10

In order to maintain oscillations of constant amplitude the loss through the resonant circuit must equal the gain through the coupling circuit. On occasion, as a result of accident or excessive deterioration due to aging of certain parts 15 of the system, such as space discharge devices, major changes in the gain or loss through either the coupling or resonant circuits occur. To ascertain whether the oscillator is operating satisfactorily the material having the non-rectilinear voltage current characteristic is removed and an impedance inserted in the oscillation circuit which results in a gain of energy through the coupling circuit which is greater than the loss of energy through the resonant circuit. If the operation of the oscillating circuit has previously 25 been normal, then under this new condition an increasing amount of energy is supplied to the resonant circuit causing vibrations or oscillations of increasingly greater amplitudes to be produced. An instrument, such as an alternating current voltmeter in the output circuit of the oscillator, indicates whether this increase in the amplitude of oscillation is produced. If this increase in amplitude does not result, an improper gain and loss relationship between the coupling and the resonant circuits is manifested. This impedance is then removed and another impedance which, if the oscillator is functioning normally, results in a loss through the resonant circuit 40 which is greater than the gain through the coupling circuit, is inserted in the oscillating circuit. The oscillations under this condition, if the oscillator has previously been normal, die down. If, however, the coupling gain is greater than normal or the resonant circuit loss less than normal the oscillator continues to oscillate. From the knowledge obtained by these two tests, a check is obtained of the operation of the circuit. 50

A better understanding of this invention is obtained by reference to the drawing in which a schematic diagram of a tuning fork oscillator embodying the invention is illustrated. The tuning fork oscillator described is employed as a 55

source of frequency in the timing system described in U. S. Patent 2,045,414 granted on June 23, 1936 to C. H. Rumpel.

In the drawing the numeral 1 represents a tuning fork which with driving coil 3 and pick-up coil 2 comprise the resonant circuit portion of the oscillator. The vibrations of the tuning fork prongs induce a small alternating current voltage in the pick-up coil 2 which is transmitted by means of the line 4 to the primary of transformer 5. From the secondary of transformer 5 this alternating current voltage is impressed on the space discharge device 6 and amplified. The output of space discharge device 6 is further amplified by space discharge 7 after passing through a condenser resistance coupling network consisting of series condenser 8 and shunt resistance 9.

The output of the space discharge 7 is transmitted to the driving coil 3 and also to a power amplifier comprising space discharges 16 and 17 in push-pull relation. The circuit to the driving coil 3 is traced as follows: Anode of space discharge device 7, line 14, resistance 15, variable condenser 19, line 20, line 21, driving coil 3, line 22, line 23, line 30, line 31, line 12 to the cathode of device 7. The circuit to the power amplifier is as follows: The output of the space discharge device 7 passes through the primary of transformer 24. The voltage generated across the secondary of transformer 24 is impressed on space discharge devices 16 and 17.

Bridged across the driving coil 3 is a material 25 having a non-rectilinear voltage current characteristic for maintaining the power supply to the coil relatively constant. Semi-conductive crystalline particles held in random contact in a matrix of an insulating medium possess this non-rectilinear voltage current characteristic. The specific material employed, prepared in accordance with the above stated patent to McEachron, consists of silicon carbide and kaolin. The circuit by which this material is bridged across the driving coil 3 is as follows: Line 22, line 23, material 25, line 26, contact 65 of key 11, armature 83, line 27, contact 75 of key 11, armature 93, line 20, line 21 to driving coil 3.

In order to determine whether the circuit constants of the oscillator are satisfactory for producing the desired frequency, two resistances 28 and 29 are provided for inserting across the driving coil 3. The value of resistance 28 is such that when bridged across the driving coil 3, a loss is produced through this part of the circuit which is less than the gain of the amplifier when the proper gain and loss relationship exists between the amplifier and fork circuit without the use of material 25 and condenser 19. The insertion of resistance 29 in place of resistance 28 results in a loss through the fork circuit which is greater than the gain through the amplifier if the oscillator is functioning properly.

