

March 21, 1933.

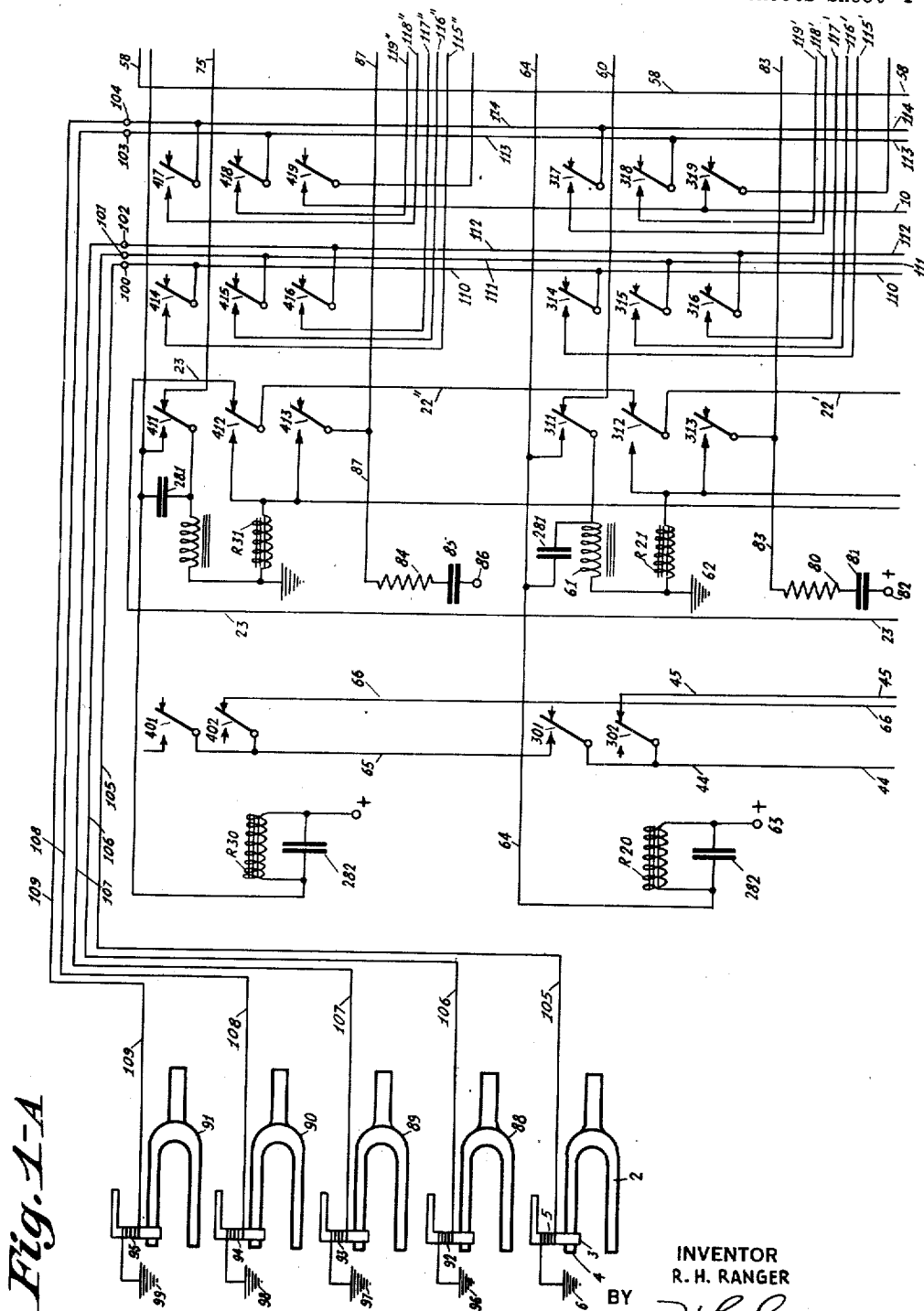
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1,901,985

