Oct. 15, 1935. N. LANGER 2,017,542

ELECTRICAL MUSICAL INSTRUMENT

Filed April 5, 1933 3 Sheets-Sheet 1

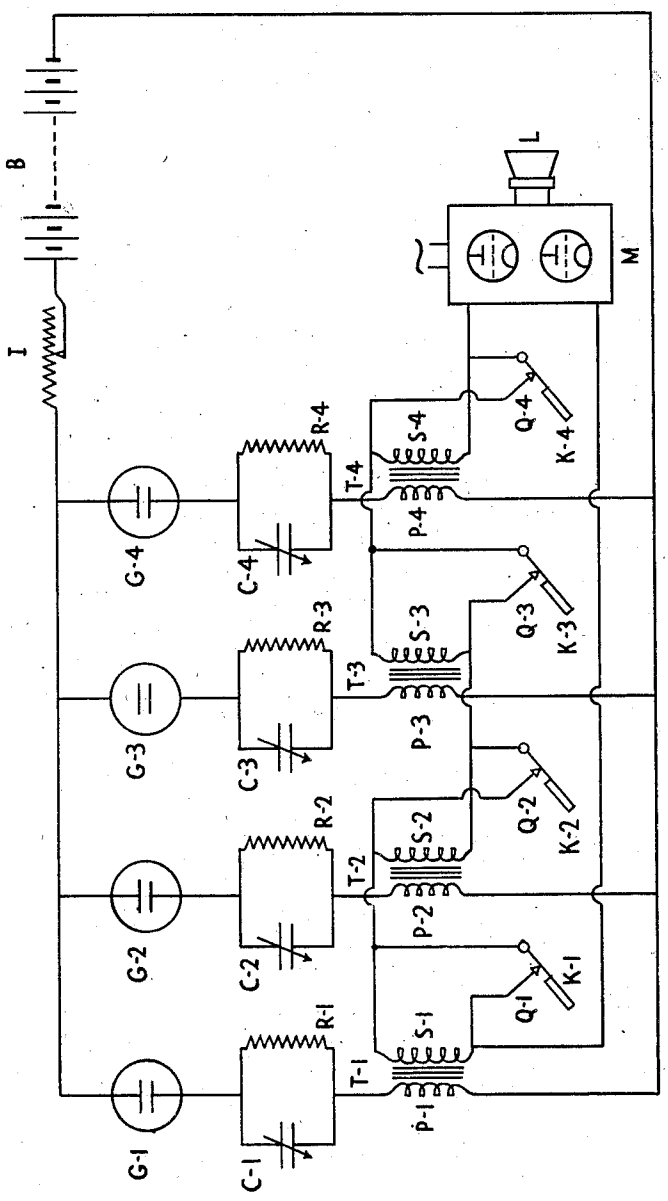


FIG. 1

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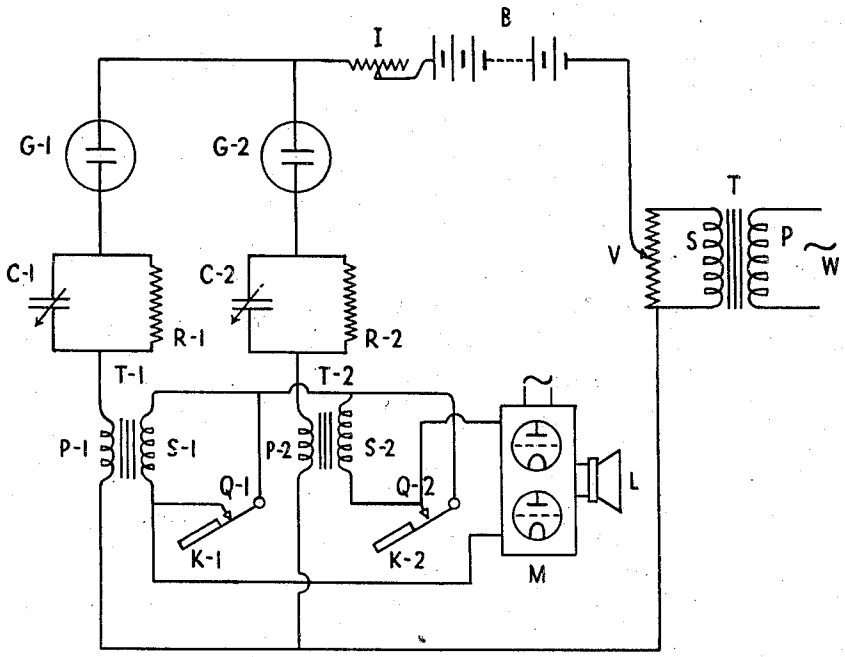


