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FREQUENCY STABILIZED GLOW-DISCHARGE TUBE OSCILLATOR AND ELECTRICAL MUSICAL INSTRUMENT EMPLOYING THE SAME

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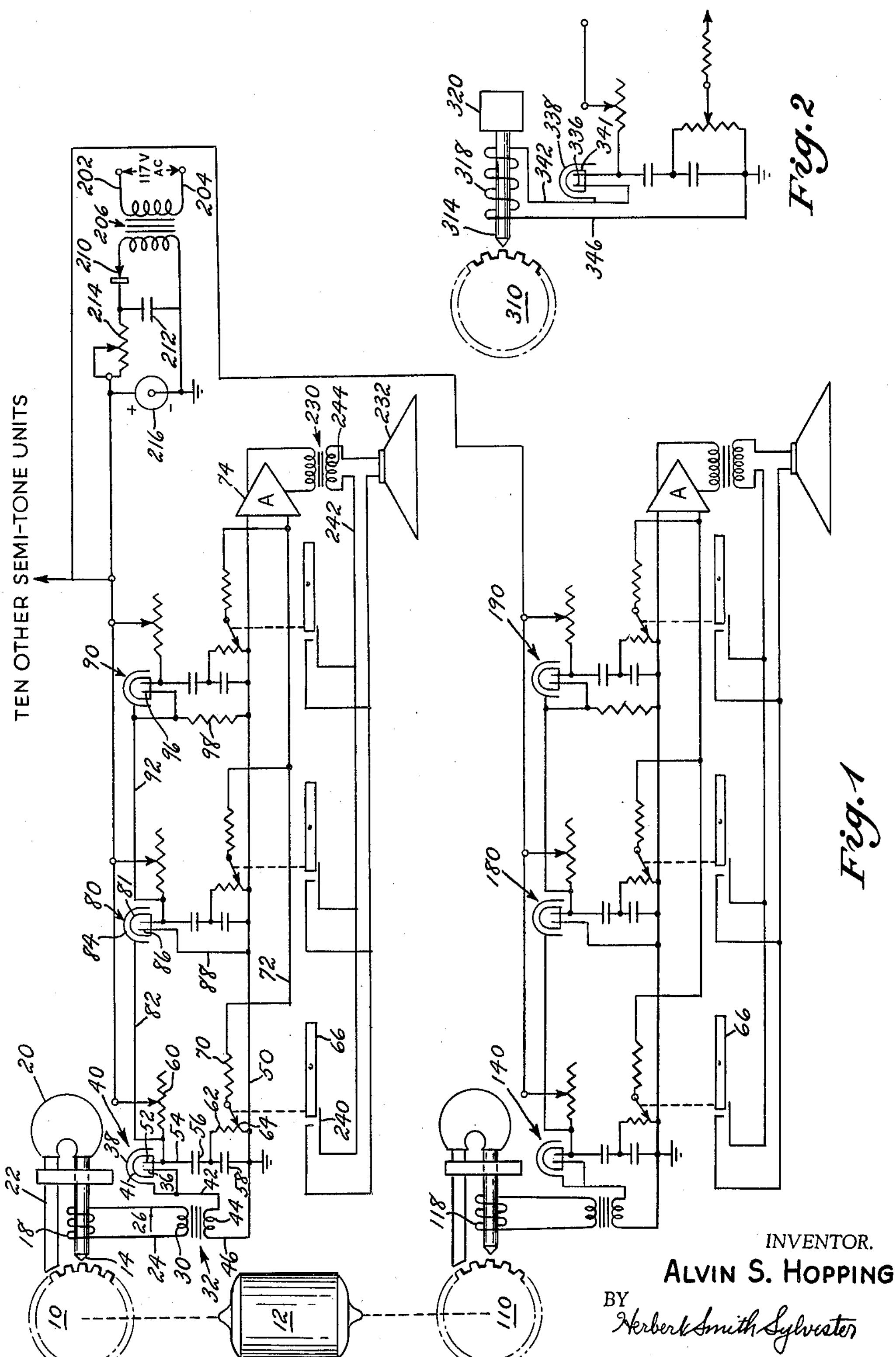