ELECTRICAL MUSIC SYSTEM

Filed Dec. 30, 1929

8 Sheets-Sheet 1



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ELECTRICAL MUSIC SYSTEM

Filed Dec. 30, 1929

8 Sheets-Sheet 2

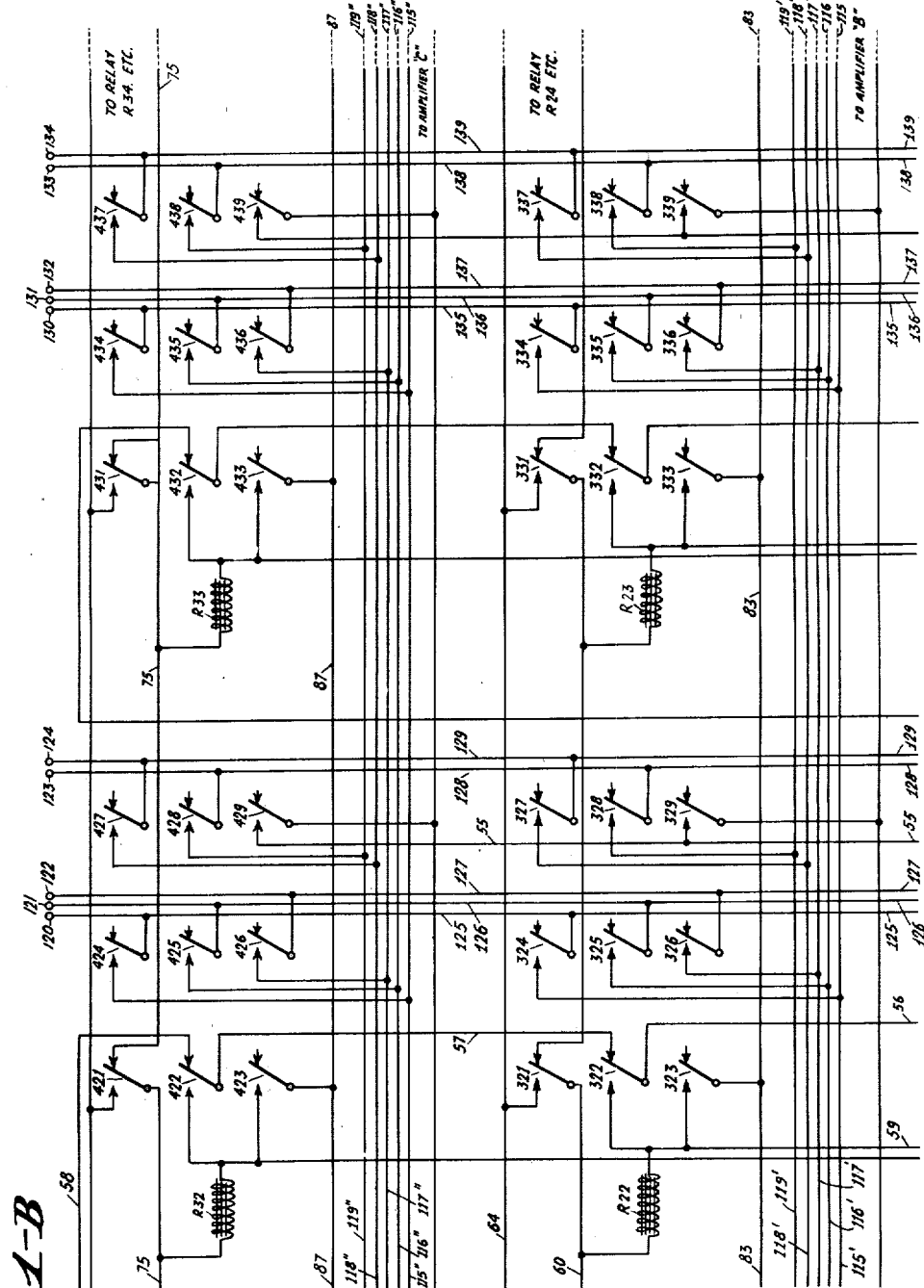


Fig. 1-B

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Filed Dec. 30, 1929

8 Sheets-Sheet 3

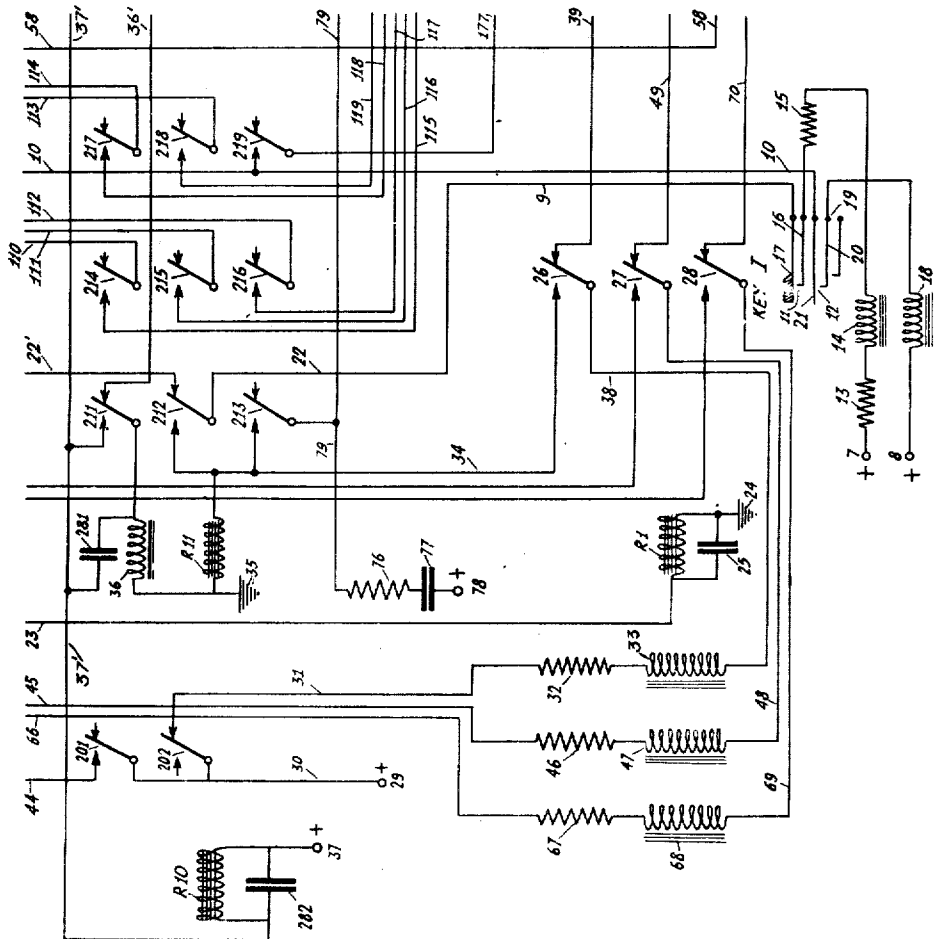


Fig. 1-C

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Filed Dec. 30, 1929

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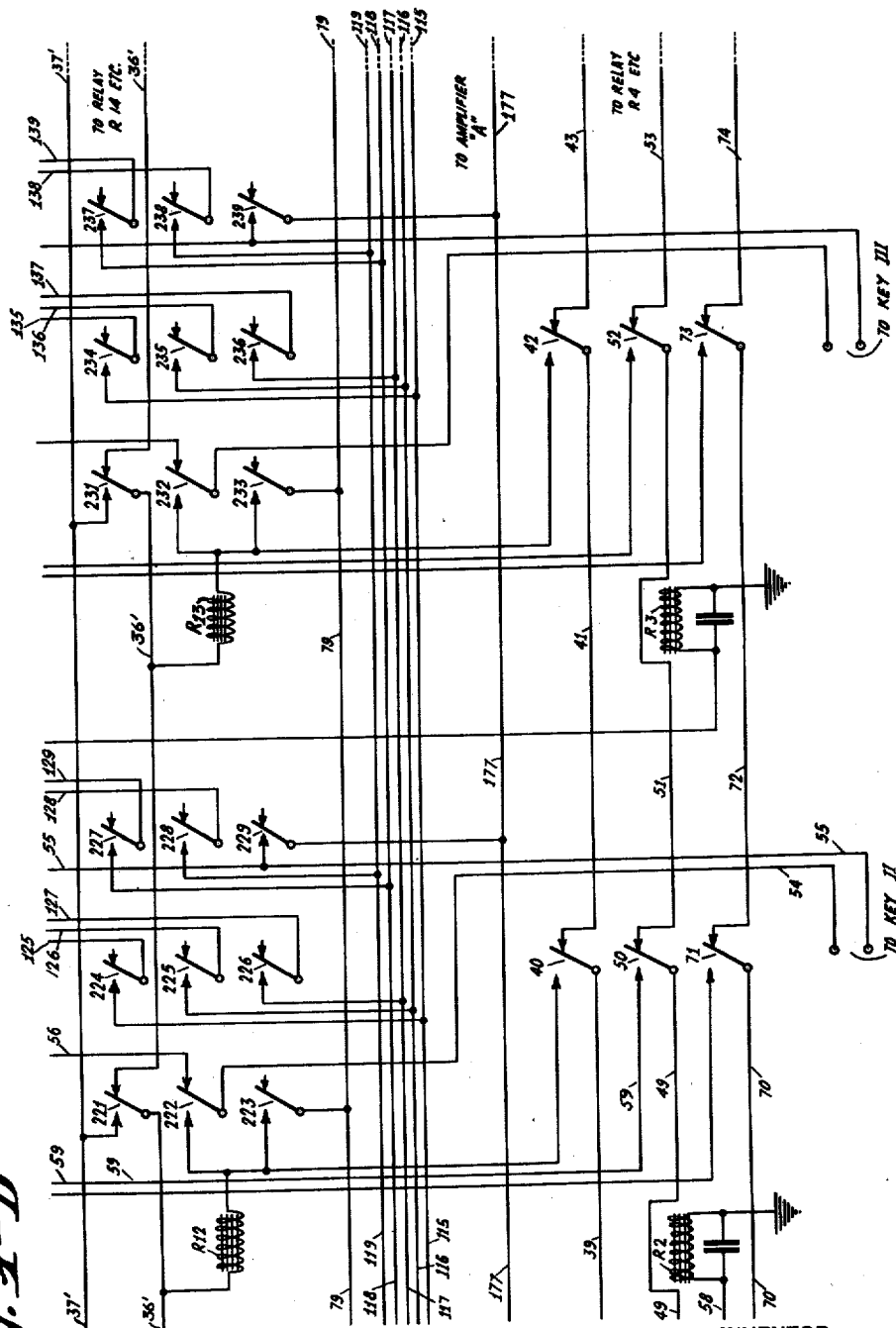


Fig. 1-D

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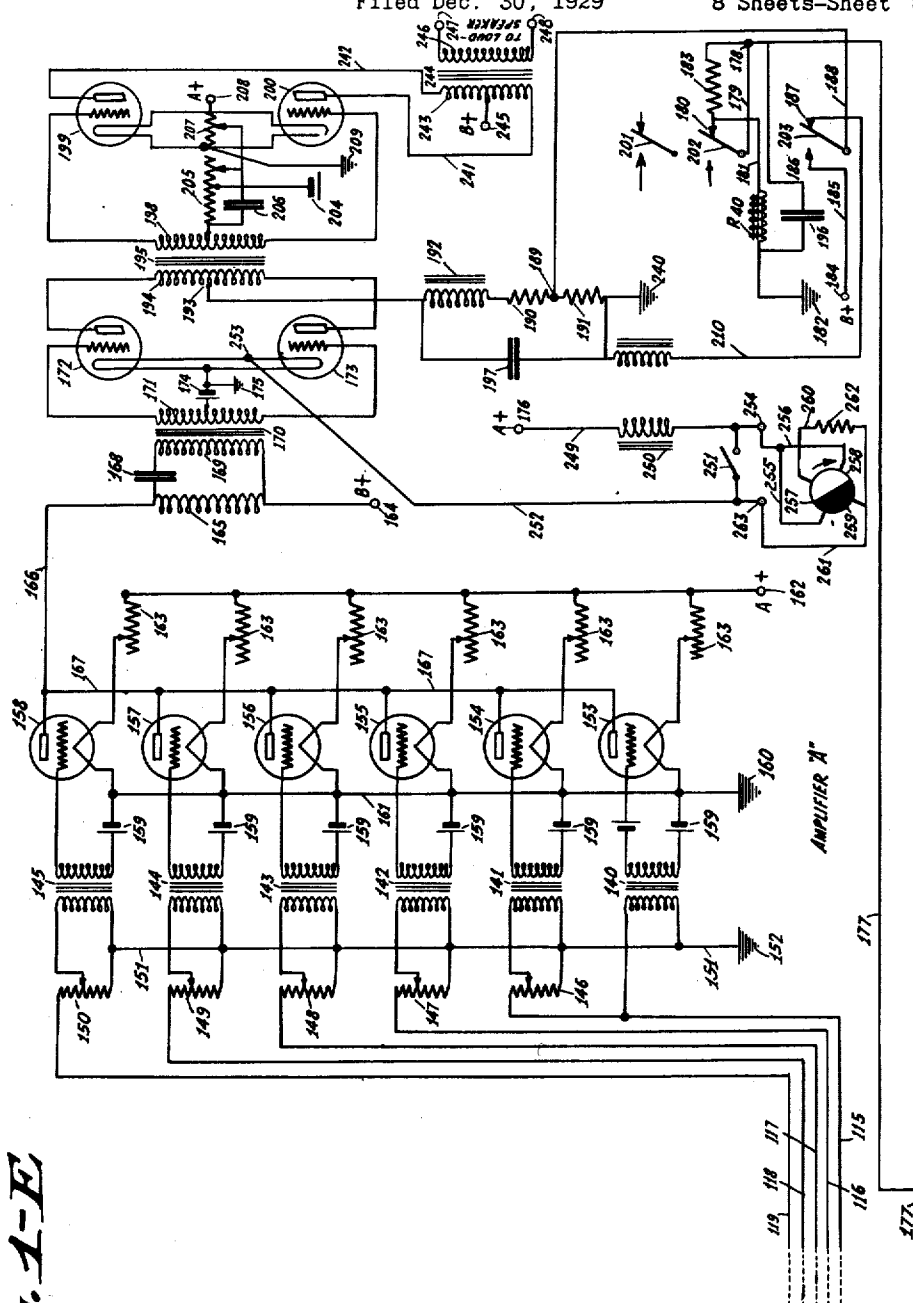
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Filed Dec. 30, 1929

8 Sheets-Sheet 5



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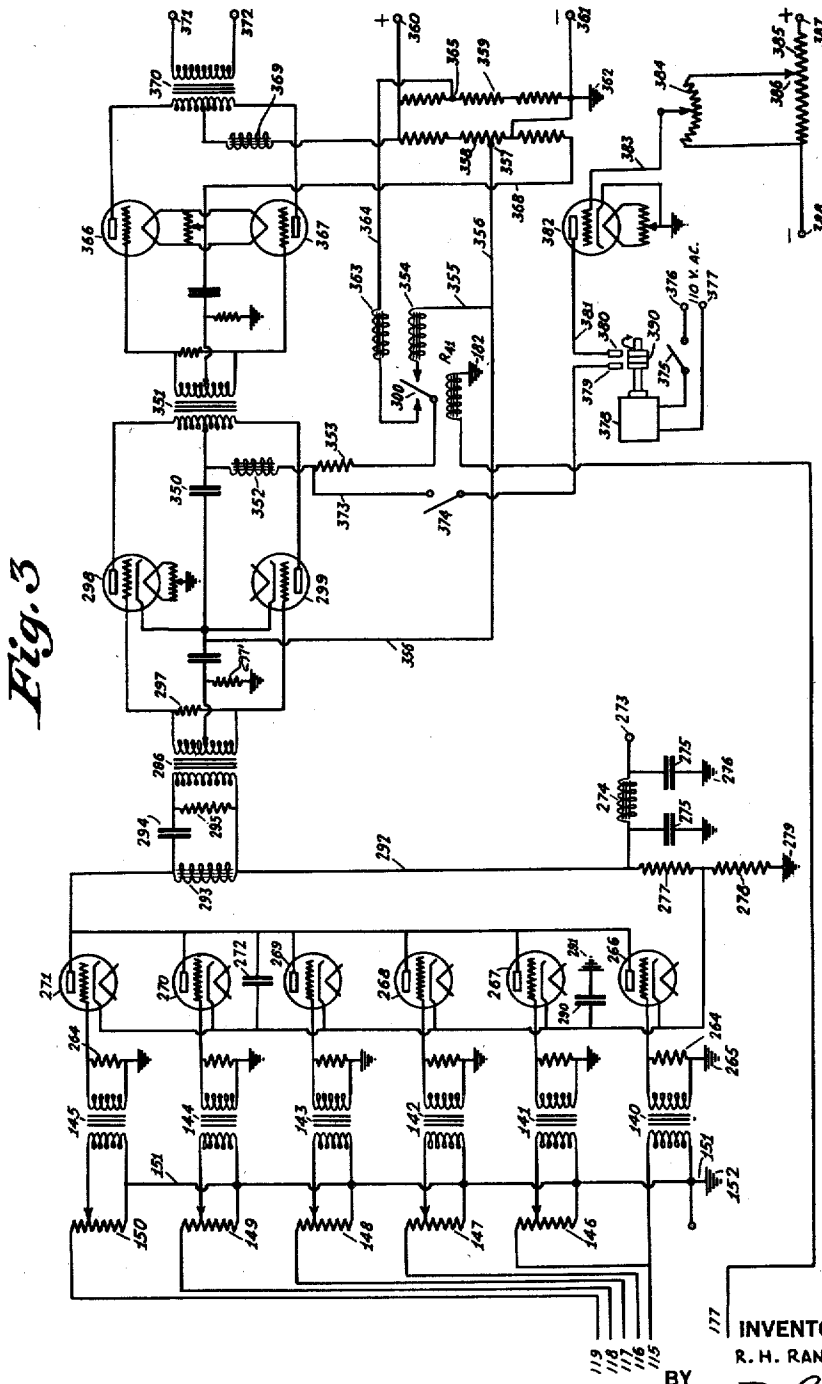
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Filed Dec. 30, 1929