FIG. 2

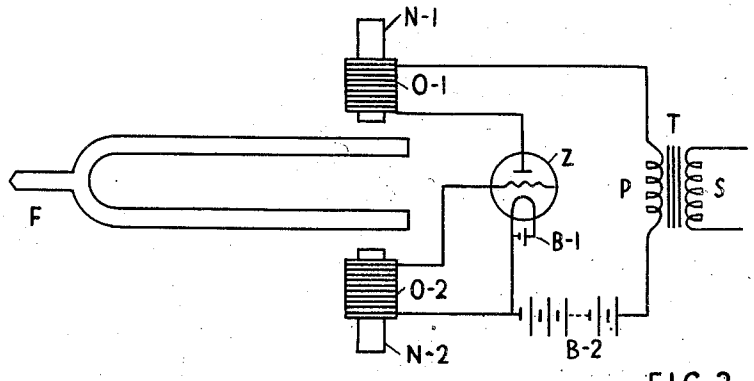


FIG. 3.

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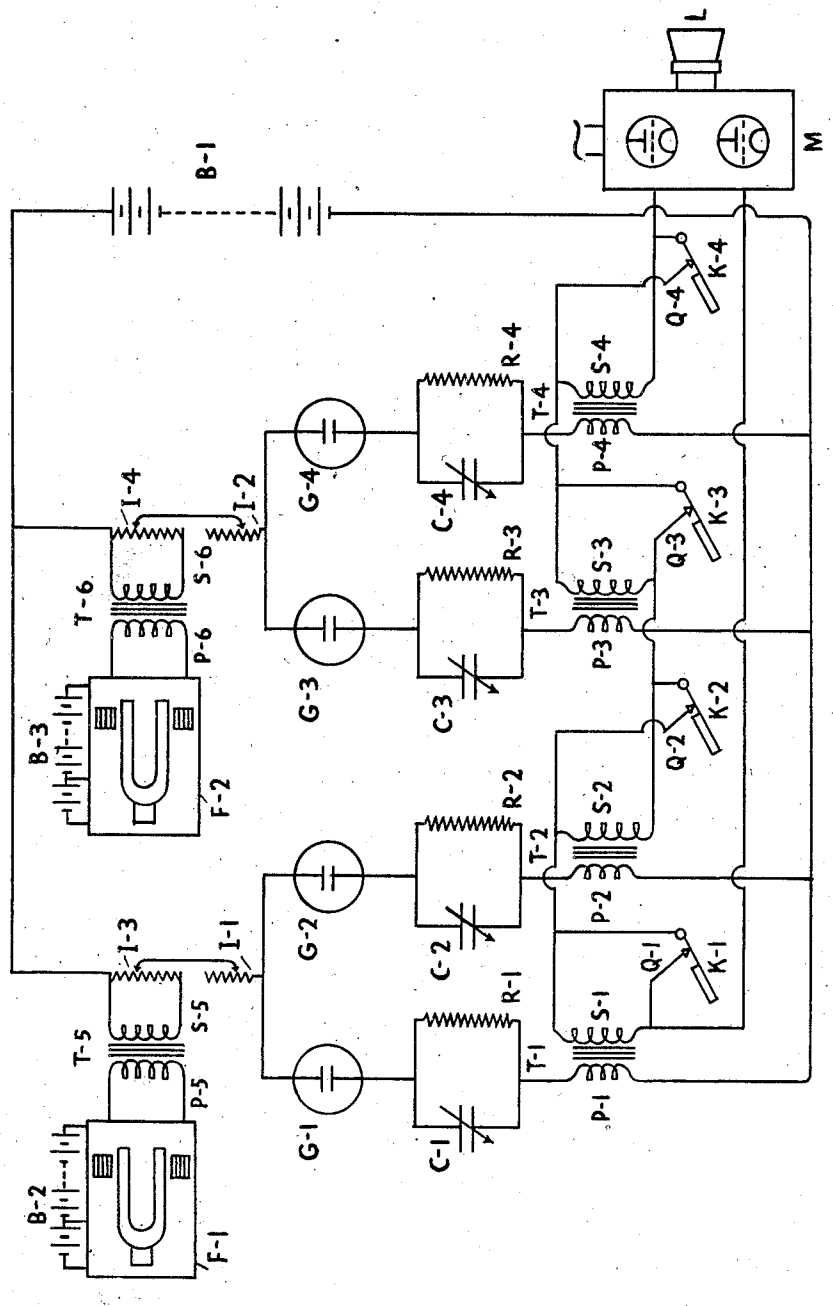