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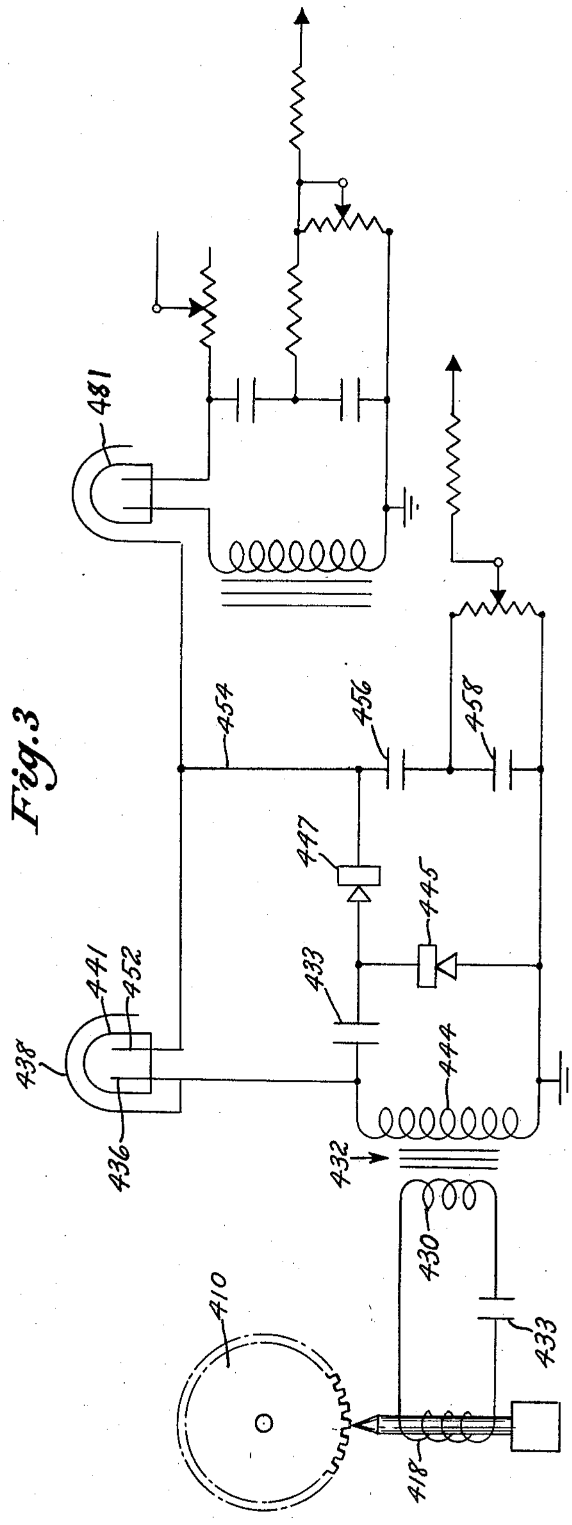

Fig.3

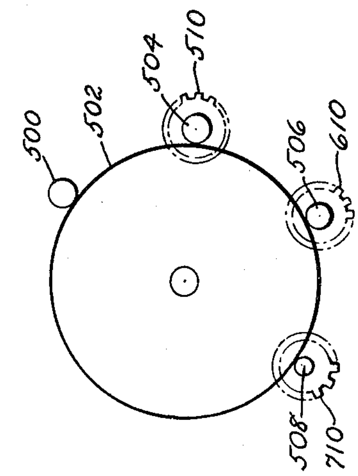

Fig.4

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ABSTRACT OF THE DISCLOSURE

A frequency stabilized glow-discharge tube oscillator in which the frequency of oscillation is synchronized by voltage derived from an inductor in which an alternating electric current is generated by a rotor which has a plurality of magnetic-field-influencing means equally spaced about it circumferentially and which is driven at constant speed.

The present invention relates to frequency stabilized glow-discharge tube oscillators, and to electrical musical instruments employing the same.

It has previously been proposed to construct electric musical instruments such as "electronic organs" in which glow-discharge tube oscillators are employed for producing electrical oscillations at musical frequencies. Such instruments are economical and simple to construct, but unfortunately simple glow tube oscillators are not adequately stable and must be stabilized as to their frequency of oscillation.

