

Dec. 20, 1938.

N. LANGER ET AL

2,140,840

AUDIO FREQUENCY OSCILLATOR

Filed March 27, 1937

2 Sheets-Sheet 1

Fig. 1.

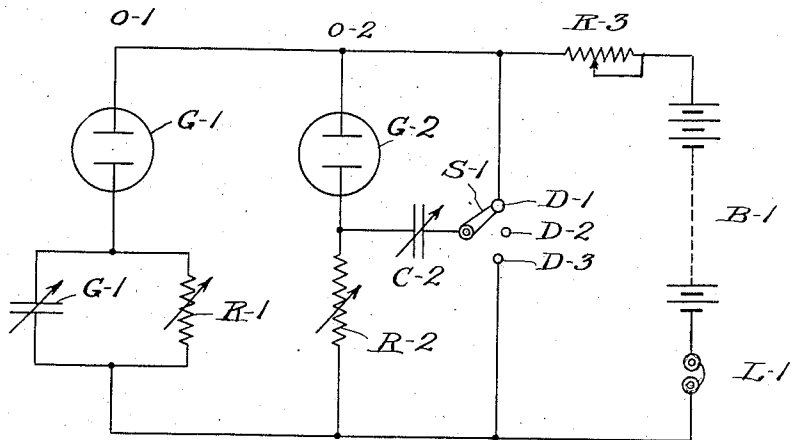
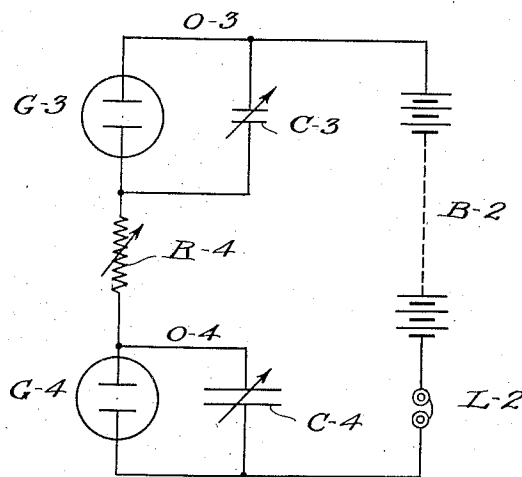


Fig. 2.



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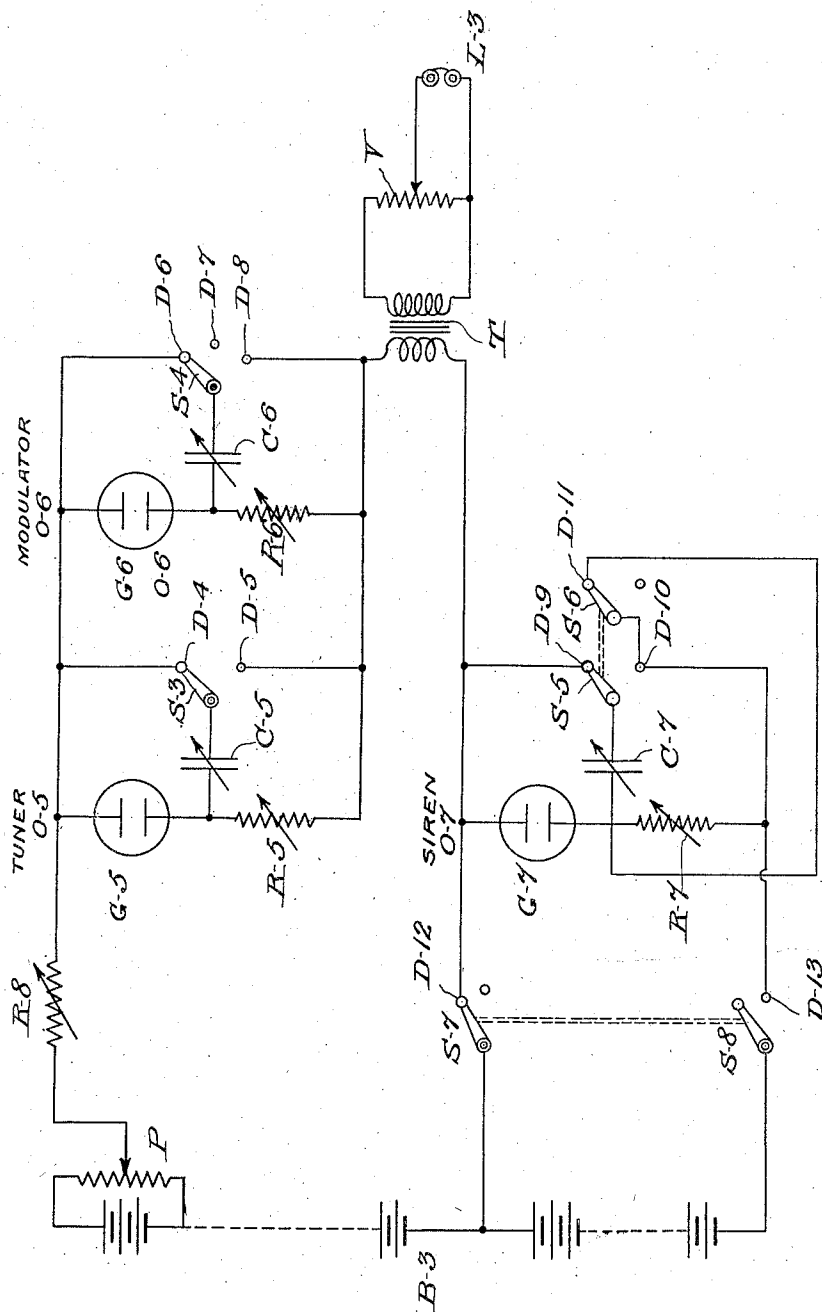
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2 Sheets-Sheet 2