FIG. 4.

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UNITED STATES PATENT OFFICE

2,017,542

ELECTRICAL MUSICAL INSTRUMENT

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Application April 5, 1933, Serial No. 664,487

8 Claims. (Cl. 84—1)

The present invention relates to improved electrical musical instruments containing glow-discharge lamps.

A primary object of the present invention is to eliminate substantially all of the instability of the tuning of electrical musical instruments containing glow-discharge lamps and to provide arrangements for keeping in tune indefinitely.

It is another object of the present invention to use alternating current sources of very constant frequency such as oscillating audion tubes controlled by quartz crystals, magnetostriction oscillators, tuning fork oscillators and the like for stabilizing the frequency of glow-discharge lamp oscillators individually, or in suitably arranged groups.

It is a further object of the present invention to produce alternating currents of very stable frequency by keeping tuning forks in continuous vibration electrically.

Other objects and advantages will become apparent from the following description taken in conjunction with the accompanying drawings in which:

Fig. 1 is diagrammatic view of the circuit of a polyphonic electrical musical instrument embodying the present invention in which glow-discharge lamp oscillators in "tight coupling" are employed;

Fig. 2 is a fragmentary diagrammatic view of a circuit of the improved electrical musical instrument in which an external alternating current source of constant frequency is used to stabilize the frequency of oscillations produced by a group of glow-discharge lamps.

Fig. 3 illustrates somewhat diagrammatically, a tuning fork and an electrical circuit for maintaining the fork in continuous vibration.

Fig. 4 depicts diagrammatically the circuit of an electrical musical instrument embodying the present invention in which a number of glow-discharge lamp oscillators arranged in groups are controlled by a master oscillator in each group.

I have discovered that undesirable variations in the frequency of glow-discharge lamp oscillators were due largely to variations in the critical voltage (break-down and extinction voltage) of the lamp, while other factors governing the frequency such as the electromotive force, the capacity and resistance can easily be kept constant. As a result of numerous experiments I have found that the discharge through a glow-discharge lamp at the right moment, even with small variations in the characteristics of the lamp, can be easily obtained by applying a weak alternating current voltage of suitable value, frequency and phase to the electrodes of the lamp.

According to my discovery, the auxiliary weak alternating current when added to the constant electromotive force of the current source and when pressing approximately the same frequency as the glow-discharge lamp oscillator tends to build up a discharge through the lamp every time it reaches one of its maximum (peak) voltages, either the positive or the negative peak depending upon the method of connections. In this manner, the impressed weak alternating current voltage, which only has to be a fraction of the voltage of the direct current source will have a marked stabilizing effect on the frequency of the glow-discharge lamp oscillator. Tests have shown that even considerable variations of the condenser capacity or of the resistance or of the characteristics of the lamp will not change the frequency. Moreover, it has also been found that it is not absolutely necessary to have the frequency of the glow-discharge lamp oscillator and of the impressed alternating current exactly the same because it was found that one of the frequencies may be a multiple of the other.