Previously proposed stabilizing systems involve the use of piezo-electric crystal controlled master oscillators, tuning forks, and the like, which require the use of driving and amplifying systems with complex and expensive electronic circuits, and which in turn may be subject to "drift" on aging, changes in line voltage, and other factors.

In accordance with the present invention, a frequency stabilized glow-discharge tube oscillator comprises a glow-discharge tube oscillator in which a glow-discharge tube is biased to a normally extinguished, non-oscillating condition, an inductor, a magnetic field source for generating a magnetic field which permeates said inductor, a rotor having a plurality of magnetic field-influencing means spaced apart equal distances about the circumference of said rotor, said field-influencing means being disposed within said magnetic field such that on spinning of said rotor, said magnetic field influencing means periodically disturb said magnetic field and generate an alternating voltage in said inductor, means for spinning said rotor at a constant speed selected to generate in said inductor an alternating voltage having a constant frequency approximately equal to the free running frequency of oscillation of said oscillator, and means for applying said constant frequency alternating voltage to said gas discharge tube, said applied voltage having an amplitude sufficient to cause said glow-discharge tube to become alternately conductive and nonconductive.

The invention will be further described in connection with the accompanying drawings, which are to be considered as exemplary of the invention and do not constitute limitation thereof.

In the drawings:

FIG. 1 is a representation, partially schematic and partially diagrammatic, of a musical instrument comprising two semi-tone oscillators in accordance with the present invention;

FIG. 2 is a combined diagrammatic and schematic representation of an alternative fundamental tone generating oscillator;

FIG. 3 is a combined diagrammatic and schematic representation of a particularly preferred fundamental tone generating oscillator; and

FIG. 4 illustrates a preferred mechanical drive system for the moving elements of the instant device.

In FIG. 1 a ferro-magnetic gear 10 is driven at constant speed by a synchronous motor 12 with the teeth of the gear in close proximity to a magnetic core 14 of an inductor 18. The magnetic core 14 is permeated by the magnetic field of a permanent magnet 20 which is situated with one pole at the end of the core 14 remote from the ferro-magnetic gear 10. A ferro-magnetic leg 22 further assists in establishing a complete external magnetic circuit between the poles of the permanent magnet, the magnetic core 14, the ferro-magnetic gear 10 and the ferro-magnetic leg 22.

Conduits 24 and 26 connect the inductor 18 to the primary winding 30 of a step-up transformer 32. The output of the inductor 18 is applied as the frequency controlling and auxilliary (power) supply voltage to a first glow-discharge tube oscillator stage, indicated generally by the reference character 40. More particularly, the output of the inductor 18 is applied through the step-up transformer 32 to one electrode 26 and the shield 38 of a neon-type glow-discharge tube 41 through a conduit 42. (The secondary 44 of the transformer 32 is connected by a conduit 46 to a ground bus 50 to establish a reference voltage.)

The transformer secondary 44 preferably is of a high impedance nature, typical suitable values for the inductor 18, the transformer primary 30, and the secondary 44 being approximately 250–1000 ohms, 1500 ohms, and 500,000 ohms respectively, these impedances being typical values at about 1,000 cycles per second.

The second electrode 52 of the neon tube 41 is connected to the remaining components of the glow-discharge tube or relaxation-type oscillator 40. Thus, a conduit 54 connects the second electrode 52 to one plate of a capacitor 56. The capacitor 56 is in series with a second capacitor 58 which forms a voltage divider therewith. Also connected to the second electrode 52 is a rheostat 60, through which is supplied the D.C. operating power for the oscillator stage 40. The values of the rheostat 60, the capacitors 56 and 58, and the secondary of the transformer 44 are selected such that the natural or free running frequency of oscillation of the first stage 40 is approximately equal to the frequency of the electrical voltage generated in the inductor 18 when the ferro-magnetic gear 10 is driven at constant speed by the synchronous motor 12, e.g. when the synchronous motor is operated on 60 cycle supply.

An output tone signal is taken from the oscillator across the voltage-dividing second capacitor 58 by means of a potentiometer 62 which has its slider 64 mechanically linked to a playing key 66. In the normal rest position of the key illustrated, the slider 64 of the potentiometer 62 is disposed at the grounded end of the potentiometer, and thus no output is taken from the oscillator.