The resistances 28 and 29 are inserted in turn across the coil 3 and the material 25 and the condenser 19 are removed by means of the key 11. When the key 11 is moved toward the left, resistance 28 is bridged across the driving coil 3 through the following circuit: Coil 3, line 22, line 23, line 30, line 31, resistance 28, contact 76 of key 11, armature 93, line 20, line 21 to driving coil 3. When the key 11 is moved toward the right resistance 29 is shunted across the coil 3 through the following circuit: Coil 3, line 22, line 23, line 30, line 31, resistance 29, contact 66 of key 11, ar-

mature 83, line 27, contact 75 of key 11, armature 93, line 20, line 21 to coil 3.

When the key 11 is moved from its central position either to the right or to the left, the material 25 having the non-rectilinear voltage current characteristic is removed from bridging the coil 3, the condenser 19 is short circuited and a voltmeter 32 is connected across the output of the push-pull power amplifier circuit comprising space discharge devices 16 and 17. Assuming the key is moved to the right and tracing the circuit by which the material is normally shunted across the coil 3 the break in the circuit responsible for the removal may be noted as follows: Coil 3, line 22, line 23, line 26, material 25, contact 65, break in the circuit due to the disengagement of contact 65 of key 11 with the armature 83. In a similar manner the removal of material 25 when the key 11 is moved to the left is demonstrated by attempting to trace the circuit by which the material is normally bridged across the coil 3 as follows: Coil 3, line 22, line 23, material 25, line 26, contact 65 of key 11, armature 83, line 27, contact 75, and a break due to the disengagement of contact 75 of key 11 with the armature 93.

The circuit by which the voltmeter 32 is inserted across the output of the power push-pull circuit comprising space discharge devices 16 and 17 is also completed by moving the key from the central position. The output of the push-pull power amplifier circuit is obtained from the secondary of transformer 33. When the key 11 is moved to the right, the circuit for the insertion of the voltmeter 32 across the secondary of transformer 33 is as follows: Secondary of transformer 33, line 34, contact 61 of key 11, armature 81, line 35, contact 72 of key 11, armature 91, voltmeter 32, armature 92, contact 73 of key 11, line 36, armature 82, contact 64 of key 11, line 37, to the secondary of transformer 33. If the key 11 is moved to the left from the central position, the circuit is as follows: Secondary of transformer 33, line 34, line 38, contact 71 of key 11, armature 91, voltmeter 32, armature 92, contact 74 of key 11, line 39, line 37 to the secondary of transformer 33. The circuit by which the condenser is short circuited when the key 11 is moved from its central position to the right is as follows: Condenser 19, line 20, armature 80, contact 60 to condenser 19. When the key 11 is moved to the left, the circuit is as follows: Condenser 19, line 20, armature 90, contact 70, to condenser 19.

A system for maintaining the temperature of the fork of the oscillator relatively constant is also provided. The atmosphere surrounding the fork 1 is heated by means of resistance 40 supplied with current from the external power supply of the frequency generator 41 through the following circuit: Generator 41, line 44, line 47, resistance 40, line 45, the armature of relay 42, line 46, line 43, generator 41. A circuit containing a thermostat element 48 and an electromagnetic device 42 controls the operation of the heating system. An element 49 consisting of a material having a non-rectilinear voltage characteristic is shunted across the relay. This element prevents the discharge current of the windings of relay 42 from building up a high voltage across the thermostat 48 when the thermostat interrupts the flow of current through the winding of relay 42.

The current for the cathode for space discharge devices 6 and 7 is supplied through the coil 52 while that for the devices 16 and 17 is

supplied through secondary transformer winding 53. The primary of these transformers and the other portions of the filament power supply are well known and will not be described here. The source of space current for devices 6, 7, 16 and 17 is battery 50. This power may be supplied from an alternating current source after rectification and passage through a suitable filter. Space current is supplied to the anode of device 6 from the battery 50 through the line 54 through the series impedance 55 and resistance 9. The power supply for the anode of device 7 passes from the battery 50 through line 54, series impedance 55, primary of transformer 24 to the plate of device 7. The anode current for devices 16 and 17 passes from the positive electrode of battery 50, line 54 through resistance 56, primary of transformer 33 to the anode of either device 16 or 17.