In carrying the invention into practice, the alternating current voltage to be impressed may be taken from an auxiliary external source of current. It is preferred, particularly in the simplest case, to obtain the auxiliary voltage from another glow-discharge lamp oscillator which is in more or less "tight coupling" with the auxiliary external source of current.

Referring to Fig. 1 an arrangement of the foregoing kind may be seen in which four glow-discharge lamp oscillators, consisting essentially of lamp G—1, condenser C—1, resistor R—1; lamp G—2, condenser C—2, resistor R—2; lamp G—3, condenser C—3, resistor R—3 and lamp G—4, condenser C—4, resistor R—4, are operated from a common current source B. The four oscillators are preferably tuned in multiples of the same frequency, for instance, in octaves. In other words, if the circuit G—1, C—1, R—1 is tuned to the frequency f, the others are tuned, for instance, to $2f$, $4f$ and $8f$.

The coupling between the individual oscillators is effected by means of a variable impedance I which is common to all circuits. The amount of alternating current voltage impressed by one oscillator upon the other can be adjusted by making the aforesaid coupling tighter or looser.

The output of the individual oscillators is taken off by means of the transformers T—1 to T—4. Each oscillator has the primary winding

P—1 to P—4 of one of these transformers, in series, while all the secondaries S—1 to S—4 of the transformers are connected in series with each other and to the input side of the thermionic amplifier M which is operatively associated with sound-producing means L.

The switching keys K—1 to K—4 keep the contacts Q—1 to Q—4 normally closed and the secondaries S—1 to S—4 of the transformers short-circuited so that, although the four oscillators are each continuously producing an oscillation none of these oscillations can reach the amplifier. As soon, however, as any one or several of the keys are depressed, the corresponding secondary winding will have its short-circuited lead opened and the output of the associated oscillator will go to the amplifier, thereby producing a musical note, when only one key is depressed, and a musical chord, when several keys are depressed.

In case the oscillators associated with lamps G—2, G—3 and G—4 are tuned in multiples of the frequency of lamp G—1, preferably in octaves, they will always maintain a constant frequency relation. It is believed that the reason for the newly discovered phenomenon is that the voltage drop in impedance I is proportional to the total current drawn by all the glow-discharge lamp oscillators and acts as an alternating electromotive force which is opposed to current source B and which will facilitate the discharge through the glow-discharge lamps in the right moment when a minimum has been reached. The four oscillations will be always in phase with each other and will maintain their constant frequency relationship even in case condensers C—1 to C—4 or resistors R—1 to R—4 are slightly changed on purpose.

Although only four glow-discharge lamp oscillators are shown in Fig. 1 it is apparent that a greater number of them can be connected in the way indicated in order to obtain the usual range of a piano or of an organ, as one skilled in the art will readily understand. For instance, in order to obtain the usual range of 7 octaves of a piano, seven circuits with a common coupling impedance I can be arranged in such a manner that all the circuits are tuned in octaves of the same note of the tempered scale, for instance "C". Another group of seven oscillators with another series impedance is tuned in octaves of the next note of the tempered scale, "C sharp", and, so forth, through all the 12 notes of the scale. It is easily understood by those skilled in the art that it is only necessary to keep 12 groups of oscillators in tune instead of the former 84 independent oscillators and that the present invention represents a remarkable improvement because the new group by itself is much more constant than a single former oscillator.

In Fig. 2 a further improvement is illustrated. Except for the transformer T on the right side of Fig. 2, the circuit is identical with that shown in Fig. 1. The oscillators G—1, C—1, R—1 and G—2, C—2, R—2 are tuned in multiples of the same frequency and have their frequency relationship maintained constant by means of a tight coupling effected by the impedance I.