8 Sheets-Sheet 7



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Filed Dec. 30, 1929

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Fig. 6

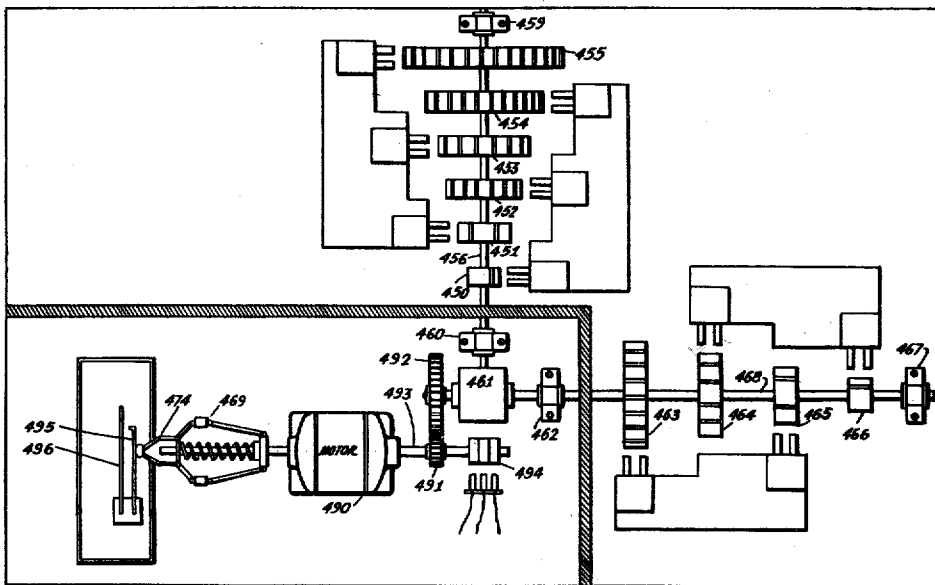
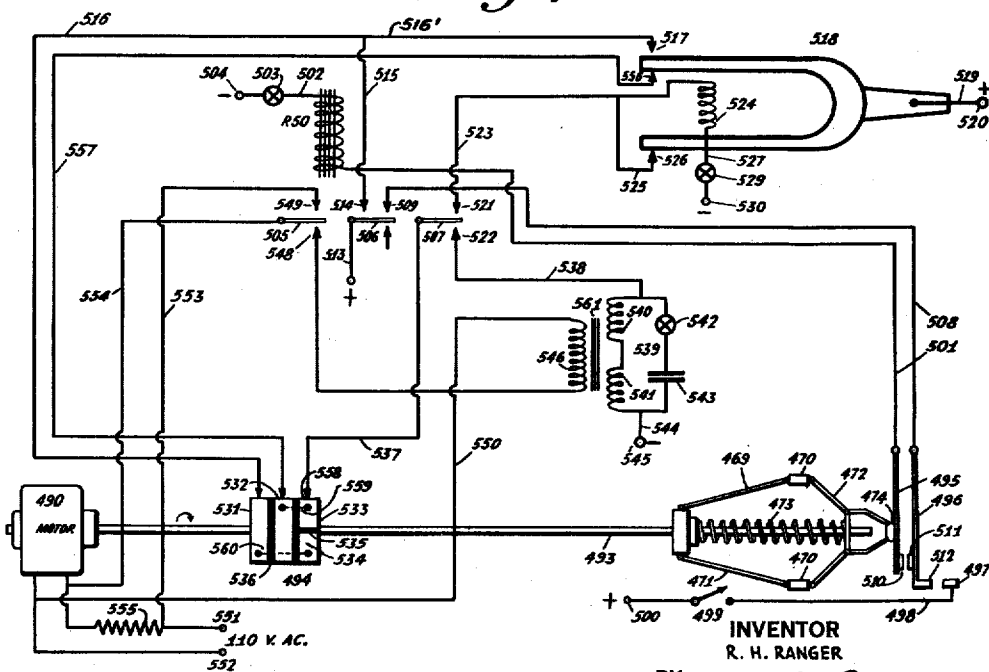


Fig. 7



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UNITED STATES PATENT OFFICE

RICHARD HOWLAND RANGER, OF NEWARK, NEW JERSEY, ASSIGNOR TO RADIO CORPORATION OF AMERICA, A CORPORATION OF DELAWARE

ELECTRICAL MUSIC SYSTEM

Application filed December 30, 1929. Serial No. 417,466.

My invention relates to a system for producing musical sounds. Broadly, the invention relates to a sound producing apparatus or instrument of the type embodying constant frequency means for producing sounds as musical tones or notes of constant pitch, and variable volume and timbre for the particular note which it is to produce. In combination with such type of apparatus, I provide a system for selectively amplifying each of the produced notes or tones, so as to produce a composite note corresponding to each which will have the proper timbre and frequency characteristics.

Of course, I am aware of the fact that it has heretofore been possible to produce musical sounds through the aid of oscillators or frequency generators of either the audion or the generator type coordinated with sound reproducing instruments, and am also aware of the fact that it has heretofore been known in the art to utilize a system for producing musical sounds in which a high frequency source has been used together with a generator of variable frequency so as to produce by heterodyne action a resultant beat note of a frequency varying in accordance with the frequency of the note or sound which is desired. In each of the systems of the type above described, it has also been customary to amplify either the frequency of the generator source or the beat note frequency so as to produce a well rounded-out tone such as may, for example, be clearly audible in large concert halls.

My invention, however, differs from what has heretofore been done in the art in that I employ a plurality of constant frequency "tone" sources for each of the plurality of notes comprising the musical scale so that each separate note, as it becomes audible upon amplification and by being directed through a sound reproducer, is formed from the fundamental frequency together with all of the other partials, harmonics, or modulating notes of appropriate interval to give special effects, as minor amplitudes of thirds or fourths, suitable for producing the proper timbre, for example. These tones will hereinafter be referred to merely as the funda-

mentals (the partial of lowest frequency) and the other partials, or as the fundamentals and harmonics, or as the fundamental and overtones so as to avoid needless repetition of the above. With these tone producers I connect, in a manner to be hereinafter described, the reproducers or loud speakers for causing the generated frequencies to become audible.

My system also provides an especially flexible means by which the intensity of each of the harmonics or partials accompanying the chosen fundamental or first partial may be regulated at will so as to simulate the "stop effects" on the usual organ, such as, in one instance, perhaps to produce a note simulating a reed effect, while, at another instance, perhaps produce a note simulating a violin effect by proper regulation of the intensity or amplitude value of the various partials or harmonics accompanying the particular first partial fundamental.

Still further, my invention has provided a system in which the tones or notes of the musical scale may be produced from absolutely constant frequency standards, and, in combination with these frequency standards, I may utilize what I have herein termed a "selector system" and a plurality of tone amplifiers, such that the selector system prevents more than one single tone or note together with its partials or harmonics from being impressed upon one amplifier at the same time. Thus, the note reproduced at any one instant by any one amplifier and sound reproducer contains only the basic and desired partial frequencies of the particular note chosen, and eliminates cross-modulation between a plurality of separate notes.

So far as I am aware, it has in the past been customary either to provide each note with a separate amplifier or oscillator tube, or to combine all tones from all sources in a common amplifier, or to have a plurality of separately located amplifiers and sound reproducers so coordinated that only one of the plurality is used at any one time. The first of these systems has the disadvantage that an unusually large number of amplifiers or oscillators are necessary in order to obtain the desired results, and with them a great loss

in efficiency is experienced, and the second type of system has the disadvantage that, as above stated, several tones simultaneously impressed upon a single amplifier or sequentially impressed upon a single amplifier cause, first-
 5 ly, cross-modulation between various tones in the amplifier and thus produce distortion, or secondly, noises are produced in the amplifier by successively keying different tones or notes
 10 thereon prior to the time when the first tone has been cut off from the amplifier. In the production of pure tones of considerable amplitude, this cross-modulation is very serious. To avoid cross-modulation in a single ampli-
 15 fier; it is necessary to have great reserve power which is uneconomical.

My invention may further be characterized as being selective for the different notes played, somewhat similar to the selection of
 20 unused telephone lines with the automatic switching practice in telephone switchboards of today, in that it provides a separate amplifier for each of the notes that are to be struck simultaneously up to a predetermined maxi-
 25 mum. Where more notes than the predetermined maximum are struck simultaneously, provisions are made to prevent sound reproduction from more notes than there are ampli-
 30 fiers. This limiting system will become apparent from the description which follows.

Careful research has disclosed that the number of separate notes which are usually played or struck simultaneously is limited and would rarely exceed ten for organ work,
 35 for example, assuming that four notes may be simultaneously played with each hand and one note played with each foot. However, for practical purposes and for convenience of illustration, I have merely chosen to illus-
 40 trate my invention as capable of simultaneously producing six tones, but it should be understood that such illustration is merely given by way of example and not in a sense
 45 of limiting my invention to six notes played simultaneously, and I may, should I so desire, use more than six tones simultaneously (or less than six tones simultaneously) in accordance with conditions existing at any particu-
 50 lar time.

To discuss further the utility of a plurality of separate amplifiers so that one amplifier is obliged to carry only a single note and the overtones, harmonics or partials accompany-
 55 ing or modulating it at the same time, the advantages over a single amplifier are many:—first, no amplifier is absolutely linear, of course, and the result of this is that one note is bound, therefore, to modulate another in the amplifier after they are combined in
 60 the amplifier circuits; secondly, unless all notes amplified at any one time are struck simultaneously, there is a tendency towards a scratching noise as the second note is brought upon the amplifier, due to the fact
 65 that the contact is not made instantaneously

or is not made at a period of zero alternating current voltage upon the amplifier circuit. This scratching noise is not due to the direct current, as, of course, care must be taken to see that there is no direct current operated
 70 directly in the amplifier circuit, which would give rise to distinct thumps, but is due to the keying of the tone frequency energy. As a third advantage of separate amplifiers for each note and a separate sound reproducer
 75 or loud speaker associated with each amplifier, it is obvious that any one amplifier can handle much larger volumes for any given note, if there is no need for a considerable amount of reserve energy to be available for
 80 other notes added thereon at the same time.

Therefore, as a primary object of my invention, I have sought to develop an electric organ system of the type herein described in which there is a separate amplifying means
 85 for each of the notes or tones simultaneously produced.

Another object of my invention is to produce an electric organ system which is capable of simultaneously playing any predetermined
 90 and desired number of musical tones or notes without experiencing interference between the several tones or notes.

Another object of my invention is to provide means for preventing any single ampli-
 95 fying system from being obliged to handle more than a single note or tone together with its partials at any one instant.

Still another object of my invention is to develop an electric organ system in which
 100 means is provided for selectively keying an amplifier not then in use with any particular note as the note is struck.

A further object of the invention is to provide a system in which the lag effect of sound
 105 reproduction is reduced to a minimum by reason of sound generation which is entirely electric.

Still another object of my invention is to provide an electric music system in which the
 110 tones as produced by the tone generators including the first partial fundamental tone and all desired accompanying partials or overtones may be keyed to appropriate ampli-
 115 fying systems prior to the time when the amplifier is keyed with the sound reproducer, or, in other words, the sound reproducer keying is delayed until the tones are keyed, so as to avoid all objectionable effects of keying
 120 noises and the like.

Also a further object of the invention is to provide a system by which the connection between the amplifiers and coordinated sound
 125 reproducers may be broken prior to the time when the tones are removed from the amplifier so as to avoid all objectionable noises from keying and the like. In each of these last
 130 two named objects, the electrical contacts associated with each of the keys representing the different notes of the musical scale are

such that as the key representing the note which is to be played is depressed, the first connection so far as impressing the generator tones on the amplifier and sound reproducer is concerned will be to key the tones with the amplifier, and then at a later time through a delayed action system the sound reproducer is keyed to the amplifier; then, as the key is raised or released, the first operation taking place is the disconnection or disassociation of the sound reproducer and the amplifier, after which the generated tones in the form of the fundamental and chosen overtones are removed from the amplifier.

Another object of my invention is to provide an electric organ system such as is capable of playing each note or tone together with all of the harmonics or partials accompanying the particular tone or note.

Still another object of my invention is to provide a means for controlling the volume of each of the harmonics or overtones accompanying or modulating each particular fundamental note or tone in accordance with the character of the note or tone which it is desired to produce.

Still another object of my invention is to provide a means for accentuating any one part of the amplifier selection so far as the different notes therein are concerned so that, for example, in one selection the bass or lower frequency notes might be accentuated throughout, whereas, in another selection, the tenor or higher frequency notes might be accentuated throughout.

Still another object of my invention is to provide a means wherein I preferably coordinate particular amplifiers to particular groups of tones. That is, one amplifier may be particularly suited for the lower frequency tones, and another amplifier may be more particularly suited for the higher frequency tones.

Still a further object of my invention is to provide an electric organ system in which separate tremolos may be assigned to separate parts of the musical selection being played. This may be accomplished, for example, as will hereinafter be set forth, by changing the amplifying characteristics of the various amplifying systems in accordance with a predetermined schedule of changes.