A grid bias filter network is associated with the device 6. This network comprises the resistance 57 and the condenser 58 in series with the cathode of the device. Resistance 59 is in series with the secondary of transformer 5 and the condenser 51 is connected between the secondary of transformer 5 and the cathode of space discharge device 6. A cathode resistor 63 and by-pass condenser 62 is associated with the cathode of device 7.

Resistance 9 has a value of 48,000 ohms; resistance 10—200,000 ohms; resistance 15—24,000 ohms; resistance 57—17,000 ohms; resistance 59—100,000 ohms; resistance 63—3,150 ohms. Both condensers 58 and 51 are .5 microfarad, condenser 62 is 2 microfarads, while condenser 8 is .1 microfarad.

The operation of the oscillator is as follows: The vibrations of the tuning fork 1 induce a small alternating electromotive force in the winding of pick-up coil 2 by varying the reluctance of the air gap of an associated permanent magnet. This alternating electromotive force after passing through the transformer 5 is amplified by the space discharges 6 and 7. The amplified current then passes through ground return and line 14, condenser 19, lines 20 and 21 through the driving coil 3.

The element 25 consisting of a material having a non-rectilinear voltage characteristic bridged across the coil 3 prevents the energy supplied to the driving coil 3 from exceeding a predetermined limit. As the electromotive force of the amplified alternating current increases a greater proportion of the current passes through the element 25. The composition of the material having the non-rectilinear voltage current characteristic and its physical dimensions are selected so that when the electromotive force attains a predetermined value for the production of a desired supply of energy to the coil 3, a definite portion of the current passes through the coil 3. However, when the electromotive force impressed on the coil increases above this value, the current passing through the material instead of increasing proportionately for each unit of the electromotive force applied to the coil, as it would if an ohmic resistance were shunted across the coil, rapidly increases in a non-linear manner for each rise in the electromotive force. For example, with one type of material employed, the current passing through the material increases $12\frac{1}{2}$ times, each time the applied electromotive force is doubled. Accordingly, as the electromotive force increases the proportion of current passing through the coil 3 decreases and the

energy supplied to the coil is maintained at a relatively constant value.

The output of the space discharge device 7 is also connected to the power amplifier circuit comprising push-pull devices 16 and 17. An infinitesimal amount of the power of the alternating current generated in the oscillator part of the circuit is withdrawn to operate the power amplifier used to drive the timing motors in the athletic timing device described in the above stated co-pending application of applicant.

In the event that it is desired to check the circuit constants of the oscillator, key 11 is first moved to the left. This movement of the key removes the element 25 from bridging the coil 3 and inserts in its place the resistance 28. It also short circuits the condenser 19 and shunts the voltmeter 32 across the output of the power circuit. The value of resistance 28 is such that its insertion across the coil 3 produces a loss through the fork or resonant portion of the oscillator circuit which is less than the gain of energy produced by the amplifier when the oscillator is functioning normally. The value of this resistance for a tuning fork oscillator shown in the drawing is approximately 2500 ohms. Whether the oscillator maintains oscillations with this resistance inserted across the coil is indicated by the voltmeter 32. A drop either gradual or sudden in the reading of the voltmeter indicates that the loss through the fork couple of the oscillator is greater than the gain through the amplifier. The circuit constants of the oscillator may be adjusted to correct this condition.