Fig. 3.



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AUDIO FREQUENCY OSCILLATOR

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Application March 27, 1937, Serial No. 133,370

15 Claims. (Cl. 250—36)

The present invention relates to audio frequency oscillators, and, more particularly, to an audio frequency oscillator of novel and improved character for diagnosing and treating deficiencies of the auditory organs.

It has been already suggested to employ sound of predetermined pitch and intensity for re-developing and re-educating the auditory organs which through sickness, deformity or disuse have partially lost their ability to convert sound waves into auditory sensations. Thus, it has been proposed to provide a thermionic tube oscillator capable of producing audio frequency oscillations within the full audible range. These oscillations have been converted into sound by means of earphones or other sound producing means applied to the ears of the patient to be treated. The patient's ears have been subjected to sounds substantially within the frequency range wherein the hearing was found to be deficient and it was expected that re-education of the auditory organs and gradual decrease of the hearing loss will follow from this treatment. Although the principle has been found to be clinically sound and at times highly encouraging results have been obtained, great difficulties have been experienced in producing the required wide range of audio frequency oscillations. The conventional audio frequency oscillators employing thermionic tubes have been found to be very unsatisfactory in view of the fact that these oscillators generally produce oscillations of a pure sinus wave form or, more generally, oscillations very poor in the higher harmonics. On the other hand, experiments seemed to indicate that the ear is generally accustomed to react to audio frequency oscillations of a very complex character such as, for example, the human voice, the sounds of the conventional musical instruments, the various unpitched sounds, or noises, etc. Thus, the thermionic tube oscillators produced sounds which hardly, if ever, occur in nature and which treated and tested the auditory organs with sound waves of such character to which the ear was not generally accustomed. Clearly, this circumstance not only falsified the diagnostic results but at the same time made the treatment by means of sound extremely difficult, if not altogether impossible. Moreover, experiments indicated that extremely beneficial therapeutical results are frequently obtained by means of sounds of very complex character having no constant pitch but a pitch varying at a predetermined and complex rate. In many cases it was found to be desirable to treat the ears with sounds which have

been quite distinct from musical sounds proper and which comprised a relatively large number of individual sounds of various intensities, having variable pitch, and modulating each other at a varying and predetermined rate. Obviously, such extremely complex oscillations cannot be produced by means of a finite number of thermionic tube oscillators nor by means of any other known type of audio frequency oscillators in a simple and economical manner. The art was faced with a grave problem since the beneficial result of certain type of oscillations on the defective hearing was clinically proved, but it was practically impossible to produce such oscillations by means of a simple apparatus which would be available for the average practitioner. Although also many other suggestions and proposals have been made to solve the outstanding problem, none, as far as we are aware, of these various suggestions and proposals was completely satisfactory and successful when carried into practice.

We have discovered that the problem may be solved in a remarkably simple manner.

It is an object of the present invention to provide an audio frequency oscillator particularly for the purposes of diagnosing and treating hearing defects which is free from the disadvantages and inconveniences of conventional devices.

It is another object of the present invention to provide an audio frequency oscillator of novel and improved character which is capable of producing oscillations of a very complex wave form and containing a very substantial percentage of the higher harmonics.

It is a further object of the present invention to provide oscillators adapted to produce audio frequency oscillations the frequency of which is varied or modulated at a predetermined rate.

Still another object of our invention is to produce audio frequency oscillations of extremely complex character including modulated, tremulated and interrupted oscillations without the help of thermionic tubes by means of simple, inexpensive and highly efficient glow discharge tubes.

Moreover, the invention contemplates a novel audio frequency oscillator including a plurality of glow discharge lamp oscillators combined in such a manner that the oscillations produced by one of them will react on and will modify or modulate the oscillations produced by the others so that the most varied sounds, including the various pitched and unpitched sounds found in nature, may be imitated in a simple and direct manner.

It is also within contemplation of the inven-

tion to provide an audio frequency oscillator of the described character which is simple in construction and easy and inexpensive to manufacture and to operate.

5 Other and further objects and advantages of the invention will become apparent from the following description taken in conjunction with the accompanying drawings, in which:—

Fig. 1 illustrates a novel circuit employing two glow discharge lamp oscillators in co-operating and modulating relation, producing modulated or interrupted oscillations;

Fig. 2 depicts a circuit employing two glow discharge lamp oscillators in such a manner that the frequency of the oscillations produced by one of said oscillators is varied according to the rate of the oscillations produced by means of the other oscillator; and

Fig. 3 is a circuit of an audio frequency oscillator embodying the principles of the present invention and a suitable combination of circuits 1 and 2.