While in many instances it is desirable to have the same tremolo effect for all amplifiers and their associated sound reproducers, it should be noted also in connection with the tremolo that it is possible to provide tremolos which are of different rates for different amplifiers, that is, for amplifiers carrying higher frequencies the rate might be higher, for example, than for amplifiers carrying the lower frequencies. To specify an example of tremolo operation which might be found suitable, a three to two ratio for high and low frequency amplifier tremolos has been

found suitable where it is desired to produce a different tremolo effect for different amplifiers, although it is to be understood that this ratio is merely illustrated by way of example and not in a limiting sense, since any desired and suitable ratio may be substituted where it is desired to have different tremolo effects on different amplifiers.

Still another object of my invention is to provide a system wherein the usual "stop effects" for producing different character notes may be conveniently regulated by merely changing predetermined resistance values, or other appropriate means suitable for controlling the current flow in the amplifying circuits, so as to regulate the quality of the output energy from the amplifier through appropriate control of the intensity or amplitude relationship between the fundamental and the various partial frequencies.

Still another object of my invention is to provide an arrangement which will permit the playing of notes not ordinarily known or produced by the usual type of musical instruments. This, for example, might be accomplished by accentuating particular partials or harmonics of the basic frequency or even of entirely different notes added in controlled degree in order to differentiate from any usual character of note.

A still further object of the invention is to produce a system for representing or simulating a pipe organ in which the tone color is most flexible, due to the fact that it is possible to independently regulate the relative percentage of the various partials or harmonics with respect to the first partial fundamental note by varying the voltage of the particular partial or fundamental frequency impressed upon appropriate tone amplifiers.

Another object of my invention is to provide an electric organ system or the like in which it is possible to gradually "slide" from one type of note into another type of note by controlling the resistance value, for example, in the amplifying circuit, in much the same manner as these values are changed for producing the usual stop effects.

Still a further object of my invention is to provide a means in which there is an extreme ease of regulating the temperament of the system, that is, the raising or lowering of the pitch of each note of the entire scale relative to the other, in accordance with the desired temperament, with minimum inconvenience.

A further object is to provide a musical system in which the pitch of the whole instrumentality may be raised or lowered to match the range of singers being accompanied or of instruments less flexible.

A further object is to provide a musical system in which the temperament may be modified from equal temperament to favor any given key.

Other objects of my invention are to provide an electric organ system which is totally and absolutely independent of temperature fluctuations which are so detrimental to the usual organ utilizing pipes of either metal or wood, or other types, for reproducing the notes.

Other objects of my invention are to provide an electric organ system in which the objections of changes in pitch due to changes in circuit characteristics are substantially eliminated by the elimination of all oscillators or the like for producing the basic frequencies in which temperature or supply voltage changes produce changes in frequency.

Still another object of my invention is to utilize the various frequencies generated for the various notes comprising the musical scale in proper reduced intensity in order to provide for the harmonics or partials accompanying any predetermined basic frequency.

Still another object of my invention is to produce and provide an electric organ system in which the usual space requirement for setting up the arrangement is reduced to a minimum by providing compactly arranged switching and selecting circuits, together with a minimum number of amplifiers and associated standard frequency tone producers, and to eliminate totally the objectionably large number of pipes used to produce the desired sound effects.

Also as a further object and advantage of my invention, I seek to provide an electrical music system in which the usual blowers, assuming the system is an organ, for producing vibration in the organ pipes are eliminated by substitution of the tone generators and coordinated loud speakers or other appropriate sound reproducers.

Still another object of my invention is to provide an electric organ system in which the mechanical driving means for the various tone or note producers may be reduced to a minimum.

Still other objects of my invention are to provide an electric organ system such as is relatively simple in its construction and arrangement; to provide an electric tone producing system which when once installed is substantially free from the need of attention so far as tuning adjustments and the like are concerned because of the substantial independents of tone change with any change in temperature; and to provide an electric tone producing system which is efficient in its use, compact in its arrangement, easy to install, conveniently operated, substantially fool-proof in operation, and readily set up.

Still other and further objects of my invention will become apparent and at once suggest themselves to those skilled in the art to which the invention relates by making reference to the following specification and

claims in connection with the accompanying drawings, wherein:

By way of diagrammatic illustration of a portion of my invention, I have illustrated by Fig. 1 an arrangement consisting of three keys of my organ and one amplifier associated therewith. In Fig. 1 of the drawings, Fig. 1-A constitutes the upper left hand corner of the drawing to the right hand portion of which is attached Fig. 1-B; immediately below Fig. 1-A, the arrangement shown by Fig. 1-C is to be connected; to the right of Fig. 1-C and beneath Fig. 1-B the portion shown by Fig. 1-D is assumed to be connected; and, the amplifying system shown by Fig. 1-E is connected to the amplifying connections from Fig. 1-D;

Fig. 2 illustrates a modification of the means for producing varying tone effects from that shown by Fig. 1-E;

Fig. 3 illustrates a modification of the amplifying system (also assumed to connect to the amplifying connections of Fig. 1-D) from that illustrated by Fig. 1-E, to illustrate the application of alternating current types of amplifying tubes to the system;

Fig. 4 illustrates a modification of the tone producing arrangement from that shown by Fig. 1-A, wherein Fig. 4-a illustrates a side view of a single tone wheel and the signal or tone pick-up means therefor, and Fig. 4-b illustrates a top view of a similar tone wheel;

Fig. 5 illustrates a complete assembly of a plurality of tone generating wheels in which a turbine drive is used for rotating the tone wheels, and with this an appropriate form of speed governing means is illustrated;

Fig. 6 illustrates a similar tone generator wheel arrangement to that shown by Fig. 5, but shows an electric drive as being substituted for the turbine drive of Fig. 5; and,

Fig. 7 illustrates a preferred form of synchronizing system for use in connection with the tone generator wheel driving means of Fig. 6.

In accordance with the arrangement herein set forth, and in order to accomplish the purposes and objects of my invention by one of many suitable arrangements, for the purpose of diagrammatic illustration, a relay set-up is used to show my invention. For convenience, the keyboard of the organ, usually consisting of sixty-one separate notes, is arbitrarily divided into two parts at middle C at, for example, substantially 262 cycles, upon the basis of middle A being at 440 cycles in the octave above this C. In accordance with the present disclosure, three amplifiers work from middle C downward and constitute the left side of the system, as shown in the drawings. In order to complete the set-up, another set of three amplifiers works for all of the notes on the keyboard from the same middle C upwards, and are connected in identical manner to that shown in

the drawings, but have not been herein illustrated for the purpose of convenience.

Similarly, separate amplifiers are provided for the purpose of reproducing the notes played by the organ foot pedals. The selection to be desired in an instrumentality of this type may work, for example, in the following manner, although not necessarily limited thereto. The first amplifier should preferably always be set to work on the first note struck on the left side, the second amplifier arranged to work with the second note struck, and then the third amplifier to work with the third note struck. As has been above stated, with the arrangement shown for the purpose of illustrating my invention, only three notes played by each hand can simultaneously be accommodated in the amplifiers. If two notes are to be struck simultaneously, provision must be made for keying each of these notes with a particular amplifier, and, therefore, I have arbitrarily assumed that the lower frequency note struck will play on the first amplifier, and the next note struck, that is, the note of higher frequency and nearer towards the "C" note, which, as above stated, was chosen as the dividing point, will play on the second amplifier. Similarly, if three separate notes are struck simultaneously, the third note towards "C" will play on the third amplifier, with the first two playing as previously stated.

For the right hand side of the system, not illustrated, the selection, according to the arbitrary system of operation to be herein described, should work in exactly the opposite direction; namely, if three notes are struck simultaneously, the highest note struck or the one furthest away from middle "C" will play on the first amplifier on the right side, the second one down toward "C" will play on the second amplifier, and the third one down toward "C" will play on the third amplifier. The purpose of the relays and amplifiers is thus seen to be that of selecting and amplifying appropriately the given notes desired, while the individual tones are produced extraneous to these arrangements.

Since in many cases it may be desirable to play more than three notes near the center of the keyboard, it is possible to "dovetail" the left and right hand relays so that each set overlaps and thus provides a means whereby the entire number of notes to be played simultaneously may be played within a close range of frequencies or notes on the keyboard. In many cases, it is advisable to have only a very few notes capable of being played by amplifiers and reproducers coordinated with the relays for each side or end of the keyboard. By this means the system may be so interlocked that the last two or three notes to the left and right of the keyboard may be played only through a single reproducing system, and thus conserve relays. Of course,

under the last named condition, care should be taken to make certain that it would never be necessary to play more than one note at a time at the ends of the keyboard, because, if it were, one note would be "lost", in the sense that it would not be reproduced.

In order to produce these various tones, it is, of course, possible to use several different arrangements. For example, I may use, where desired, air driven tuning forks, one fork being provided for each note of the scale desired. Air driven tuning forks are preferred to electrically driven forks for the reason that there is a total freedom from separate vacuum tube drives for each fork with the consequent large amount of electrical circuits and energy. Of course, the forks may be of either the steel or the quartz type since in utilizing an air drive, it makes no difference whatever as to the particular type of fork so far as convenience of driving the same is concerned.

In another arrangement, I may, where desired, use "tone wheels", which consist of a series of wheels each of which is provided with teeth adapted to complete an electric tone generation circuit either through electromagnetic or electrostatic means. The number of teeth on each wheel is different so that as the series of wheels is rotated the progressive change in the number of teeth gives the effect of the same notes in different scales. To produce the other notes in each scale and for the complete series of scales similar sets of toothed wheels are used, or, in other words, there are twelve different sets of wheels to produce the tones corresponding to the tones or semitones of the octave. Now, to produce the different frequency notes the corresponding wheels forming each complete set may all be of the same number of teeth and rotated at different speeds, or all of different number of teeth and rotated at the same speed. However, for convenience of installation, the former has been found more suitable.

Also, the various tones produced may be produced by piezo-electric bodies, or, in fact, all types of crystalline bodies which may be caused to vibrate at constant frequencies.

In addition to each of the types of tone producers of constant frequency above set forth, I may produce tones electrically without the liability of distortion and noise by providing photo cells and associating therewith chopping disks interposed between the source of the light directed to the photo cell and the cell itself. In such a case, the chopping disks may be provided with holes there-through arranged about their outer margin so as to interrupt periodically the light reaching the cell at the frequency corresponding to the note which is to be produced, for example, of the general type shown by my Patent No. 1,789,687, granted January 20,

1931. With such an arrangement, it is, of course, possible to use a single photo cell for each of the notes, and by properly arranging a plurality of sets of openings in the light chopping disk in paths concentric with each other (as is also shown by said above named application) cause each photo cell to produce only an electrical output corresponding to the exact frequencies desired, together with only the particular harmonics which are to be coordinated therewith for the purpose of rounding out the tone or timbre produced from the particular note in the individual speakers as they are successively coordinated therewith as each separate key corresponding to each photo cell frequency is depressed on the keyboard.

In each of the above cases, it is the frequency of the generated tone, and not the sound itself, as for example the sound of the vibrating forks, which controls the reproduced tone output of the sound reproducer connected with each of the amplifiers.

To refer now to the drawings forming a part of this specification, a key I is shown at the lower right hand corner of Fig. 1-C, and this key, for example, may correspond to the note "C" having a frequency of approximately 65.4 cycles. According to the showing of the drawings, the keys I, II, III, etc. are each intended to represent one of the plurality of keys of the usual organ console. Beneath each key, in the usual manner of connecting electric contacts, I have provided the switching contacts to be hereinafter described. In this manner all of the switching associated with the key for the purpose of selectively keying the various amplifiers is contained beneath the various keys and is out of sight.