On depression of the playing key 66 under the influence of digital pressure, the slider arm 64 is moved along the potentiometer to an extent determined by the extent of depression of the key 66. Output signal is tapped off the potentiometer 62 and passed through an isolating resistor 70 to the input of an amplifier 74.

A second stage neon type glow-discharge tube oscillator, indicated generally by the reference character 80 is provided. This oscillator is adapted to operate as a frequency divider and to oscillate at one-half the frequency of oscillation of the first stage 40. The oscillators are comparable with the exceptions that the second (and subsequent stages) are biased to a free-running condition, that the natural or free-running frequency of the second stage is one-half that of the first stage and that synchronizing voltage for the second stage is obtained from the second electrode **52** of the neon tube **41** and is applied, by means of a conduit **82**, to the shield **84** of the glow-discharge tube **81** of the oscillator **80**. The electrode **86** of the neon tube **81** is grounded through a conduit **88**.

A third cascaded frequency-dividing oscillator stage, indicated generally by the reference character **90**, is also provided. This stage operates at one-half the frequency of the next preceding or second stage and is similar in operation and circuitry to that stage, the synchronizing signal being obtained by means of a conduit **92**. In the case of the lowest frequency stage **90**, synchronizing voltage is fed to the shield of the neon tube and also to one electrode **96** thereof across an isolating resistor **98** provided in the ground leg of the neon tube inasmuch as the lowest octave requires somewhat more synchronizing voltage than the higher frequency oscillators.

Although but three cascaded stages are illustrated, as many may be provided as octave tones are desired.

A second series of oscillators, operating in the same harmonic relationship as stages **40**, **80**, and **90**, is provided as shown in the lower portion of FIG. 1. The circuitry of these stages **140**, **180**, and **190** is identical to that of stages **40**, **80**, and **90**, and again the master synchronizing signal is provided by the magnetic impulses delivered on rotation of a ferro-magnetic gear **110** which is driven by the same synchronous motor **12** that drives the ferro-magnetic gear **10**. However, the teeth on the gear **110** are disposed according to a spacing which generates an alternating voltage in an inductor **118** which is in semi-tone relationship to the frequency of the voltage generated by the gear **10** in the inductor **78**. Thus, the oscillator stages **140**, **180**, and **190** provide a plurality of tones in octave relationship each of which are in semi-tone relationship to the tones provided by cascaded stages **40**, **80**, and **90**, the appropriate adjustments being made in the values of the respective circuit elements and (free-running) oscillator frequencies. It is readily seen that on provision of ten other such semi-tone units, to provide a total of 12 semi-tone units, the complete tempered scale may be provided over a range of octaves as numerous as the number of cascaded stages provided for each master oscillator **40**, **140**, and the like.

Operating power for the oscillators is readily obtained from 117 volt mains **202** and **204** by means of an isolating transformer **206** and a conventional half-wave rectifier with an R-C filter and a voltage regulating tube. In the rectifier circuit, a silicon diode **210** provides the necessary rectification, while an electrolytic filter condenser **212** and a power resistor **214** provides the customary filtering action. A 105 volt gas-filled voltage regulator **216** is a preferred, but not essential element of the power supply. The power supply supplies power in common to all of the stages of the instant musical instrument.

The cascaded stages, **40**, **80**, and **90**, which operate in harmonic relationship, each drive the common amplifier **74**, the output of which is coupled through an output transformer **230** to a loudspeaker **232** for these harmonic tones. As shown in connection with the first stage **40**, (and also illustrated for the remaining stages) the key **66** which actuates the slider **64** of the potentiometer **62** (or corresponding element in the other stages) from which output of any given tone is taken also actuates a normally open switch **240** in a conduit **242** between one terminal of the secondary **244** of the output transformer **230** and the voice coil (not illustrated) of the loudspeaker **232**. (The other side of the voice coil is returned directly to the other side of the secondary **244**.)