Broadly stated, we have discovered that the oscillations produced by means of glow discharge lamp oscillators possess remarkable properties for the diagnosis and treatment of hearing defects. As those skilled in the art know, glow discharge lamp oscillators essentially comprise a glow discharge lamp having two cold electrodes, a condenser and a high resistance connected to each other. If these elements are combined in a suitable manner and are connected to a source of direct current, the condenser will be periodically charged and discharged, the rate of charge and thus the frequency of the oscillations produced being a function of the various circuit constants and of the voltage of the source of current. The oscillations produced in this manner have a wave form sometimes referred to as a saw tooth wave, which indicates the presence of very substantial amounts of the higher harmonics. The principles of designing and operating such audio frequency oscillators are disclosed, for example, in U. S. Patent No. 1,832,402, granted November 17, 1931, to Langer.

We have found that the oscillations produced by glow discharge lamps have all of the desirable properties required for the diagnosis and treatment of hearing defects. The oscillations have a character which can closely simulate the harmonics of the human voice and of the principal musical instruments and have a therapeutical effect which is greatly superior to that obtainable by any one of the conventional oscillators, including thermionic tube oscillators. Another very important advantage of glow discharge lamp oscillators is that they may be combined in various ways and in such a manner that the oscillations produced by one of the oscillators is modulating and influencing the oscillations produced by means of the others. It has already been known that glow discharge lamp oscillators are greatly subject to modulation and to feed-back effects by other oscillators operated in proximity thereof and supplied from the same source of current and this effect has been discovered and recognized as a disturbing factor in the construction of electrical musical instruments in which a large number of such oscillators is simultaneously operated. However, in the prior art this property of glow discharge lamp oscillators was felt as a disadvantage which is to be carefully avoided or to be compensated for. In contrast to this, one of the objects of the present invention is not to avoid but to deliberately increase and facilitate

the production of such complex and modulated oscillations, as this will be explained more fully hereinafter.

Referring now more particularly to Fig. 1, the combination of two glow discharge lamp oscillators is illustrated for the production of modulated oscillations of a complex character. The first of the glow discharge tube oscillators comprises a glow discharge tube G—1, a variable high resistance R—1 connected in series with said tube, and a variable condenser C—1 connected in parallel to said resistance. An oscillator of this character, when connected to a source of direct current of suitable voltage, is capable of producing electrical oscillations the frequency of which is determined by the capacity of the condenser, the value of the resistance, the constants of the glow discharge tube, and the voltage of the source of current. The produced oscillations are of a very complex form and contain strong harmonics. The second oscillator comprises a glow discharge tube G—2 which is connected in series with a variable resistance R—2. A variable condenser, C—2, is connected to the common point of the tube and of the resistance and is having its other side connected to a three position switch S—1. Switch S—1 may selectively contact any one of three contacts D—1, D—2, or D—3. Contact D—1 is connected to the free terminal of glow discharge tube G—2, contact D—3 is connected to the lower or free terminal of resistance R—2, and center contact D—2 is insulated from the circuit. Therefore, in the first position of the switch, the condenser will be connected across the glow discharge tube, in the third position it will be connected across the resistance, whereas in the second or center position the condenser will be completely disconnected and will be inoperative so that no oscillations will be produced. Both glow discharge tubes G—1 and G—2 have their upper terminal connected to one pole of a battery B—1 having a voltage of about 110 volts through an adjustable resistance R—3 of about 5000 to about 50,000 ohms, the two lower terminals of resistances R—1 and R—2 are connected to the other pole of the battery through a sound producing means L—1. It will be noted that both resistance R—3 and sound producing means L—1 are in the common branch of the circuit and in series with the battery.

From the preceding description the operation of this circuit will be readily understood by those skilled in the art. Oscillator O—1, constituted of G—1, C—1, and R—1, is adjusted to produce an oscillation of the desired frequency. Oscillator O—2, constituted of G—2, C—2, and R—2, is adjusted to produce another oscillation which preferably is of a considerably lower frequency. It will now be found that each time when during the oscillations of G—2 current is drawn from B—1 through resistance R—3, this will cause a drop in voltage across this resistance and will decrease the electromotive force available for the oscillator O—1. Reduction of the voltage will cause a decrease in the frequency of the oscillations produced. Thus, the frequency of the oscillations will be periodically influenced in accordance with the frequency of oscillator O—2. It is also to be observed that the wave form of the oscillations produced by means of O—2 will be considerably different when switch S—1 is in its first or in its third position, that is, when condenser C—2 is connected across the tube or across the resistance, respectively. In the first case, condenser C—2 will be slowly charged and will