In some cases even when the oscillations have their frequency relations maintained constant, they might change their absolute frequency together. In order to eliminate even this small chance of possible variations, an auxiliary alternating current voltage is impressed on the circuit through the transformer T, the amount of this voltage can be adjusted by means of the potentiometer V across the secondary winding S of the transformer. The alternating current source W can be any of the oscillation generators known for their constancy in the radio art, as for example a quartz crystal controlled thermionic tube oscillator or a so-called magnetostriction oscillator. It is preferred, however, to produce a constant alternating current voltage by means of a tuning fork which is maintained in continuous oscillations electrically. An oscillator of the tuning fork type is much more simple and economical in operation than any of the previously mentioned methods and is less expensive and less bulky than prior oscillators. These features are of considerable importance because generally twelve "master oscillators" tuned to a different note of the tempered scale are necessary for a complete electrical musical instrument.

The method heretofore known for keeping tuning forks in continuous vibration can be generally divided in three groups to wit: (1) the interrupter method, (2) the microphone button method and (3) the air pressure method. The first two methods have the disadvantage, that both the interrupter or the microphone button put a load on the tuning fork so that it cannot oscillate freely and, in addition, they are not reliable for self-starting. The third method necessitates the use of compressed air for driving the tuning fork which, of course, is a very undesirable complication in an electrical musical instrument.

As a result of numerous experiments I succeeded in discovering a novel method of maintaining a tuning fork in continuous vibration electrically which is extremely simple and cheap, which does not put any load whatever on the fork and which is at the same time self-starting and is capable of continuing to oscillate as long as the necessary current is supplied. In the foregoing manner, a reliable source of alternating current of constant frequency is provided.

In Fig. 3 embodiment of the novel tuning fork oscillator is shown. On both sides of the tuning fork F are two coils O—1 and O—2, each of which has an iron or steel core N—1 and N—2. These cores are preferably either permanently magnetized or polarized by a permanent magnet of adequate form not shown in the drawings. The tuning fork itself is preferably made out of magnetized steel.

A thermionic tube Z is associated to the coils O—1, O—2 in such a way that coil O—2 is connected to the grid circuit and coil O—1 in the plate circuit of the tube in series with the primary F of the output transformer T and the plate battery B—2.

The operation of the foregoing arrangement may be described as follows: If the tuning fork is in vibration with a very small amplitude, for example, due to external mechanical vibrations, such vibration will change the magnetic flux in coil O—2 and, consequently, induce a current in this coil. The induced current will flow directly to the input (grid) side of the thermionic amplifier Z. The amplified current will pass through the coil O—1 in the plate circuit of the tube and, in case the direction of the windings is selected properly, will attract the tuning fork in the right phase. Such an attraction will increase the movement of the tuning fork a little and thus increase the current induced in the coil O—2, which amplified again will in turn increase the movement of the tuning fork and so on. Ob-

viously, the amplitude of the oscillations will steadily increase as long as the quantity of energy derived from the plate circuit of the amplifier tube equals the energy losses due to the vibration of the fork. It is very remarkable and, at the same time, of great advantage, that the tuning fork builds up the oscillations without any external help. In other words, the oscillator is self-starting even when the tuning fork has been previously in a state of complete rest. I believe what occurs when the current source is connected is that the momentary current impulse is sufficient to produce a little displacement of the tuning fork, which in a short while will be built up to continuous oscillation. Of course, the foregoing is only a theory which I do not wish to be bound by.

It appears that the same system of maintaining tuning forks in continuous vibrations electrically can be used as well for maintaining strings, metal bars, wire coils, chimes, etc., in vibration. Of course, the arrangement of the coils might be changed slightly and care should be taken, that either the vibrating member should be made out of steel, nickel or some other magnetic material, or at least part of the member next to the two (pick-up and driving) coils should be made of such material.

A plurality of tuning forks maintained in continuous vibration electrically by the described method can be used to produce numerous electrical currents of different frequencies. A switching key can be provided for each oscillator and for one or several sound-producing means. The switching keys keep the tuning fork oscillator output circuit normally disconnected from the sound-producing means, but can connect any number of the circuits simultaneously to the sound-producing means when operated, and cause them to emit a musical chord.