Thus it may be seen, that on actuation of the key **66**, the normally open switch **240** is closed, connecting the loudspeaker to the output of the amplifier **74**. At the same time, actuation of the key causes output from the oscillator gradually to be fed to the amplifier as the slider **64** of the potentiometer **62** is advanced. Corresponding action occurs with each of the other oscillator stages illustrated, the key actuated switch **240** for each stage of those units operating in octave relationship to each other being in parallel for actuation of the common loudspeaker. A similar arrangement is provided for all of the stages of each semi-tone unit e.g. stages **140**, **180**, and **190**. This mode of normally open-circuiting each loudspeaker and of engaging it only at such times as signal is being taken from a stage which drives that loudspeaker insures the quietest possible operation, i.e., when no note in the harmonic family delivered by any one loudspeaker is being player, the loudspeaker is open circuited and completely quiet.

FIG. 2 illustrates an alternative first stage high frequency oscillator embodiment in which a ferro-magnetic gear **310** is driven in close proximity to a magnetic core **314** of an inductor **318**. A permanent magnet **320** is situated at the end of the core **314** remote from the rotor **310**.

The alternating voltage developed in the inductor **318** on rotation of the rotor **310** by a synchronous motor (not shown) is delivered directly by conduits **342** and **346** to a first electrode **336** and shield **338** of a neon type glow-discharge tube **341** and to ground respectively, to provide a synchronizing voltage of constant frequency as in FIG. 1. The remainder of FIG. 2 is comparable to stage **40** of FIG. 1.

FIG. 3 illustrates a preferred master oscillator which is completely isolated in its operation from substantial variations in line voltage inasmuch as the operation of this oscillator is essentially entirely dependent upon the operation of the ferro-magnetic gear **410**.

In the device of FIG. 3 the ferro-magnetic gear **410** generates alternating current in an inductor **418** in the same manner as in FIG. 1, however the inductance of the inductor **418** and of the primary **430** of a transformer **432** is tuned by a capacitor **433**. As is apparent from FIG. 3, the output voltage obtained from the secondary **444** of the transformer **432** is applied in the same manner as in FIG. 1 to the shield **438** and one electrode **436** of a neon tube **441**. The same voltage is further applied through a coupling capacitor **443** to the junction of diode rectifiers **445** and **447** which, together with the output-voltage-dividing capacitors **456** and **458** form a half-wave voltage doubler. It has been found, for example, with the circuitry illustrated that by properly selecting the capacitor **433** to tune or resonate the system, output voltages on the order of 100 volts D.C. may be obtained on the conduit **454**. This voltage is more than adequate to enable proper firing of the neon tube **441** on application of the aforesaid generated A.C. voltage to the electrode **436** and shield **438**. A further advantage of this system is that the capacitors **456** and **458** also function as a voltage dividing and isolation system for the high frequency output of the oscillator, which, of course, is coupled to a suitable amplifier in the manner illustrated in FIG. 1. Synchronizing voltage for a second stage may satisfactorily be taken from the conduit **454** and applied to the shield of a neon tube in the manner illustrated, which avoids coupling of D.C. to an internal electrode of the glow-discharge tube **481** used therein. Conduit **454** also, of course, connects to an electrode **452** of the first stage neon tube **441**.

The transformer **432** is comparable to the transformer **32** described in connection with FIG. 1 in that it is a step-up transformer having a high impedance secondary, typical suitable characteristics at 1,000 cycles per second being on the order of 1,500 ohms for the primary and 500,000 ohms for secondary.

Inasmuch as any spurious tones generated in the master oscillator stage are carried through all successive stages, the purity of tone and stability of operation of the master oscillator of FIG. 3 is especially valuable. Not only does the tuning of the transformer primary circuit assist in generating adequate voltage in the secondary circuit to enable firing of the neon, but it also assists in minimizing any raspiness which may tend to develop from the use of imperfectly machined gears **410**, i.e., the transformer assists in smoothing out the wave forms generated on rotation of the gear **410**. Thus, the circuitry illustrated in FIG. 3 is of considerable value in filtering out any irregular conditions in the driven gear **410** and permitting the use of inexpensive mass produced embodiments thereof.