be quickly discharged periodically while in the other case, the condenser will be charged very rapidly and in an impulse-like manner and is discharged slowly. This will have the effect that in the first case, when the condenser of the modulating tube is connected across the tube, the oscillations will have a relatively smooth and continuous course, and the resultant oscillations will be of a smooth character and of a slowly modulated frequency. In the case, however, when the condenser C—2 is connected across the resistance R—2, the oscillations produced will be of a very abrupt character and the oscillator will momentarily draw a very substantial current. At times so much current will be drawn through R—3, that the voltage available for O—1 will be decreased below the ignition voltage of the tube G—1 and will completely interrupt the oscillations thereof. Thus, the oscillations will be of a modulated frequency and at the same time of an intermittent or interrupted character, the number of interruptions per second equaling the frequency of O—2. For the sake of simplicity, the first aforesaid condition, that is the production of smooth and frequency modulated oscillations will be referred to in the following as tremulated oscillations and the effect so produced the tremolo effect, while the production of interrupted modulated oscillations will be referred to as the banjo effect. Any one of these effects may be produced at will by placing switch S—1 either into the first or into the third position, while in the center position O—2 will be rendered completely inoperative so that only the simple unmodulated oscillations of O—1 will be produced. Of course, L—1 will be at all times under the additive effect of these oscillations and will emit a sound in accordance with such oscillations. The obtained effects will be greatly subject to variations in accordance with the respective frequencies of O—1 and O—2 whereby a great variety of interesting sound effects of complex and of periodically repeating character will be obtained.

While Fig. 1 illustrates an arrangement in which two glow discharge tube oscillators O—1 and O—2 are arranged parallel to a common source of current, B—1, Fig. 2 depicts a circuit arrangement in which the two oscillators O—3 and O—4 are arranged in series and are supplied from a common source of current, B—2. In view of the fact that in this circuit the tubes are in series, it is preferred to employ a substantially higher voltage, for example about the double required for a single oscillator, that is about 200 to 250 volts. Oscillator O—3 comprises a glow discharge tube G—3 and a variable condenser C—3 connected across G—3; oscillator O—4 comprises a glow discharge tube G—4 and a variable condenser C—4 connected across G—4. A variable resistance R—4 generally higher than 1 megohm is connected in series with both glow-discharge tubes and is part of both oscillators. The two oscillators are connected in series with a source of current, B—2, and with a sound producing means, L—2. The values of C—3, C—4 and R—4 can be varied within wide limits, approximately the same values may be used as in a single glow discharge tube oscillator. The voltage of B—2, however, has to be at least twice as high as the break-down voltage of one glow discharge tube since the two tubes are connected in series.

The oscillations produced by this circuit are of a very complex character. Assuming that the break-down voltage of the two lamps is not very

far one from the other, then the lamp connected to the condenser of smaller capacity will light up first, since this condenser will be first charged up to a potential higher than the break-down voltage of the tube. This will cause a discharge to take place through the other tube, but the operating voltage of each tube-condenser system will be affected every moment by the momentary condition in the other. As a result of this condition, an electrical oscillation will be produced in the common part of the circuit, the frequency of which will be regularly varying between two extreme values. After the continuously decreasing frequency has reached its lower limit, it will suddenly jump to the highest frequency and will start decreasing again. Thus, by changing the proportion of C—3 to C—4, very different and strange effects can be obtained. In case C—3 and C—4 are very closely of the same capacity, only one oscillation of constant frequency and of considerable amplitude will be produced. If there is some difference between the two capacities, a note will be produced in the sound producing means L—2, the frequency of which will be subject to small periodical fluctuations, similar to the well-known vibrato or tremolo of the string instruments or of the singing voice. If the difference between C—3 and C—4 is very great, for example C—3 equals about 0.001 microfarad and C—4 equals about 2 microfarads, then the frequency fluctuations will be carried out within a very wide range, and the sound heard in L—2 will give a close imitation of the sound of a fire siren. In other words, the pitch of the sound will be varying between two extreme values and will gradually decrease to the lower limit and then will suddenly jump to the highest limit and will start slowly decreasing again. The most various results as to the frequency region of the oscillations produced, the limits between which the frequency varies, and as to the rate of the variations can be obtained by adjusting C—3, C—4 and R—4 with respect to each other. In the following this effect obtained by the combination of two glow discharge tube oscillators arranged in series will be referred to as the siren effect.

Both the circuits shown in Figs. 1 and 2 are capable of producing practically infinite combinations of various complex sounds. Thus, it will be readily understood that by combining the circuits of Figs. 1 and 2 into the modified audio frequency oscillator depicted in Fig. 3, this will be capable of producing practically any recurrent acoustical phenomenon irrespective of pitch, timber, and irrespective of the circumstance whether this acoustical phenomenon be more of the character of a musical sound or of a noise.

The audio frequency oscillator illustrated in Fig. 3 essentially comprises three glow discharge tube oscillators, O—5, O—6 and O—7, referred to in the following for the sake of simplicity as the tuner, modulator and siren oscillators, respectively. The tuner oscillator, O—5, comprises a glow discharge tube G—5, a variable high resistance R—5 connected in series with the tube, and a variable condenser C—5 having one of its terminals connected to the common connecting lead of G—5 and R—5 and its other terminal connected to a two-position switch S—3 having two contact points, D—4 and D—5. Contact D—4 is connected to the upper terminal of glow discharge tube G—5, and contact D—5 is connected to the lower terminal of resistance R—5 whereby the variable condenser may be connected

either across the tube, or the resistance, by placing switching arm S—3 on contact D—4 or D—5, respectively.