As shown by the accompanying diagram, for example, the note "C", which may be assumed to be equal to 65.4 cycles, may be generated by means of a tuning fork 2 (Fig. 1-A). This fork 2 may be of either the steel or quartz type and driven by air in any desired and appropriate manner, for example, in accordance with the principles shown and described in United States Patent No. 1,831,638, granted on November 10, 1931 jointly to me and to C. E. Nelson. Energy generated through the vibration of the fork may be electromagnetically picked up through the use of the horseshoe-shaped magnet 3 surrounding the tine 4 of the fork and having a coil of wire 5 surrounding the same. One terminal of the coil 5 is preferably grounded at 6 and the other terminal connected to a terminal of the relay or selector system, as will hereinafter be described. The function of the key I is to supply positive current derived from a source of energy connected to the terminals 7 and 8 to the separate pair of wires 9 and 10 connected with the bank of relays. These relays function to serve as a por-

tion of a "selector system" to selectively key the various amplifiers, to be hereinafter described with the tone producers and those relays associated with the key I are indicated as R_1 , R_{11} , R_{21} and R_{31} , in which, for convenience of reference, the last numeral of each is a "1", while those associated with key II are indicated with numerals ending in a "2", etc. These contacts are then made by depressing the key I and causing it to close contacts 11 and 12 so that current from the source 7 may be passed, for example, through resistance 13, choke coil 14, the resistor 15 through the contact arm 16, the contact 11, the lower portion 17 of the key I and the conductor 9 to one of the armatures of the relay systems R_{11} , R_{21} and R_{31} , or, upon further depression of the key, from the terminal 8 to the choke 18, the terminal 19, the contact arm 20, the contact 12, the contact arm 21, through the conductor 10 connecting with one of the various contact points hereinafter termed the "keying contacts" and later described in connection with the operation of the relays R_{11} , R_{21} and R_{31} . Thus, as the key is depressed current first flows through conductor 9 and later, as the key is further depressed, current flows through the conductor 10 to the "keying contacts" of the various relays.

The first horizontal row of relays R_1 , R_2 and R_3 , etc., are what will hereinafter be termed "starting relays", and are respectively coordinated with the keys I, II, III, etc. These relays act whenever a key associated with the particular unit note is played, and their purpose is to select one of the relays shown in the vertical row of relays above each note that is not otherwise "busy", for the purpose of transferring the tone to the amplifiers, as will hereinafter be explained. For the purpose of illustration, it will now be assumed that key numbered I, assumed to correspond to the note "C", is the first key to be struck in the system and that it alone is struck. According to the above outlined requirement, it must, therefore, select the relay R_{11} as the one that will place the required tones into the first amplifier "A", shown to the right of this relay by Fig. 1-E, which will lead to its particular loud speaker or tone reproducer, not shown but which may be of any known type, such as dynamic, magnetic or electrostatic.

That this is done is seen by following diagram of connections from a view of Figs. 1-C, 1A, 1-D, and 1-E combined. Now, assuming the key I to be depressed or closed, current from the source connected at 7 and 8 flows through the lower portion 17 of the key I through the conductor 9, the conductor 22 to the armature 212 of relay R_{11} , through conductor 22' to the armature 312 of relay R_{21} , through conductor 22'' to the armature 412 of relay R_{31} , through conductor 23 and thence back to the relay R_1 , which it operates,

to close the several armatures thereof, and then to ground at 24. The relay R_1 is preferably shunted by a capacity 25.

As shown, all of the relays are indicated in their "off" position and the relay coil R_i operates all of the armatures shown immediately to the right thereof, such as 26, 27, and 28; the relay R_{11} operates all of the armatures shown immediately to the right thereof, such as 211 through 219 inclusive, and relays R_{21} and R_{31} likewise close all of the armatures to the right thereof during periods when current is passed therethrough. As the relay winding R_1 is energized, the armatures 26, 27 and 28 are closed against the contacts shown on Fig. 1—C as immediately to the left thereof. As the armatures 26, 27 and 28 are closed, the only one of these which has current on it is the armature 26, which is because the relay R_{10} , as shown, is in what may be termed a "spacing" position, and has its armature 202 resting upon the contact to the right thereof to supply positive current from the positive source connected at 29, through the conductor 30, the armature 202 and associated right side contact, the conductor 31, the resistor 32 and the choke 33 to the armature 26. The purpose of the resistance and choke is to keep the current wave front to a gradual slope rather than to a steep front, which would act to cause interference on amplifiers that are already working. The resistance and choke have, however, no function in the straight selection operation for keying the different amplifiers as the tones are selectively applied to the selector system.

Now, when the relay R_1 contact or armature 26 moves to the left so as to rest against the left side contact point, positive current coming from the source 29 through the armature 202 may be traced up directly to the right side of relay R_{11} through the armature 26 and the conductor 34 so as to cause relay R_{11} to close all of its associated armatures upon the left side contacts by reason of the current flowing from source 29 through the relay R_{11} to ground at 35. This closing of all of the armatures of relay R_{11} to the left will then cause the positive current coming from the key I through the conductors 9 and 22 to then flow through the relay R_{11} to control the same directly without the intermediary of the relay R_1 .

At the same time, the closure of relay R_{11} will break the circuit previously described through the right side contacts of armatures 212, 312, 412 of relays R_{11} , R_{21} and R_{31} for operating the relay R_1 , as the operating current for the relay R_1 passed through the conductor 22 upward through the armature 212 of relay R_{11} and the right side contact thereof, then through the conductor 22' and the right side contact of the armature 312 of relay R_{21} , the right side contact of the

armature 412 of the relay R_{31} , and thence down through the conductor 23 to the relay R_1 to ground, when the armatures of relay system R_{11} rested on the right side contacts, or in their non-operating position, as shown.

Since in the operation of the relay R_{11} all of the armatures are moved to the left, as above described, the closure of the armature 211 upon the left side contacts opens the ground circuit of all of the relays R_{12} , R_{13} , etc., to the right of relay R_{11} which otherwise passed through conductor 36', the choke 36 to ground at 35 so that now none of these relays R_{12} , R_{13} , etc. to the right of R_{11} can operate no matter what other keys are depressed, since the circuit connecting each of these relays is now open. This effectively prevents any other relay in line (horizontal line as shown) with the relay R_{11} , such as R_{12} , R_{13} , etc. for example, from closing tone currents into the amplifier system "A" to the right thereof, and likewise fits in with the previous stipulation set forth above in the general statement of invention and objects thereof that when more than one key is depressed at a time, the amplifier "A" will be worked only by the first note to the left of middle "C" that is played.

Armature 211 when actuated by relay R_{11} to move to the left-side contact point closes a circuit to ground at 35 through the choke 36, the armature 211 and the left side contact thereof through to the conductor 37' and thence through relay R_{10} to the positive potential source 37, so as to close the armatures 201 and 202 of the relay R_{10} over upon contacts to the left from the position shown. This actuation of the relay R_{10} and the movement of the armatures 201 and 202 to the left breaks the circuit from the positive potential source connected at 29, through the armature 202, the contact to the right thereof, the conductor 31, the resistor 32, the choke 33, the conductor 38 to the armature 26 of relay R_1 , and thence through the right side contact of armature 26 through the conductor 39 to the armature 40 of relay R_2 and its right side contact terminal, the conductor 41, the armature 42 of relay R_3 and its right side contact, etc. This arrangement of cascading armatures 26, 40, 42, etc. to the right of the relays R_1 , R_2 , R_3 , etc., likewise carries out the provision set forth in the statement and objects of invention that if more than one key is operated at the same time, it will be the relay to the left that carries forward its operation first.

Likewise, when the relay R_{10} operates, it closes the armature 201 against the left side contact thereof so that positive current from the terminal 29 may flow through the conductors 30 and 44 through the armature 302 in its position of rest against the right side contact thereof (as shown by Fig. 1—A), and

thence down through conductor 45 to resistor 46 and associated choke coil 47, conductor 48, through to right side contacts of the armatures 27, 50, 52, etc. through conductors 49, 51, 53, etc. respectively. This provides that if key II, arranged similarly to key I and connected to the conductors 54 and 55 is closed or depressed, it will operate the relay R_2 by causing current to flow from conductor 54, through armature 222 and its right side contact of relay R_{12} , and from there through conductor 56 through the right side contact of armature 322 of relay R_{22} , to conductor 57, to the armature 422 of relay R_{32} from the right side contact of which it flows through conductor 58 to the winding of relay R_2 , and thence to ground at 59, in a manner similar to that hereinbefore described in connection with the key I operating the relay R_1 .

Now, bearing in mind the fact that, as above described, the relay R_{10} has been actuated to move armatures 201 and 202 to the left, so that positive current from source 29 can now flow through armature 302, conductor 45, resistor 46, choke 47, conductor 48, armature 27 of relay R_1 , conductor 49 to armature 50 of relay R_2 , and that no current from source 29 can flow through armature 202 of relay R_{10} to armatures 26 or 40 of relays R_1 or R_2 , and that relay R_{20} has not yet operated so that no current can flow toward the armature 402 of relay R_{30} , because armature 301 of relay R_{20} forms a break in the circuit, it follows that current from the source connected at 29 may flow through armature 50 of relay R_2 , closed now upon its left side contact, through conductor 59 to actuate relay R_{22} by flowing through the winding thereof, the conductor 60, the armature 311 of relay R_{21} , which rests upon the right side contact, to the inductance 61 and to ground at 62. Thus, it is apparent that relay R_{22} is operated in the same manner as was relay R_{11} when the key I was depressed. When relay R_{22} operates, it clears relay R_2 by breaking the circuit from the positive source connected through key II to conductor 54 by moving the armature 322 away from the right side contact. Likewise, the closure of relay R_{22} operates relay R_{20} through the movement of armature 321 to the left and upon the left side contact thereof, so that a circuit is closed from the source of positive potential connected with relay R_{20} at terminal 63; through the relay R_{20} ; through conductor 64 from relay R_{20} to the left side contact of armature 321; through armature 321 resting on the left side contact, and thence through conductor 60, and inductance 61 to ground at 62.

Thus, the operation of relay R_{20} moves armatures 302 and 301 to the left and breaks the circuit previously completed from source connected at 29 through armature 302 to armatures 27, 50, 52, etc. In a manner simi-

lar to that above described for supplying current to armatures 27, 50, 52, etc., when the armatures 302 and 301 of relay R_{20} move to the left so that armature 301 closes on its left side contact current from the source connected at 29 flows through the conductor 30, the armature 201, the left side contact thereof, the conductor 44, the armature 301 and its left side contact to the conductor 65, to the armature 402 of relay R_{30} and its right side contact to conductor 66, resistor 67, choke 68, and conductor 69, to the armature 28 of relay R_1 and the right side contact thereof, thence to conductor 70, armature 71 of relay R_2 and the right side contact thereof to conductor 72, to the armature 73 of the relay R_3 and the right side contact thereof to operate one of the various tone selecting relay systems for the third key to the right that is pressed.

Assuming that key III is the third key to be operated (which, of course, would probably not do for harmony, but is illustrated by way of example), then the relay R_{33} operates in like manner to the relays R_{11} and R_{22} , and this in turn operates the relay R_{30} through armature 431 and the left side contact thereof and conductor 76 which "clears" the entire side of the system, as shown, and prevents any other note playing until one of these three notes represented by the keys I, II and III is released.

Now, to give a concrete example of this illustration, it will be recalled from above that the depression of key II caused the action relay R_2 to move all armatures 40, 50 and 71 to the left. Then, with armature 50 moved upon its left side contact, and since relay R_{10} was in "locked" position with its armatures moved to the left, current flowed from source 29 to actuate the relay R_{22} . Then, as relay R_{22} was closed, the relay R_2 was released, while relay R_{20} was closed. Under this condition the energy to keep relay R_{22} closed was derived from the source (not shown) connected with conductor 54 through the depression of the key II, due to current flowing from the positive source connected with conductor 54 through depression of the key, through the conductor 54, to the armature 322 of relay R_{22} and thence through the left side contact of armature 322 through the relay winding R_{22} , the conductor 60, and choke 61 to ground at 62. Therefore, so long as key II is depressed, the relay R_{22} must remain in closed position.