Although the greatest field of this method lies in the building of electrical musical instruments or in stabilizing the frequency of oscillations produced by glow-discharge lamps, many other applications of the same principle are obvious to those skilled in the art. A few of the applications are producing a continuous and pure sinus wave-form current or a pure musical note for electrical or acoustical experiments, synchronizing photo-telegraphic and television apparatus and functioning in sweeping circuits for cathode-ray oscillographs, etc. All of the foregoing applications are within the scope of present invention.

It is to be observed that the present invention provides the following improvements: first, the securing of the constancy of intervals by providing a tight coupling between individual glow-discharge lamp oscillators; secondly, the stabilizing effect of an external auxiliary source of alternating current of constant frequency impressed on the current produced originally by the glow-discharge lamp; and finally the method for producing an alternating current of very stable frequency by keeping a tuning fork in continuous vibrations by the method described hereinabove. Moreover, the invention provides a practical electrical musical instrument capable of producing a plurality of musical notes and capable of being manufactured on the basis of mass production. In other words the present improved instrument is capable of producing chords in such way that the frequency of all the oscillations involved is absolutely constant over a long period of time.

The complete arrangement of an electrical musical instrument of the aforesaid type may be seen in Fig. 4 which shows for the sake of simplicity and clarity only four glow-discharge lamp oscillators. The essential parts of the oscillators are lamp G—1, condenser C—1, resistor R—1; lamp G—2, condenser C—2; lamp G—3, condenser C—3, resistor R—3; and lamp G—4, condenser C—4, resistor R—4. The variable impedance I—1 provides the necessary "tight coupling" between the circuits G—1 and G—2 variable impedance I—2 between G—3 and G—4. G—2 preferably produces the octave of the note produced by G—1; and G—4 the octave of G—3. A tuning fork "master-oscillator" F—1 and F—2 operated by the batteries B—2 and B—3 respectively is provided for each group. The output of each tuning fork is taken off through the transformers T—5 and T—6 and the secondary windings thereof S—5 and S—6 have an impedance I—3 and I—4 connected across them. By providing a sliding contact the exact amount of the auxiliary alternating current voltage to be applied to the glow-discharge lamps can be adjusted. It is evident that this auxiliary current should be kept as low as possible, otherwise, it might interfere with the oscillations to be stabilized. The natural frequency of F—1 is preferably the same as of one of the circuits associated to G—1 or G—2 and of F—2 the same as one of G—3 or G—4.

It is to be observed that one essential feature of the present method is first, to provide an adjustable "tight coupling" between several otherwise independent glow-discharge lamp oscillators tuned in multiples of the same frequency in order to secure constancy of the relative tuning; and secondly, to provide a fairly "loose coupling" between an auxiliary source of alternating current of constant frequency and a group of glow-discharge lamp oscillators to secure an absolute constancy of tuning. Although the so-called "galvanic coupling" indicate by a variable resistance or potentiometer (I—1; I—3 etc.) is shown in the drawings it is evident that the method by means of which the desired amount of coupling is obtained is insignificant. Any other adjustable means of coupling may be used, such as inductive, capacitive or resistance (galvanic) coupling or combinations thereof.

The output of the individual glow-discharge lamp oscillators is connected in the same way as in the circuits in Fig. 1 or 2. Small transformers T—1 to T—4 are connected with their primary winding P—1 to P—4 in series with each of the glow-discharge lamp oscillators and complete the circuit with the current source B—1 which is common to all oscillators. Since these circuits are constantly closed, an alternating current of different and constant frequency will exist in each of the secondary windings S—1 to S—4 which are all in series and connected to the input side of the thermionic amplifier M. A contact (Q—1 to Q—4) normally closed is associated with each of the secondaries S—1 to S—4 and keeps them short-circuited so that the output cannot reach the amplifier. As soon, however, as any of the switching keys K—1 to K—4 are operated, the corresponding short-circuiting lead will be interrupted and a musical note will be heard in the sound-producing means L associated with the amplifier, and a musical chord will be heard when several keys are operated simultaneously.