The modulator oscillator, or modulator O—6, comprises a glow discharge tube G—6, an adjustable resistance R—3 connected in series with the tube, and a variable condenser C—6 having one of its terminals connected to the common connecting lead of G—6 and R—6 and its other terminal connected to a three-position switching arm S—4 having three contacts, D—6, D—7, and D—8. Contact D—6 is connected to the upper or free terminal of glow discharge tube G—6, contact D—8 is connected to the lower terminal of resistance R—6, and contact D—7 is insulated from the circuit. Thus, when contact arm S—4 is on contact D—6, condenser C—6 is connected across tube G—6, when the contact arm is on contact D—8, condenser C—6 is connected across resistance R—6, and when the contact arm is on contact D—7, the condenser is altogether disconnected from the circuit, rendering the oscillator inoperative.

Same as in the circuit shown in Fig. 1, the tuner and the modulator oscillator are connected with each other by connecting the upper terminals of the two tubes and the lower terminals of the two resistances with each other. The tuner and modulator oscillator are energized from the upper portion of a battery B—3 having a potentiometer P connected across the uppermost section thereof for adjusting the operating voltage. The common lead of tubes G—5 and G—6 is connected to the sliding contact of potentiometer P through a series resistance R—2 of adjustable character providing the coupling between the two oscillator circuits whereby the oscillations of the one are impressed upon the other. The common lead of resistances R—5 and R—6 is connected through primary winding of transformer T to contact D—12 of switching arm S—7. Switching arm S—7 is connected to the intermediate terminal of battery B—3. Thus, when switching arm S—7 is on contact D—12, the circuit of the two oscillators O—5 and O—6 is completed. The common and modulated output of these oscillators is obtained through the secondary winding of transformer T having a volume control potentiometer V connected across the same whereby the intensity of the sound produced in sound producing means L—3, connected between the sliding contact of the potentiometer and the lower terminal of the potentiometer, may be adjusted. In view of the similarity of this circuit to the one shown in Fig. 1, its operation will be readily understood by those skilled in the art without any further explanation.

The siren oscillator, O—7, comprises a glow discharge tube G—7, a variable resistance R—7 connected in series with the tube, and a variable condenser C—7 having one of its terminals connected to the common lead of the tube and of the resistance and having its other terminal connected to switching arm S—5. Switching arm S—5 is provided with two contacts, D—9 and D—10, of which D—9 is connected to the upper terminal of tube G—7, the other, D—10, being connected to the lower terminal of resistance R—7. Thus, when switching arm S—5 is in the upper position and touches contact D—9, condenser C—7 is connected across tube G—7, and when switching arm S—5 is in its lower position and touches contact D—10, condenser C—7 is connected across resistance R—7. Siren oscillator O—7 has also another switching arm S—6

associated therewith which is connected to the lower end of resistance R—7. Switching arm S—6 has merely one operative contact, D—11, which is connected to the common terminal of tube G—7, resistance R—7, and condenser C—7 and is contacted by switching arm S—6 in the upper position thereof. Switching arms S—5 and S—6 are so constructed and arranged that both of them are simultaneously actuated and form a double pole, two position switch. It will be noted that switching arm S—6, in the upper position thereof, short-circuits resistance R—7 and at the same time switching arm S—5 connects condenser C—7 across tube G—7. The siren oscillator is provided with a condenser and a resistance of such value as oscillator O—4, shown in Fig. 2. To supply oscillator O—7 with current, the upper terminal of tube G—7 is connected to the primary winding of transformer T and the lower terminal of resistance R—7 is connected to a contact D—13 which may be connected to the lower terminal of battery B—3 in the lower position of switching arm S—8. Switching arm S—8 is positively connected to another switching arm S—7, for example by means of an insulating rod, so that they are always simultaneously actuated. Thus, it will be noted that when S—7 and S—8 are in the upper position, merely the connection of tuner and modulator oscillators O—5 and O—6 is established with the upper portion of battery B—3 and the circuit of the siren oscillator is interrupted at D—13, whereas when the two switching arms are in their lower position, the connection of the primary winding of transformer T with the intermediate terminal of battery B—3 is interrupted at D—12, and the siren oscillator is supplied with current from potentiometer P through the tuner and modulator oscillators and the primary winding of T. At the same time, the circuit of the siren oscillator to the lower terminal of the battery is completed by contact D—13 being closed by switching arm S—8.