The key 11 is now moved to the extreme right. This movement removes the non-rectilinear element 25, inserts the resistance 29 across the coil 3, short circuits the condenser 19 and connects the voltmeter 32 across the output of the power circuit. The value of the resistance 29 is such that when bridged across the coil 3, it produces a loss through the fork or resonant portion of the oscillator circuit which is greater than the gain through the amplifier when the oscillator is functioning properly. The loss through the fork should be less than the gain through the amplifier in order for the system to oscillate. Accordingly, if the circuit constants of the oscillator are correct for the production of oscillations, the indicator of the voltmeter gradually drops to zero. If the voltmeter indicates no decrease in the output of oscillations, the gain through the amplifier is considerably greater or the loss through the fork considerably less than normal for the production of the desired frequency. From these two tests the relative gain through the amplifier and the loss through the fork couple can be ascertained for the proper functioning of the system and adjustments made accordingly.

While a preferred embodiment of this invention has been shown and described, various modifications therein may be made without departing from the scope of the appended claims.

What is claimed is:

1. In combination, an oscillator, an output circuit connected thereto, and means in said output circuit comprising a material having the characteristic that the current passing therethrough increases more rapidly than in proportion to the voltage applied thereto for stabilizing the frequency of oscillations of said output circuit.

2. In combination, a mechanically controlled oscillator, and means connected to said oscillator 75

comprising a material having the characteristic that the current passing therethrough increases more rapidly than in proportion to the voltage applied thereto for stabilizing the frequency of oscillations of said oscillator.

3. In an oscillation circuit, an oscillator, a mechanical member for controlling the frequency of said oscillator, an output circuit connected to said oscillator, and means bridged across said output circuit for stabilizing the frequency of oscillations of said circuit, said means comprising a material having the characteristic that the current passing therethrough increases more rapidly than in proportion to the voltage applied thereto.

4. In combination, a mechanically controlled oscillator comprising a mechanical vibratory element, a driving member for actuating said element, an amplifier for supplying energy to said element and a material having the characteristic that the current passing therethrough increases more rapidly than in proportion to the voltage applied thereto bridged across said driving member for maintaining the energy supplied to said element relatively constant.

5. In combination, an oscillator comprising an amplifier and a couple connected thereto, and means for determining the relative gain and loss in energy through said amplifier and said couple respectively.

6. In a mechanically controlled oscillator comprising an amplifier and a mechanical couple, means for maintaining the energy supplied to said couple relatively constant, and means for determining the relative gain and loss through said amplifier and said couple respectively.

7. In an athletic timing system, a tuning fork oscillator comprising an amplifier, input and output circuits connected thereto, a couple comprising a tuning fork, a driving coil connected to said output circuit for vibrating said fork, a pick-up coil connected to said input circuit for transmitting energy from said fork to said input circuit,

a power circuit connected to said output circuit for supplying oscillations to said system, means for maintaining said fork at a relatively constant temperature, a material having the characteristic that the current passing therethrough increases more rapidly than in proportion to the voltage applied thereto bridged across said driving coil for controlling the energy supplied to said driving coil, and means for determining the relative gain and loss through said amplifier and said couple respectively.

8. In combination, a mechanical vibratory element, a driving member for driving said element, and means bridged across said driving member comprising a material having the characteristic that the current passing therethrough increases more rapidly than in proportion to the voltage applied thereto for controlling the amplitude of vibration of said element.

9. An oscillator comprising a resonant circuit system, a coupling circuit, a path connecting said resonant circuit system and said coupling circuit, and means in said path comprising a material having the characteristic that the current passing therethrough increases more rapidly than in proportion to the voltage applied thereto for stabilizing the frequency of oscillations of said oscillator.

10. An oscillator comprising a resonant circuit system, a coupling circuit, means for stabilizing the frequency of oscillations of said oscillator, and means for determining the relative gain and loss of energy through said resonant circuit system and said coupling circuit.

11. In combination, an oscillator, a tuning fork for controlling the frequency of oscillations of said oscillator, a vibratory means for vibrating said fork and a material, connected to said vibratory means, having the characteristic that the current passing therethrough increases more rapidly than in proportion to the voltage applied thereto.

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