However, as the key II is raised the circuit from the positive source connected through conductor 54 and the armature 322 to ground is broken and relay R_{22} opens. As relay R_{22} opens the armatures all move to the right (to the position shown by the drawings). As this happens, the circuit from the positive source 63 connected to relay R_{20} and to ground at 62 through armature 321 and the left side contact thereof is broken and the

"locking" relay R_{20} also opens. When this happens the armatures 301 and 302 move to the right to the position shown by Fig. 1-A of the drawings, and positive current will now be supplied from the source connected at 29 through armature 302 to the middle armatures 27, 50, 52, etc. of relays R_1 , R_2 , R_3 , etc.

In the operation previously described, the only relays of the selector system which are now assumed to be closed are relays R_{11} and R_{33} , and these are kept closed due to the depression of keys I and III. Thus, all of the relays in a vertical line above the key II are in "open" position. Likewise, this is true of the corresponding relays associated with all other keys in the left hand register of the scale corresponding to other notes (neither relays nor keys being shown due to repetition of circuits), so that as any key is depressed (of course excepting keys I and III already depressed) a circuit will be closed to actuate relays R_2 or other similar relays coordinated with the other keys.

As this happens and since current is supplied to all of the middle armatures 27, 50, 52, etc., one of the keying relays in a horizontal line with relay R_{22} will be closed and the relay R_{20} will again be actuated, as before, so that an additional tone will be impressed upon the amplifiers, as will hereinafter be described.

To show now how the selection system would work if the order of depression of the three keys illustrated by way of example were changed, let it be supposed that key III is first depressed, then key I, and then key II. Under such conditions, and in accordance with the above set forth description, selector relay R_{13} would first operate, then relay R_{22} and then relay R_{31} . Thus, by varying the order of depression of the various keys the relay system which operates in the vertical line above each key (as shown) for selection purposes may be changed, and, accordingly, as will hereinafter appear, the amplifier coordinated with the particular tone will be different.

The purpose of the contacts or armatures of the various relays which end in the numeral "3" for each tone relay, such as 213, 323 and 433, for example, on relays R_{11} , R_{22} , and R_{33} respectively, is to provide a charge on the capacity elements 77, 81 and 85 through resistors 76, 80, and 84 and conductors 79, 83 and 87 so as to hold the relays R_{11} , R_{22} and R_{33} (assuming notes I, II and III were played, as above described) closed for a slight time interval after any of the keys I, II or III are released. The reason for such an arrangement is to provide a short time interval after release of the keys for the remaining circuits to clear the tones out of the amplifier before new tones pro-

duced by depressing other keys are impressed upon the input to the amplifiers.

In addition to the armatures already mentioned as being associated with and forming a part of all of the relays such as R_{11} , R_{12} , R_{22} , R_{33} , etc., for example, there are six other armatures provided on each keying relay. Thus, relay R_{11} , for example, is provided with additional armatures 214, 215, 216, 217, 218 and 219; relay R_{22} is provided with additional armatures 324, 325, 326, 327, 328, and 329, etc., and, upon current flowing through the various relays, such as R_{11} and R_{22} , for example, all of the last named armatures will move to the left from the position shown by the drawings so as to rest upon their associated left side contacts. Of these various armatures, for purposes of identification as to function, I have termed all of the armatures ending in numerals "4, 5, 6, 7 or 8" the "tone contacts" and all ending in the numeral "9" as the "keying contacts".

Each of the armatures identified as the "tone contacts" is connected with one of the particular tone generating elements, as, for example, a tuning fork, as shown by Fig. 1-A. In the arrangement shown, provision is made for producing a resultant note in the output of the amplifiers, to be hereinafter described, which will be composed of the basic or first partial fundamental frequency of the note played and, in addition, four other partials or harmonics. Thus, making reference to the note "C" assumed to be played by depressing the key I, the note played will include the tone produced by the vibration of the fork 2, producing the fundamental; the tone produced from the vibration of fork 88 as picked up in the pick-up coil 92 grounded at 96, similarly to the pick-up coil 5 of fork 2, forms the next partial or first harmonic for this note; the tone impressed upon pick-up coil 93, grounded at 97, from the vibration of fork 89 forms the succeeding partial or second harmonic; likewise, the tone picked up in the coil 94, grounded at 98, of the fork 90 forms the following partial or third harmonic; and, similarly, the uppermost partial or harmonic used in the tone production is produced in the coil 95, grounded at 99, through vibration of the fork 91.

Confining the explanation of the tone production to the note corresponding to key I, for example, the tones produced through the vibration of forks 2, 88, 89, 90 and 91, as impressed upon the pick-up coils 5, 92, 93, 94 and 95 are transferred to the terminals 100, 101, 102, 103, and 104 of the selector system above the key I through conductors 105, 106, 107, 108 and 109 respectively. When the tones from the various tone generators 2, 88, 89, 90 and 91, for example, are impressed upon the terminals 100, 101, 102, 103 and 104, they are simultaneously impressed upon the particular armature of the various relays R_{11} , 130

R_{21} and R_{11} coordinated and connected with these terminals. Thus, through conductor 110, the tone applied to terminal 100 from fork 2 is simultaneously applied to each of the armatures 414, 314, and 214 of relays R_{31} , R_{21} and R_{11} respectively. In the event that none of the relays R_{31} , R_{21} or R_{11} are closed (opposite position from that shown by Fig. 1) there is no place for the electrical energy generated by the fork to flow, because the right side contacts upon which the armatures 414, 314 and 214 rest with the relays open are blank, and, therefore, while the tone is generated, it is put to no useful purpose.

Similarly, tones produced by forks 88, 89, 90 and 91 are impressed upon contacts 101, 102, 103 and 104 are directed through conductors 111, 112, 113 and 114 to the sets of relay armatures 415, 315 and 215; 416, 316 and 216; 418, 318 and 218; and 417, 317 and 217 respectively, all of which are also in "open" position and resting upon the blank right side contact unless a note is played.

As any one of the keys I, II or III is depressed, and assuming for purpose of illustration that the key depressed is the key I, the operation of which was first, described, then, as has been above set forth, the relay system R_{11} is actuated and all of the armatures 211, 212, 213, 214, 215, 216, 217, 218 and 219 are closed so as to rest upon their left side contacts (see Fig. 1—C). Under such conditions, of course, due to the interlocking feature hereinbefore described, it would be impossible for the relays R_{21} or R_{31} to close, and, of course, when it is the tone from the tone corresponding to the fundamental and the chosen partials for the key I which is desired, it is obvious that there would be no reason for impressing these tones upon more than one relay in the selector system.

Now, as the relay R_{11} has closed and tones impressed from the forks coordinated with the key I, as above described, are impressed upon the armatures 214, 215, 216, 218 and 217, a circuit will be completed through conductors 115, 116, 117, 118, and 119 connected respectively to the left side contacts of the relays 214, 215, 216, 217 and 218.

Each of the conductors 115, 116, 117, 118, 119 is connected to an amplifying system designated as "A", to be hereinafter described. Similarly, if the relay system R_{21} were closed, then the tones corresponding to the note coordinated with the key I would be impressed upon similar conductors 115', 116', 117', 118' and 119' through the armatures 314, 315, 316, 317 and 318, and, likewise, if it were the relay R_{31} which were actuated instead of the relay R_{11} , the tones would be impressed upon the conductors 115'', 116'', 117'', 118'' and 119'' in a similar manner, only in the latter two cases the conductors connected to the armatures of the relays R_{21} and R_{31} would be respectively coordinated

and connected with amplifying systems designated as "B" and "C" respectively.

In this connection, it should be noted that all of the relays in a horizontal line with relays R_{11} , R_{21} and R_{31} are coordinated with the same amplifier. Thus, all relays in the horizontal line with relay R_{11} are coordinated with the amplifier "A"; those in the horizontal line with relay R_{21} are coordinated with the amplifier "B"; and those in the horizontal line with relay R_{31} are coordinated with the amplifier "C".

As the arrangement is shown, it appears that each of the forks 2, 88, 89, 90 and 91 are used only for supplying the fundamental and partials for the key I, but this is merely for convenience of illustration, since it should be borne in mind that while the fork 2 furnishes the fundamental for the note corresponding to the key I, it may also furnish one of the partials for some other note coordinated with any other key, and, similarly, to consider the fork 89, for example, this fork is indicated as generating the second partial of the fundamental shown coordinated with the key I, but likewise this fork having a predetermined output frequency may furnish the fundamental for some other note coordinated with any other particular key chosen, and at the same time, may also furnish one of the partials for some other key. Therefore, by a careful analysis of each tone comprising the usual sixty-one tones or more notes of the organ keyboard, it is possible to so coordinate each of the different tone generators as to have them function both as generators of the basic or fundamental frequency for the particular notes and also as generators for the harmonics or partials coordinated with various other notes.

Thus, for example, it might be possible to also connect the pick-up coil 93 of the fork 89 through the conductor 107 with another terminal such as 130, for example, connected with the key III so that in this case the fork 89 would furnish the fundamental tone for this key. This illustration is given merely by way of example and not in any limiting sense so that the application of the invention will be more readily understood, but it should be further understood that in an arrangement of the type which I have devised and developed, there will be a fundamental (a first partial) and four other partials for each note and that there will be provided in the system tuning forks or other tone generators of an appropriate number, so that all of these fundamentals and partials may be produced.

Under such conditions, and assuming that relay R_{11} is closed due to the depression of the key I, the tones impressed thereon from the tone generators will pass as electric currents along the conductors 115, 116, 117, 118 and 119 to one of the amplifiers, such as amplifier

"A", to be described. The currents flowing in the conductors are impressed on the primary windings of the audio transformers 140, 141, 142, 143, 144 and 145 through resistors, which may be, for example, in the form of potentiometers 146, 147, 148, 149 and 150. Thus, current corresponding to each partial and the fundamental flows from one side of each potentiometer through a conductor 151 to ground at 152 to complete the tone circuit. Here it should be noted that the fundamental tone coming from the fork 2 as a tone producer and through conductor 115 is applied to the primary winding of both of transformers 140 and 141, being impressed directly on transformer 140 and through the potentiometer 146 on transformer 141. This serves to provide for better regulation of the fundamental tone than if it were supplied to only a single amplifying tube.

The secondary of each of the transformers 140, 141, 142, 143, 144 and 145 is connected to vacuum tube amplifiers 153, 154, 155, 156, 157 and 158 respectively of the triode type (for example in D. C. installations, a tube of the type known in the art as the UX-207-A). The grid electrode of each tube is supplied an appropriate bias potential from a bias battery 159. One side of the filament member (preferably the negative) of each amplifying tube is grounded at 160 through a conductor 161. Appropriate filament current is supplied to each tube from a positive source connected at 162 and is preferably regulated independently for each tube by means of the usual filament rheostat 163. Plate current from a source of positive potential connected at 164 is supplied through the choke 165 to conductor 166 and thence through conductor 167 to the plate electrode of all the aforementioned tubes, which, as is readily seen, are connected with their outputs in parallel.

In well known manner, the tones impressed upon each of the amplifiers 153, 154, 155, 156, 157, and 158 are amplified and impressed, due to the parallelly connected outputs through conductors 167 and 166 and capacity 168 upon the primary winding 169 of the transformer 170, from the secondary circuit 171 of which the energy is directed to a pair of push-pull connected amplifiers 172 and 173. The push-pull connected amplifiers 172 and 173 have their grid electrodes appropriately biased through a biasing battery 174, and one side of the filament of each tube is grounded at 175. To the other side of the filament appropriate filament current is supplied from a source connected at 176 in a manner to be hereinafter described.