The gear drive method illustrated in FIG. 1 requires the use of gears having different teeth spacings by virtue of the fact that all gears are driven at the same speed. A preferred rim drive system is illustrated in FIG. 4 in which a motor shaft **500** drives a large idler wheel **502**, which also contributes fly-wheel effect. A plurality of tone generator shafts **504**, **506**, and **508** are frictionally driven by the rim of the idler wheel **502**. The shafts **504**, **506**, and **508** differ in diameter the appropriate amount to spin or rotate identical driven gears **510**, **610**, and **710** respectively mounted thereon at speeds in the proper frequency relationship to establish the tonal relationships required for the instrument. In this system, identical gears may be employed on each of the tone generator shafts, thus facilitating the use of identical, comparatively inexpensive, driven gears.

The inductor present in the highest frequency or master stage of each series of cascaded oscillators serves not only as a source of frequency regulating voltage for the stage with which it is associated, but also aids in modifying the wave form of the signal generated by that stage to more nearly resemble a sine wave, rather than the customary saw-tooth, thereby improving the purity of tone of the oscillator and facilitating harmonic mixing. The application to the highest frequency stage of the induced constant frequency alternating voltage at an amplitude sufficient positively to fire and to extinguish the neon tube of each such master oscillator has been found to improve substantially the frequency stability thereof, thus protecting these stages as well as the subsequent cascaded stages which are synchronized either directly or in a derivative fashion therefrom against line voltage variations, temperature changes, aging effects on components, and other such variations and modifications which normally are very troublesome and tend to cause drifting of glow-discharge tube oscillators. For example, it has been found on removal of the voltage regulator **216**, the output frequency of the instant master oscillators is maintained to within 0.1% independently of line voltage variations such that the D.C. output voltage of the rectifier stage powering the instant oscillators changes over the range from 75 volts (at which oscillation ceases) to as much as 150 volts D.C.

As indicated hereinabove, one characteristic of the instant oscillators is that the master stages, e.g. stages **40**, and **140**, are normally extinguished, i.e. are not free running. It is the synchronizing voltage which provides the power to cause firing of the neon tube in each of these stages. Similarly, the synchronizing voltage also serves, on the (negative) peak voltage opposed to the output of the power supply, to cut off or extinguish each neon oscillator. Thus, both the positive and the negative peaks of the synchronizing voltage delivered to each master stage acts in a positive manner in synchronizing that stage.

The secondary or cascaded stages **80**, **90**, **180** and **190**, however, are free-running at approximately one-half the frequency of the next preceding higher frequency stage and are synchronized to exactly one-half the frequency thereof by the synchronizing voltage coupled to each secondary stage.

The initial synchronizing voltage developed by the inductor associated with each master oscillator is applied to the highest frequency stage in each octave bank in order to insure stability at the highest frequency, where it is the most essential. The open circuiting of the loudspeakers and the grounding of the output of each oscillator stage when the playing keys **66** are not depressed insures quietness of operation, and the use of twelve separate channels, one for each semi-tone, eliminates mixing

problems and allows full use of the available power in the oscillators and amplifiers associated with each semitone. The only (electrical) mixing is of notes in octave relation which, of course, combine harmoniously and without any difficulty.

Even though all of the elements of a given stage normally are selected to resonate at the desired frequency, regulation of the supply voltage to plus or minus 1 percent of 105 volts D.C. is desirable to assist in maintaining a wide factor of safety against aging or replacement of neons, capacitors, resistors or other elements.

Finally, it will be seen that the entire musical instrument of the instant invention will remain "in tune" and retain a constant pitch or relationship thereof throughout its range as long as a constant speed mechanical drive is available, and that in view of the ready availability of synchronous motors and constant frequency alternating current, the instant invention provides for a very high degree of reliable frequency stabilization, and thus also for the construction of eminently satisfactory electrical musical instruments.

It is to be understood that the invention herein illustrated and described is to be limited only by the scope of the appended claims and that various changes and substitutions may be made in details of construction without departing from the true spirit of the invention.