To understand the operation of the complete oscillator, it is to be observed at the outset that all of the condensers and resistances employed are variable in steps and/or continuously, for permitting adjustment of the oscillations produced by the various oscillators within wide limits. Whether such elements variable continuously or in steps are employed, depends primarily on practical considerations. Thus, in the tuner, it is preferred to make the condenser continuously variable and the resistance variable in steps in view of the fact that continuously variable high resistances are generally difficult to obtain, are unstable and expensive. Preferred values for C—5 are from a minimum as low as possible, up to about 0.004 microfarad, whereas R—5 may be a resistance which may be varied from about 1 megohm up to about 50 megohms, and more. In the modulator, it is desirable to produce oscillations of very low frequency down to a few oscillations a second or even less. Therefore, it is preferred to employ a condenser adjustable in 4 or 5 steps, or more, between about 0.001 to about 1 microfarad, while resistance R—6 is continuously variable between 1 and 3 megohms. In the siren oscillator, R—7 may be provided with an adjustment similar to R—5, while the capacity is adjustable in steps between very wide limits such as about 0.001 to about 10 microfarads or more. Generally speaking, it is preferred to have at least R or C continuously variable in each circuit in order to obtain full cov-

erage of the frequency ranges contemplated for the various oscillators.

From the preceding description the operation of the complete oscillator will be readily understood. When S—3 is in contact with D—4 or D—5; S—4 is in the center position and in contact with D—7, while S—7 and S—8 are in their upper position, only the tuner will be operative. The modulator will be inoperative, since condenser C—6 will be unipolarly disconnected. Likewise, the siren will be inoperative since its current supply is interrupted at D—13. The circuit of the tuner is, however, complete through S—7, D—12 and the primary winding of transformer T. Thus, oscillations of any frequency within the audible range may be obtained by varying R—5 and/or C—5. By putting S—2 over into its other position, when it contacts D—5, generally does not affect the frequency of the oscillations produced but only the wave form thereof thereby permitting to obtain other sound effects of the same frequency range. When it is desired to modulate these oscillations, modulator O—5 is made operative by moving switch S—4 from the center position into one of its extreme positions. If this extreme position is the upper one in which C—6 is connected across the tube, the modulating effect will be slight and similar to the well-known tremolo effect. On the other hand, if the switch S—4 is in its lower position, the modulating effect will be strong enough to practically stop and start the oscillations produced by the tuner and to practically amount to an interrupter effect. Due to the similarity of this effect to the sound of the plucked string, it will be referred to hereinafter as the banjo effect. The modulator is generally tuned to a frequency of relatively low value, such as 5 to 10 oscillations per second, although modulation with much higher frequencies is by no means excluded from the contemplation of the present invention and provides other and further interesting effects. In both of these cases only the upper half of the source of current, B—3, is operative having a voltage of at least about 100 volts which, if desired, may be adjusted by means of a potentiometer P.

If it is desired to actuate the siren oscillator, switches S—7 and S—8 are changed over into their lower position in which the full voltage of current source B—3 is operative and the tuner and siren oscillators are connected in series much in the same manner as in the circuit shown in Fig. 2. It will be noted that when switch S—3 contacts D—4, S—4 is in the inoperative center position, S—5 contacts D—9, and S—6 contacts D—11, the circuit becomes almost identical with that of Fig. 2, and, of course, will produce sound effects having a periodically varying frequency, the character of periodicity being variable in accordance with the adjustments of the siren circuit. This wide scale of sound effects which permits almost infinite number of combinations is still further extended by simultaneously operating the modulator by putting S—4 into one of its extreme positions. Likewise, further modifications in the character and periodicity of the oscillations produced may be obtained by varying the positions of switches S—3 and/or S—5. By adjusting the electrical constants of the tuner, modulator and siren circuits such wide variety of audible oscillations may be obtained that practically any periodically repeating sound effect including strange and unusual sounds, noises, etc. can be reproduced by means of suitable adjust-

ment of the oscillators. Of course, the oscillators are preferably provided with dials (not shown) in conventional manner so that any sound effect once obtained can be reproduced with the greatest facility after a few simple adjustments. Experiments have demonstrated that the oscillator embodying the principles of the present invention is capable of imitating sounds as widely different as the sound of a thunderstorm, the rattling of machinery, or the call of birds and of various animals.

The output of the oscillator is taken off through the secondary winding of transformer T, the intensity of the output being adjusted by means of a volume control potentiometer V. The resulting oscillations of controlled intensity are introduced into a sound producing contrivance, L—3 and are converted into sound. In practical operation it is generally preferred to connect a suitable amplifier between the output transformer and the sound producing contrivance.

It will be noted that the advantages of the oscillator embodying the principles of the present invention are numerous. First of all, in diagnosing and treating deficiencies of the auditory organs, it is possible to produce practically any sound impulse to which the human ear may be subjected. Thus, when the device is employed as a tuner oscillator, the hearing may be diagnosed and the hearing loss for the individual frequencies of the audible range may be determined, in conventional manner. Hereafter, once the character of the hearing loss has been ascertained, the ear may be subjected to treating impressions of the most various character produced by the oscillator. These treating impressions are varying according to the character of the hearing defects and are based on clinical experience. It has been established that frequently very unusual sequential combinations of sounds rarely if ever encountered in nature have a very high curative effect much in the same manner as the well-known finger exercises written for certain musical instruments permit mastering of the technical difficulties of the particular instrument although in themselves represent such artificial combinations of sounds which are far from being euphonic and which never occur in musical compositions. All of these combinations of oscillatory effects are readily obtained and reproduced at any time by means of the present oscillator.