Thus, it is seen that as tones corresponding to the tone frequencies of the separate sources producing the fundamental and accompanying partials of the notes which it is desired to reproduce are impressed upon the amplifiers

153, 154, 155, 156, 157 and 158, and are then carried over through the transformer 170 to be impressed upon the amplifiers 172 and 173, it is necessary to provide some means for keying these amplifiers as the tones are impressed. Accordingly, I have provided a means by which the amplifiers 172 and 173 may be keyed through their plate circuits.

To refer back to the relay system R_{11} and the armatures associated therewith, it should be understood that as the relay is actuated, the armature 219 closes (of course assuming that note "I" is played) and current from the source 8 may then flow through the choke 18, the terminal 19, the contact arm 20, contact 12, the contact arm 21 on the key I, the conductor 10, the left side contact of the armature 219 and the conductor 177 to the terminal 178 where it passes through the conductor 179, the armature 202 of the relay R_{40} , through the right side contact 180 of the armature 202 and the conductor 181 down through the relay R_{40} to ground at 182. Thus, seen that as current flows through the armature 219, it is the current flowing causes the relay R_{40} to operate. As the relay R_{40} operates so as to move the armatures 201, 202 and 203 to the left, the circuit connection through the conductor 179 and the armature 202 to the relay R_{40} is broken. Current is now adapted to flow from the same source 8 through the same conductors previously described to the terminal 178, and, due to the open circuit through the conductor 179, current now flows through the resistor 183, (which had previously been short-circuited by the conductor 179), and the conductor 181 so as to keep the relay R_{40} in closed position against the left side contacts. Due to the drop in voltage of the current passing through the resistor 183, the current now operating to keep the relay in closed position merely serves as a holding current and barely holds the relay armatures open and away from their right side contacts.

As the relay R_{40} is actuated by current flowing through the conductor 177, and either through the armature 202 for initial closure or through the resistor 183 for holding, the armature 203 is moved to the left from the position shown in the drawings. Under such conditions plate current from the source connected at 184 may then flow through the conductor 185, the left side contact 186, through the armature 203 and the conductor 188 to a terminal point 189 connected between a pair of resistors 190 and 191, and flows through the resistor 190 and the choke 192 to the midpoint 193 of the primary winding 194 of the transformer 195. The current reaching the point 193 then divides through each half of the primary winding 194 to furnish plate current for the tubes 172 and 173.

It should be noted that the relay R_{40} has in shunt therewith a capacity element 196 for the purpose of reducing any sparking effect.

Also, a capacity element 197 is placed in shunt with the series connected resistors 191, 190 and the choke 192 for the purpose of smoothing out the plate current to reduce the steepness of the current wave front. This tends to reduce any possible key thumps. Likewise, with the vacuum tube amplifiers 172 and 173 connected in push-pull fashion, as shown, the thump will be materially reduced if the tubes, which may, for example, be of the type known in the art as the UX-120, are, for this action, carefully matched as to their operating characteristics.

When the relay R_{40} again opens due to the key I being raised, due to a release of pressure thereon for example current supplied from the source 8 to actuate or hold the relay in open position is cut off and a short circuit is placed about the resistor 191 by the closure of the armature 203 upon the right side contact 187. At the same time plate current from the source connected to 184 is cut off from the amplifiers 172 and 173. With the armature 203 resting against the right side contact 187 of the relay R_{40} so as to short circuit the resistor 191, the tube plate current is reduced to zero much more quickly than would otherwise be the case because this arrangement provides a connection between the resistor 190 and ground at 240 through the conductor 210.

With plate current supplied to the tubes 172 and 173, as the various keys which are to be coordinated with this amplifier are played, it is apparent that current will flow through these tubes and through the transformer 195 from which it may be impressed upon the transformer secondary 198 and further amplified through the tubes 199 and 200. The grid electrodes of the tubes 199 and 200 are appropriately biased from a source 204 connected to a point on the resistor 205. A capacity element 206 having one terminal thereof connect to one end of the resistor 205 and the other connect to a point on the filament rheostat 207 shunts the resistor and a part of the filament rheostat. Filament current is supplied to these tubes in any appropriate manner from a source of filament potential connected at 208, for example, and grounded from the other side of the filament at 209.

The output energy from the push-pull connected tubes 199 and 200, which may be, for example, of the type known in the art as the UX-842, is then fed through conductors 241 and 242 to the primary winding 243 of the transformer 244 to which plate current is supplied at the mid-point of the primary from a source of plate potential connected at 245, for example. As current flows through the transformer 244, electrical energy is then transferred to the transformer secondary winding 246 to actuate a loud speaker system (not shown) connected to the terminals 247 and 248.

In order to produce the tremolo effect pre-

viously outlined in connection with the statement and objects of invention, among the various systems which may be used, it has been found convenient to provide a system for cyclically and continuously changing the filament current supplied to the amplifiers 172 and 173 for the purpose of controlling the electronic emission thereof and thus changing the amplifying characteristics of the tube so as to increase and/or decrease the output thereof, or, in other words, increase and/or decrease the input to the coordinated sound reproducer according to a predetermined schedule. Of course, other embodiments may be found suitable for producing this tremolo effect, and while I herein describe one means by which this may be accomplished, I believe myself to be entitled to make and use any and all modifications such as fall fairly within the scope of the present scheme, which might, for example, be done by variations in grid control bias current, by appropriately varying the plate supply energy, or by interruption of keying, and the like, where desired.

As above stated, filament current is supplied to the filaments of the tubes 172 and 173 from a source connected at 176, for example, and this current may then flow through the conductor 249, the choke 250, the switch 251 (assuming the switch to be in closed position) and the conductor 252 to the connection 253 to the filament. In such case, with the switch 251 closed there would be a steady flow of current to the filament from the source 176 which might be smoothed by the choke 250, but with the switch 251 arranged in the open position, as shown, then current from the source connected at 176 may flow to the terminal 254 to which a pair of conductors 255 and 256 are connected. The conductors 255 and 256 are then each arranged through appropriate brushes to bear against the surface of a commutator, diagrammatically shown as 257, which is rotated by any appropriate constant speed device, and which has thereon a conducting segment 258 and a non-conducting segment, 259, each occupying one half the surface of the commutator.

Also connected to the commutator is a second pair of conductors 260 and 261 between which is a resistor 262. The conductor 261 then connects to a terminal 263 so as to supply filament current to the conductor 252. Thus, for example, in the position in which the commutator is shown, current from the source connected at 176 may flow through the conductor 249, the choke 250, the terminal 254, the conductor 256 to the conducting portion 258 of the armature and then to the conductor 260, the resistor 262 and the conductor 261 through the terminal 263 and conductor 252 to the point of connection 253 to the filament of the tube 172. Due to the filament supply

current flowing through the resistor 262, there is a decrease in the voltage of the filament supply, and thus the tube functions with decreased output. However, now assume that
 5 the commutator 257 has rotated through 90° from the position shown, so that the conductor 256 still bears upon the conducting segment 258 of the commutator but so that the conductor 260 will then rest upon an insulating
 10 portion of the commutator. For this position of the commutator, the conductor 261 will also rest upon the conducting segment of the commutator so that current may then flow from the source of filament current
 15 connected at 176 through the conductor 156 and the conducting segment 258 of the commutator through the conductor 261 and thence to the filaments of the tubes 172 and 173. Thus, an arrangement has been provided whereby the resistor 262 has been short
 20 circuited, and by which there is an increase in the voltage supplied to the filament electrode to change the amplifying characteristics of the tube from the previously explained characteristics so that the output energy becomes greater. This cyclic rising and falling
 25 of the tube output at a sub-audible rate, determinable by the speed of rotation of the commutator 257, produces the same effect as the usual type of tremolo on an organ, and when it is desired to utilize the tremolo, the only thing necessary to accomplish this result is to open the switch 251 connected with each
 30 of the amplifiers A, B or C, or other amplifiers, not shown, which are connected with the notes which may be placed by the right hand or by the feet, as the case may be.

Since in many cases it is desirable to provide different tremolo effects on different
 35 amplifiers, I may, where desirable, arrange the tremolos so that the speed of rotation of the commutator 257 is different for different amplifiers. In this manner the tremolo may be made more rapid for certain notes, say, for
 40 example, the higher frequency notes, than for other notes.

In connection with the various figures of the drawings herein illustrated, it should be
 45 noted that all of the ground connections are similar and that all sources of current have the positive side thereof connected to operate the various relays, or filaments, or the like, and that the other side, or the negative side thereof, is connected to ground. Thus all circuits of the filaments, the relays, the pick-ups from the forks and the like, are completed
 50 through similar ground connections, which have been, for the sake of simplifying the illustration, shown as separate and independent ground connections. This system, in the form illustrated, therefore, functions as a single wire system with ground return. This
 55 has proven practicable by using very low impedance circuits of the order of 200 to 300

ohms. It is also practicable due to the fact that no current except desired currents are ever flowing.

Also, in connection with the illustration of Fig. 1—E, for example, I have shown the
 60 "stop effects" or "quality effects" as being produced by means of potentiometers 146, 147, 148, 149 and 150, but I wish it to be distinctly understood that this is shown merely by way of example and for illustrating a simple
 65 means by which this may be accomplished. For instance, where desired, I may provide a master switch arrangement, link motion, or a slide motion, or the like, so as to change the position of the contact on the various potentiometers, and thus change the ratio of
 70 intensity of the fundamental to any of the chosen partials, or I may completely eliminate some of the partials while increasing the intensity of others, or I may make the intensities of all partials equal depending, of course,
 75 upon the tone quality to be produced.

However, for purpose of convenience, I have chosen to provide a system by which the various "stop effects" may be produced
 80 instantaneously, and this I may do by connecting in the circuit of the primary windings of the various transformers 141, 142, 143, 144 and 145 a set of series and parallelly connected resistors, each provided with a switch for operating the same, as is shown more particularly by Fig. 2. Under this condition, tones
 85 impressed upon any one of the systems of which, for illustration purposes, I have merely assumed that the fundamental is being impressed without any of the harmonics over the conductor 115, I may connect there-
 90 to a plurality of resistance elements 664, 665, 666, 667, 668, etc., and by means of switches 669, 670, 671, 672 and 673 connect these resistors in series with the primary circuit of the transformer 141. Also, to correspond to the lower half of the potentiometer 146,
 95 shown by Fig. 1—E, which is in parallel with the transformer primary, I connect resistors 674, 675, 676, 677 and 678, and connect these all to a common conductor 679 in a manner similar to that in which the series resistors connect to the conductor 115 and the switches connect to the conductor 680. Similarly to
 100 the showing in connection with Fig. 1—E, where the fundamental and its chosen harmonics or partials was supplied to the primary of the transformer 141, with the intensity of the various harmonics or partials
 105 appropriately governed, I have grounded the primary of transformer 141 at 252.

Suppose now, for example, that it is desired to produce tones corresponding to violins, flutes, a wood wind effect, bells, reeds,
 110 etc., it is possible by a study of the intensity of the partials or harmonics with respect to the fundamental to determine what regulation should be had between these tones so as to properly represent these effects. Thus,
 115 120 125 130

for example, closing the switch 669, I may produce a resistance value for all of the various partials and fundamentals such that a violin tone will be produced in the output of the loud speaker or sound reproducer connected with the output of the amplifiers 199 and 200, whereas, if a wood tone effect was desired, the only switch which would be closed might be, for example, the switch 672, so that the condition of series and parallel resistors associated with the transformer connected with the amplifiers would hold, as illustrated in connection with Fig. 1—E.