For the purpose of describing the number of

tuning fork oscillators and glow-discharge lamp oscillators needed for a practical instrument, the frequency range of a piano will be taken as an example. This range is a little over 7 octaves, or 7 times 12 equals 84 notes. It is preferable to use an arrangement which provides twelve tuning fork oscillators, each being tuned to a different note of the tempered scale in the same octave such as: *C*, *C* sharp, *D*, *D* sharp, *E*, *F*, *F* sharp, *G*, *G* sharp, *A*, *A* sharp, *B*. Each of these tuning fork oscillators is associated with a group of seven glow-discharge lamp oscillators which are all tuned to the same note of the scale, but in different octaves. This involves twelve tuning fork oscillators and eighty four glow-discharge lamp oscillators.

What is claimed is:

1. An electrical musical instrument comprising a plurality of circuits, a glow-discharge lamp oscillator adapted to produce electrical oscillations connected in each of said circuits, the frequencies of said oscillators being adjusted to have simple numerical relations, coupling means associated with all the said circuits said coupling means providing sufficiently tight coupling for impressing part of the alternating current output of each oscillator on all of the other oscillators and thereby stabilizing their frequency relations, a common source of current and a common thermionic amplifier for all the said circuits, a switching key for each of the said circuits located intermediate the oscillator and the common amplifier and capable of permitting and stopping the transfer of said oscillations to the amplifier; and sound-producing means operatively associated with said amplifier and being capable of emitting a musical sound for every switching key operated and a musical chord when a plurality of keys are operated.

2. An electrical musical instrument comprising a plurality of circuits, a glow-discharge lamp oscillator adapted to produce electrical oscillations in each of said circuits, the frequencies of said oscillators being adjusted to have simple numerical relations a source of current and a variable impedance in series with said source of current, said impedance and source being common for all said oscillators, said common impedance providing a "tight coupling" for the individual oscillators sufficient for impressing part of the alternating current output of each oscillator on all the other oscillators and thereby assuring constancy of their frequency relations; a thermionic amplifier connected in common for all circuits, a switching key for each circuit located intermediate the oscillator and the common amplifier and capable of permitting and stopping the transfer of said oscillations to the amplifier; and sound-producing means operatively associated with said amplifier and being capable of emitting a musical sound for every switching key operated and a musical chord when a plurality of keys are operated.

3. An electrical musical instrument comprising a plurality of circuits, a glow-discharge lamp oscillator adapted to produce electrical oscillations, a transformer provided in each of said circuits, the frequencies of said oscillators being adjusted to have simple numerical relations, a source of current and a variable impedance in series with said source of current, said impedance and source of current being in common for all said oscillators, said common impedance providing a "tight coupling" for the individual oscillators sufficient for impressing part of the alternating current output of each oscillator on all the other oscillators and thereby assuring constancy of their frequency relations, the secondary winding of aforesaid transformers being connected in series and being connected to the common thermionic amplifier; a switching key for each transformer located across the secondary winding, said key being normally closed to short-circuit the secondary and being capable of actuation to open the short-circuiting lead and causing current to flow to said amplifier; and sound-producing means operatively associated with said amplifier and being capable of emitting a musical sound for every switching key operated and a musical chord when a plurality of keys are operated.

4. An electrical musical instrument comprising a plurality of circuits, a glow-discharge lamp oscillator adapted to produce electrical oscillations in each of said circuits, the frequencies of said oscillators being adjusted to have simple numerical relations, coupling means associated with the said circuits providing "tight coupling" between same thereby stabilizing their frequency relations; a source of direct current and a source of alternating current in common for all said circuits, said alternating current of constant and adequate frequency being impressed through an adjustable coupling on all glow-discharge lamp oscillators thereby assuring constancy of their absolute frequencies; a thermionic amplifier; a switching-key for each glow-discharge lamp oscillator located intermediate the oscillator and the common amplifier and being capable of permitting or stopping transfer of said oscillations to the amplifier; and sound-producing means operatively associated with said amplifier and being capable of emitting a musical sound for every switching key operated and a musical chord when a plurality of keys are operated.