It is also to be observed that the usefulness of our novel oscillator is by no means limited to the diagnosing and treating of hearing defects. As a matter of fact, the various sound effects obtained may be advantageously used in providing sound effects for talking moving pictures, broadcasting studios and for stage performances. Moreover, it has been found experimentally that certain periodically repeating sound combinations have a soporific effect and may be employed for promoting sleep of persons suffering from insomnia.

Although the present invention has been described in connection with a preferred embodiment thereof, variations and modifications may be resorted to by those skilled in the art without departing from the principles of the present invention. Thus, more than three oscillators may be used which are connected with each other in various ways and are coupled to each other by means of inductive, capacitive or ohmic coupling members. We consider all of these variations and modifications as within the true spirit and scope of our invention as disclosed in the

present description and defined by the appended claims.

We claim:—

1. In an audio frequency oscillator, the combination comprising a plurality of circuits adapted to produce electrical oscillations, each of said circuits including a glow discharge tube and a resistance and a condenser, said resistance being connected in series with said tube, coupling means in each of said circuits for providing tight coupling therebetween whereby the oscillations produced by each of said tubes will be modulated by the oscillations produced by the others, and switching means in each of said circuits for selectively connecting said condenser across said tube and across said resistance.

2. In an audio frequency oscillator, the combination comprising a plurality of circuits adapted to produce electrical oscillations, each of said circuits including a glow discharge tube and a resistance and a condenser, said resistance being connected in series with said tube, a source of current in common for said circuits, coupling means connected in each of said circuits for providing tight coupling therebetween whereby the oscillations produced by said circuits will be respectively influenced and modulated by the oscillations of the others, and switching means in each of said circuits for selectively connecting said condenser across said tube and said resistance.

3. In an audio frequency oscillator, the combination comprising a plurality of circuits, each of said circuits including a glow discharge tube and a resistance and a condenser, said resistance being connected in series with said tube, a source of current in common for said circuits, coupling means connected in each of said circuits for providing tight coupling therebetween whereby the oscillations produced by said tubes will be respectively influenced and modulated by the oscillations of the others, switching means in each of said circuits for selectively connecting said condenser across said tube and across said resistance, and means for withdrawing the resultant of said oscillations.

4. In an audio frequency oscillator, the combination comprising a plurality of circuits, a glow discharge tube and a resistance and a condenser in each of said circuits and forming an oscillator therewith, said resistance being connected in series with said tube, a source of current in common for said circuits, coupling means connected in each of said circuits adapted to transfer such amounts of energy from one of said circuits to the others as to make the operation of each circuit dependent from the oscillatory condition of the others, and switching means in each of said circuits for selectively connecting said condenser across said tube and across said resistance.

5. In an audio frequency oscillator, the combination comprising a plurality of circuits, a glow discharge tube and a resistance and a condenser in each of said circuits and forming an oscillator therewith, said resistance being connected in series with said tube, a source of current in common for said circuits, coupling means electrically connected in each of said circuits adapted to transfer such amounts of oscillatory energy from each of said circuits to the others as to make the operation of each circuit dependent from the oscillatory condition of the others, switching means in each of said circuits for selectively connecting said condenser across said tube and said resistance, and means for adjusting said coupling means.

6. In an audio frequency oscillator, the combination comprising a plurality of circuits, a glow discharge tube and a resistance and a condenser in each of said circuits, said resistance being connected in series with said tube, a source of current for said circuits, coupling means in said circuits for causing interdependence between the oscillatory condition of said tubes whereby complex oscillations are set up in the parts in common of said circuits, and switching means in each of said circuits for selectively connecting said condenser across said tube and across said resistance to change the character of said complex oscillations.

7. In an audio frequency oscillator, the combination comprising a plurality of circuits, a glow discharge tube and a resistance and a condenser in each of said circuits, said resistance being connected in series with said tube and said condenser being adapted to be selectively connected across said tube and said condenser, switching means in each of said circuits for establishing said selective connection at the will of the operator, a source of current for said circuits to cause the production of electrical oscillations therein, coupling means in each of said circuits to cause cross-modulation of said oscillations, and means for selectively adjusting the frequency and the wave form of the oscillations produced by each of said oscillators.

8. In an audio frequency oscillator, the combination comprising a plurality of circuits, a glow discharge tube and a resistance and a condenser in each of said circuits, said resistance being connected in series with said tube and said condenser being adapted to be selectively connected across said tube and across said resistance, switching means in each of said circuits for establishing said selective connection at the will of the operator, the tube and series resistance of at least one of said circuits being connected in series with the tube and series resistance of the others to cause cross-modulation of the oscillations produced, a source of current in common for said circuits, and means for withdrawing the resultant of said oscillations from said circuits.