What is claimed is:

1. A frequency stabilized glow-discharge tube oscillator comprising a glow-discharge tube oscillator in which a glow-discharge tube is in a normally non-oscillating condition, an inductor a magnetic field source for generating a magnetic field which permeates said inductor, a rotor having a plurality of magnetic field-influencing means spaced apart equal distances about the circumference of said rotor, said field-influencing means being disposed within said magnetic field such that on spinning of said rotor, said magnetic field influencing means periodically disturb said magnetic field and generate an alternating voltage in said inductor, means for spinning said rotor at a constant speed selected to generate in said inductor an alternating voltage having a constant frequency, and means for applying said constant frequency alternating voltage to said gas discharge tube, said applied voltage having an amplitude sufficient to cause said glow-discharge tube to become alternately conductive and non-conductive at the constant frequency of said generated voltage.

2. A frequency stabilized glow-discharge tube oscillator as set forth in claim 1 in which said means for applying said constant frequency alternating voltage to said gas discharge tube is a transformer having a high impedance secondary on the glow-discharge tube side thereof.

3. A frequency stabilized glow-discharge tube oscillator as set forth in claim 1 in which said means for spinning said rotor at constant speed is a synchronous motor.

4. A frequency stabilized glow-discharge tube oscillator as set forth in claim 1 in which said alternating voltage generated in said inductor is approximately equal to the free running frequency of said oscillator.

5. A frequency stabilized electrical musical instrument comprising a first glow-discharge tube oscillator, an inductor, a magnetic field source for generating a magnetic field which permeates said inductor, means for generating a constant frequency alternating electrical voltage in said inductor, said constant frequency being approximately the free running frequency of oscillation of said oscillator, a step-up transformer for coupling said constant frequency alternating voltage at increased amplitude to said glow-discharge tube, the primary circuit of said transformer being tuned to resonate at said constant frequency and said coupled voltage having an amplitude sufficient to cause said glow-discharge tube alternately to become conductive and non-conductive, a plurality of additional glow-discharge tube oscillators synchronized from said first glow-discharge tube oscillator in harmonic relationship

thereto, a common amplifier for all of said harmonically operated oscillators, a transducer for converting the output of said amplifier into sound, said transducer normally being electrically isolated from said amplifier, and separate keys associated with each of said oscillators for simultaneously connecting said transducer to said amplifier and applying the output of each of said oscillators to said amplifier.

6. A frequency stabilized electrical musical instrument comprising a first glow-discharge tube oscillator, an inductor, a magnetic field source for generating a magnetic field which permeates said inductor, constant speed driving means for generating a first constant frequency alternating electrical voltage in said inductor, said constant frequency being approximately the free running frequency of oscillation of said oscillator, means for applying said first constant frequency alternating voltage to said glow-discharge tube, said applied voltage having an amplitude sufficient to cause said glow-discharge tube to become alternately conductive and non-conductive, a plurality of additional glow-discharge tube oscillators synchronized from said first glow-discharge tube oscillator in harmonic relationship thereto, said constant speed driving means also being employed to generate an alternating voltage having a second constant frequency in semi-tone relationship to said first constant frequency for stabilizing the frequency of operation of a plurality of semi-tone glow-discharge tube oscillators oscillating in harmonic relationship to each other and in semi-tone relationship to each of said plurality of oscillators, a common amplifier for each said plurality of harmonically operated oscillators, a transducer for converting the output of each said amplifier into sound, such transducer normally being electrically isolated from each said amplifier, and separate keys associated with each of said oscillators for simultaneously connecting each said transducer to each said amplifier and applying the output of each of said oscillators to each said amplifier.

7. A frequency stabilized glow-discharge tube oscillator comprising a glow-discharge tube, an inductor which generates a constant frequency alternating voltage, means for supplying said constant frequency alternating voltage to a first internal electrode of said glow-discharge tube, and means for rectifying said alternating voltage and applying said rectified voltage to a second internal electrode of said glow-discharge tube, whereby conduction of said glow-discharge tube occurs in synchronism with said applied alternating voltage.

8. A frequency stabilized glow-discharge tube oscillator as set forth in claim **7** in which said rectifier constitutes a voltage doubler having series capacitors across its output which act as filter capacitors for the rectified voltage and as voltage dividers for the signal generated by said glow-discharge tube oscillator.

9. A frequency stabilized glow-discharge tube oscillator as set forth in claim **7** in which said inductor is tuned with a capacitor to resonate at said constant frequency.

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