5. An electrical musical instrument comprising a plurality of circuits, a glow-discharge lamp oscillator adapted to produce electrical oscillations in each of said circuits, the frequencies of the said oscillators being adjusted to have simple numerical relations, a source of direct current and a variable impedance in series therewith, said impedance and source of current in common for all said oscillators, said common impedance providing a "tight coupling" for the individual oscillators sufficient for impressing part of the alternating current output of each oscillator on all the other oscillators and thereby assuring their constant frequency relations; a source of alternating current of a constant frequency equalling the frequency of one of the oscillators or a multiple thereof, said alternating current being impressed through an adjustable coupling on all glow-discharge lamp oscillators thereby assuring constancy of their absolute frequencies; a thermionic amplifier; a switching key for each glow-discharge lamp oscillator located intermediate the oscillator and the common amplifier and being capable of permitting or stopping the transfer of said oscillations to the amplifier; and sound-producing means operatively associated with said amplifier and being capable of emitting a musical sound for every switching key operated and a musical chord when a plurality of keys are operated.

6. An electrical musical instrument comprising a plurality of circuits, a glow-discharge lamp oscillator adapted to produce electrical oscillations, a transformer connected in each of said circuits, the frequencies of said oscillators being

adjusted to have simple numerical relations, a source of current and a variable impedance in series therewith, said source of current and impedance being in common for the said oscillators, said common impedance providing a "tight coupling" for the individual oscillators sufficient for impressing part of the alternating current output of each oscillator on all the other oscillators and thereby assuring constancy of their frequency relations, a source of alternating current of a constant frequency equalling the frequency of one of the oscillators or a multiple thereof, said alternating current being impressed through an adjustable coupling on all glow-discharge lamp oscillators thereby assuring constancy of their absolute frequencies; the secondary windings of aforesaid transformers being connected in series and being connected to the common thermionic amplifier; a switching key for each transformer located across the secondary winding, said key being normally closed to short-circuit the secondary and being capable of actuation to open the short-circuiting lead and causing current to flow to said amplifier; and sound-producing means connected to said amplifier and being capable of emitting a musical sound for every switching key operated and a musical chord when a plurality of keys are operated, and a piano key-board operatively associated with said switching keys.

7. An electrical musical instrument comprising a group of circuits for each note in one octave of the musical scale, a plurality of circuits in each group, a glow-discharge lamp oscillator adapted to produce electrical oscillations in each of said circuits, the frequency of said oscillators of the same group being adjusted to consecutive octaves of the same musical note, this note being however a different note of the musical scale for every group; coupling means providing "tight coupling" between oscillators of the group sufficient for impressing part of the alternating current output of each oscillator on all the other oscillators and thereby stabilizing their frequency relations; a direct current source in common for all the groups; a source of alternating current for each group, said alternating current having a constant frequency equalling the frequency of one of the oscillators in the group and being impressed through an adjustable coupling on all glow-discharge lamp oscillators of the group thereby maintaining their absolute frequencies; a thermionic amplifier in common for all groups; a switching key for each glow-discharge lamp oscillator located between the oscillator and the common amplifier, said key being capable of permitting or stopping the transfer of said oscillations to the amplifier; sound-producing means connected to said amplifier and being capable of emitting a musical sound for every switching key operated and a musical chord when a plurality of keys are operated; and a piano keyboard operatively associated with said switching keys.

8. An electrical musical instrument comprising a plurality of circuits, a glow-discharge lamp oscillator in each of said circuits, the said oscillators having frequencies in simple numerical relation to each other, a source of direct current in common for all of the said circuits, coupling means associated with all of the said oscillators and adapted to impress part of the alternating current output of each of said oscillators on all the other oscillators whereby the frequency relations of all the said oscillators will be maintained constant, and sound producing means capable of being connected to said oscillators to produce musical sounds.

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