9. In an audio frequency oscillator, the combination comprising three circuits, a glow discharge tube and a resistance and a condenser in each of said circuits, said resistance being connected in series with said tube, a pair of said circuits being connected to each other to have the tube and series resistance therein in parallel with each other and the third of said circuits being connected with the aforesaid pair of circuits to have its tube and series resistance in series with the others, a source of current in common for said circuits, a coupling resistance in series with said source of current whereby complex oscillations will be produced by cross-modulation of the oscillations produced in said circuits, means for withdrawing cross-modulated oscillatory energy from said circuits, and switching means in each of said circuits for selectively connecting the condenser across the tube and across the resistance to vary the waveform of said withdrawn oscillations.

10. In an audio frequency oscillator, the combination comprising three circuits; a glow discharge tube, a variable resistance and a variable condenser in each of said circuits, said resistance being connected in series with said tube, a pair of said circuits being connected to each other to have the tube and series resistance therein in

parallel with each other and the third circuit being connected with the aforesaid pair of circuits to have the tube and series resistance therein in series with the others, a source of current in common for said circuits, a variable coupling resistance in series with said source of current whereby complex oscillations will be produced by cross-modulation of the oscillations produced in said circuits, means for withdrawing cross-modulated oscillatory energy from said circuits, and switching means in each of said circuits for selectively connecting the condenser across the tube and across the resistance to vary the waveform of said withdrawn oscillations.

11. In an audio frequency oscillator, the combination comprising a glow discharge lamp oscillator including a glow discharge tube, a resistance connected in series with said tube, and a condenser having one of its terminals connected to the connecting lead of said tube and of said resistance and having its other terminal selectively connected to the free terminal of said tube and of said resistance; a second glow discharge oscillator of similar character having its tube and series resistance connected across the tube and series resistance of the first oscillator and being adapted to cause frequency modulation thereof; a third glow discharge tube oscillator of similar character having its tube and series resistance in series with the tubes and series resistances of the aforesaid oscillators and being adapted to modulate the resultant of the first two oscillations; a source of current constituted of an upper and of a lower part having its upper part connected to the first two of said oscillators and its lower part to the third of said oscillators; and means for withdrawing complex oscillations of modulated frequency from said oscillators.

12. In an audio frequency oscillator, the combination comprising a glow discharge tube lamp oscillator including a glow discharge tube, a resistance connected in series with said tube, and a condenser having one of its terminals connected to the connecting lead of said tube and of said resistance and having its other terminal selectively connected to the free terminal of said tube and of said resistance; a second glow discharge tube oscillator of similar character having its tube and series resistance connected across the tube and series resistance of the first oscillator and being adapted to cause frequency modulation thereof; a third glow discharge tube oscillator of similar character having its tube and series resistance in series with the tubes and series resistances of the aforesaid oscillators and being adapted to modulate the resultant of the first two oscillations; a source of current constituted of an upper and of a lower part having its upper part connected to the first two of said oscillators and its lower part to the third of said oscillators; means for withdrawing complex oscillations of modulated frequency from said oscillators; and means in the circuit of each of said oscillators for adjusting the frequency and the waveform of said withdrawn oscillations.

13. In an audio frequency oscillator, the com-

bination comprising a glow discharge tube oscillator including a glow discharge tube, a resistance connected in series with said tube, a condenser having one of its terminals connected to the connecting lead of said tube and of said resistance, and switching means for selectively connecting the other terminal of said condenser to the free terminal of said tube and of said resistance; a second glow discharge tube oscillator of similar character having its tube and series resistance connected across the tube and series resistance of the first oscillator and being adapted to cause frequency modulation thereof; a third glow discharge tube oscillator of similar character having its tube and series resistance in series with the tubes and series resistances of the aforesaid oscillators and being adapted to modulate the resultant of the first two oscillations; a source of current constituted of an upper and of a lower part having its upper part connected to the first two of said oscillators and having its lower part connected to the third of said oscillators; means for withdrawing complex oscillations of modulated frequency from said oscillators; said switching means in the circuit of each of said oscillators being adapted to adjust the waveform of said withdrawn oscillations.

14. In an audio frequency oscillator, the combination comprising a pair of oscillators, each of said oscillators including a glow discharge tube and a resistance in series with said tube, a condenser connected across the resistance of the first oscillator, a condenser for said second oscillator, a source of current in common for said oscillators and having its terminals respectively connected to the free terminals of said tubes and to the terminals of said resistances which are not connected to said tubes, means for providing tight coupling between said oscillators to cause cross-modulation of the oscillations produced, and switching means in the circuit of the second oscillator for selectively connecting said condenser across said tube and across said resistance to vary the character of said cross-modulation.

15. In an audio frequency oscillator, the combination comprising a pair of oscillators, each of said oscillators including a glow discharge tube and a variable resistance in series with said tube, a variable condenser connected across the resistance of the first oscillator, a variable condenser for said second oscillator, a source of current in common for said oscillators and having its terminal respectively connected to the free terminals of said tubes and to the terminals of said resistances which are not connected to said tubes, means including a variable resistance in series with said source of current for providing tight coupling between said oscillators and to cause cross-modulation of the oscillations produced, and switching means in the circuit of the second oscillator for selectively connecting said condenser across said tube and across said resistance to vary the character of said cross-modulation.

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