Such an arrangement as is shown by Fig. 2 provides a much simpler set-up than that of Fig. 1—E where it is necessary to change each resistance by a different amount, since it is readily conceivable that where the resistance value necessary to cause the third partial or harmonic, for example, to produce a wood wind effect would be of a different ratio than that of the fourth partial or harmonic to produce a different effect, whereas it might possibly be the case that in order to produce another effect, such as a trumpet effect, the intensity of the third and fourth partial or harmonic might be equal, although these assumptions are merely by way of example and illustration of the principle of operation and are not intended to convey any limitations or assurances that such is actually the case. By using an arrangement of the type last described, where there are a plurality of series and parallel resistors, it is possible to coordinate with each stop all of the resistors corresponding to all of the various partials or harmonics, and thus by closing one switch in each amplifying circuit all of the like switches may be closed through any appropriate form of master switch. If it were assumed that a similar arrangement to that shown by Fig. 2 were connected with the conductors 116, 117, 118 and 119 so that there would be then a plurality of series and parallel resistors for each of these conductors, it is possible to regulate the values of the resistors 664 through 668, and 674 through 678, for example, to provide values such as will represent all tones desired.

Also, in connection with an apparatus of the type which has herein been disclosed, it is possible to arrange the system so that each of the amplifiers may produce a different effect than the other, that is, one amplifier might always be arranged to represent a violin effect, supposing, for example, that the highest note were an obligato part, then the lowest note might always represent a drum, for example. Thus, unusual effects may be obtained with minimum inconvenience. In such a case, the particular note which is to be carried by a particular amplifier may, however, be manually coordinated with the chosen amplifier by regulating the order in which

the chosen note is played with respect to the other notes.

By the arrangement of Fig. 1—E, I have herein disclosed my electric organ system as applicable to tubes of the direct current type, but it should be understood that the application is equally as simple in connection with tubes of the alternating current type which derive their plate current through appropriate rectifiers, and in which the filaments are lit or heated through the use of raw A. C., as is shown by Fig. 3.

Further, in connection with the arrangement herein shown, it should be understood that in practice it is advisable to shunt each of the relays with a capacity element, such as the capacity 281 in series with the choke 36 and around the relay R_{11} , so as to reduce the relay key clicks from the relay, and, likewise, to delay the action of the relay R_{11} , opening, as was the condenser 77, so that the keying relay on the amplifier, as has been shown at R_{10} , may have time to open and shut off the amplifier completely before the relay R_{11} opens. Otherwise, the tone currents when they are broken at the contacts 214 through 218 inclusive, for example, will give a scratching noise due to the fact that the contacts do not break cleanly. Therefore, by the accompanying diagram, I have shown various capacities shunting all of the various relay systems for the purpose of reducing clicks and the like and reducing sparking to a material extent, such as, for example, by the capacities 282 shown shunting the relay systems R_{10} , R_{20} , and R_{30} .

To refer now to the showing of Fig. 3 wherein an amplifier of the A. C. type is assumed to be substituted for the amplifier of Fig. 1—E, the tones, generated by the tone generators of Figs. 1—A, 4—*a*, 4—*b*, 5, or 6, as impressed upon the conductors 115, 116, 117, 118 and 119 are directed in a similar manner to that shown by Fig. 1—E through appropriate potentiometers 146, 147, 148, 149 and 150 which have one portion thereof in series with the primary winding of the transformers 141, 142, 143, 144 and 145, and the other portion thereof in parallel therewith. In a similar manner to that described in connection with Fig. 1—E, the tone impulses as supplied through the potentiometers to the various transformers 140 to 145 inclusive are transferred through the secondary windings thereof to the grid circuits of a plurality of amplifiers 266 to 271 inclusive, each of which have their grid electrodes connected to one terminal of the secondary of one of the transformer secondaries. The other terminal of each of the transformers is connected to ground as at 265, and also to appropriate grid stabilizing resistors 264, which also connect to the grid electrodes of the several tubes. The amplifying tubes 266, 267, 268, 269, 270 and 271 may be of the alternating current type,

for example, those commonly known in the art as the UY—227 type, which have their filaments heated in any preferred and desired manner from a source of 60 cycle A. C. at approximately $2\frac{1}{2}$ volts (not shown for convenience of illustration).

The plate electrodes of all of the various tubes 266 through 271 inclusive are connected in parallel, and shunting the plate and cathode elements of all tubes is a capacity element 272 for the purpose of by-passing radio frequencies, should any such frequencies arise in the output of the amplifiers which might affect the entire audio frequency amplifying system. As is common with most amplifying set-ups using the alternating current type of tube for amplifiers, a suitable source of plate potential is derived after rectifying alternating currents in any appropriate manner by connecting the rectified potential to appropriate voltage to the terminal 273 and passing the said voltage through an appropriate filter choke 274, which is shunted by capacity elements 275 to ground at 276, so that the rectified current, smoothed in appropriate manner by means of the choke and condenser filter, is passed through the conductor 292 and the choke 293 to the plate electrodes of all of the various tubes. Also, connected to the conductor 292 at the end thereof toward ground at 279, I provide resistors 277, 278, and it is preferably between these two resistors that I connect the cathode elements of all of the various amplifying tubes. In parallel with the resistor element 278 connected to ground at 279, I have provided the capacity element 290 which connects on one side to all of the various cathode elements of the amplifiers, and on the other side to ground at 291, for the purpose of forming a by-pass connection to ground. By means of the resistor element 278, there is produced a potential difference between the cathode and grid electrodes of all of the various amplifying tubes, because of the fact that the cathodes connect to ground at 279 through the resistance, and the tube grid electrodes connect to ground through the transformer secondaries and the ground connection 265.

In the output circuit of the various amplifiers 266 through 271 inclusive, I have provided a trap circuit including the capacity element 294, and the primary winding of the audio frequency transformer 296, which is shunted by a resistor element 295, for the purpose of transferring to the secondary circuit of the transformer 296 the combined output of all of the various amplifiers 266 through 271 inclusive as determined by the tones impressed thereon, as hereinbefore described, especially with regard to the similar arrangement of Fig. 1—E.

Connected with the secondary of the transformer 296 and in shunt therewith is a stabilizing resistor element 297. An additional

grid leak resistor element 297' is provided for the purpose of maintaining suitable grid bias potential on the grid electrodes of the amplifiers 298 and 299 which are connected in well-known push-pull fashion in a similar manner to the amplifiers 172 and 173 of Fig. 1—E. In connection with the amplifiers 298 and 299, I have again chosen to provide the usual A. C. type of amplifier, preferably of that type commonly known in the art as the UY—227, and have supplied current for heating the heater elements thereof in any appropriate and desired manner (not shown). The cathode members of these two amplifiers are connected to the center tap of the secondary of the transformer 296 through a capacity element and resistor to ground in well known manner, and also through a conductor 356 to a point on the input supply for producing a relative potential difference between the cathode and the grid electrodes.

In order to supply plate potential to the amplifiers 298 and 299 for the purpose of keying, as was described in connection with Fig. 1—A, with the description of the keying of the amplifiers 172 and 173, I have provided a keying means somewhat similar to that of Fig. 1—E. As was above described, when the key corresponding to the note to be played is completely depressed, a second contact underneath the key is closed so as to supply current from the source connected to the terminal 8 (Fig. 1—C) which, when the relay system R_{11} , for example, is closed will then supply current through the armature 219 to the conductor 177. The conductor 177, as above described, is adapted to furnish the keying current for the amplifier, and, as was above set forth in connection with the operation of the relay R_{10} , as current is applied to the conductor 177 due to the operation of the key representing the note to be played, the relay R_{11} connected to ground at 182, similar to the relay R_{10} , is adapted to be actuated so as to close the armature 300 to the left from the position shown so as to control the plate potential on the amplifiers 298 and 299. In the position in which the relay armature 300 is shown by Fig. 3, that is, against the right side contact, it is seen that plate potential may be supplied to the amplifiers 298 and 299 through each half of the primary winding of the transformer 351, the choke 352, the resistor 353, the armature 300, the choke 354, and the conductors 355 and 356 which are connected to a point 357 on the resistor element 358. This resistor element 358 shunts the source of plate potential supply which, according to the example illustrated, may be 600 volts, so that under this condition the potential at 357 will be 600 volts less the drop across resistor 358. The source of plate potential supply is derived from any appropriate and suitable form of

rectifying means (not shown) having its output connected to the terminals 360 and 361. Under conditions where the amplifier plate potentials are taken from point 357 on resistor 358, as above, it is found that since there is no potential difference at this point between the cathode and plate electrodes of tubes 298 and 299, there is no response therefrom. Therefore, there is no output current flowing from amplifiers 298 and 299 during periods when the relay R_{41} is in an open state with the armature 300 resting upon its right side contact (as shown) adjacent the choke 354. Thus, there can be no response from a coordinated sound reproducer in the absence of any keying of tones to be reproduced.

However, as a note on the musical system is played so as to cause current to flow through the conductor 177, the relay R_{41} is actuated to cause the armature 300 to move to the left from the position shown. Now, plate potential may be supplied to the amplifiers 298 and 299 through the primary winding of the transformer 351, the choke 352, the resistor 353, the armature 300, the choke 363 and the conductor 364 which connects to a point 365 on the regulating resistor 359, also connected across the source of plate supply connected at 360 and 361. Under such conditions, one complete amplifying system which is selected by the selector system, hereinbefore described, may be keyed by the depression of any individual key, since the plate potential now supplied to the amplifiers 298 and 299 is of sufficient value to produce an output current flowing through the tubes when signals are impressed upon the amplifiers 266 through 271 inclusive so as to be transferred through the transformer 296 to the input circuits of these amplifiers.

As signals flow through the output circuit of the amplifiers 298 and 299, they are transferred through the transformer 351 so as to be fed from the secondary circuit thereof to the input circuit of amplifiers 366 and 367, also connected in push-pull fashion. The amplifiers 366 and 367 are adapted to have a greater flow of plate current than the amplifiers 298 and 299, and may, where desired, be of the type tubes commonly known in the art as the UX-245, although other types of tubes may be found suitable and appropriate. The amplifiers 366 and 367, when of the type known in the art as the UX-245, are adapted to have a high plate potential which may be supplied directly from the source of positive potential connected to the terminal 360, and connected to the plate electrodes of the amplifier through the choke 369 and either half of the primary winding of the transformer 370.

As was disclosed in connection with Fig. 1—E, signals flowing in the output circuit of the last stage of the amplifying system,

represented by the amplifiers 366 and 367, are adapted to be transferred through the transformer 370 so as to actuate a sound reproducing or a loud speaker system (not shown, but preferably of the above identified type) connected to the terminals 371 and 372, which are in turn connected to the secondary windings of the transformer 370. Thus, signals impressed upon the conductors 115 through 119 inclusive are adapted to produce tones in the speaker unit connected to the terminals 371 and 372 in the same manner that signals impressed upon the same conductors were adapted to produce tones in the speaker unit connected to the terminals 247 and 248 in connection with the D. C. set-up shown by Fig. 1—E.

In connection with the showing of Fig. 1—E, I disclose a suitable method and means by which the well-known tremolo effect may be produced in connection with the amplifier therein shown. However, in accordance with the A. C. type of set-up as is shown by Fig. 3, it is possible to resort to a slightly different form of arrangement in order to accomplish the same effect. Accordingly, by the showing of Fig. 3, there is a modified form of tremolo in which the main purpose, as will hereinafter appear, will be to function as a sort of "robber" arrangement whereby the strength of the plate current flowing in the output circuit of the amplifiers 298 and 299 may be appropriately regulated and controlled in a cyclic manner and at a sub-audible rate so as to vary the tremolo strength between two predetermined limits of effective output energy from the amplifier or effective input energy to the sound reproducers.

In order to connect the tremolo with the amplifying system including the push-pull tubes 298 and 299, I have provided a switch 374 connected with the conductor 373 which is associated with the plate current supply for these tubes by connecting the same between the resistor 353 and the choke 352. When it is desired to connect the tremolo apparatus with the amplifiers, the switch 374 may be closed, and simultaneously therewith the switch 375 connected in the input circuit of the motor 378 should be closed. The input circuit of the motor 378 has alternating current voltage of approximately 110 volts (the common A. C. supply) connected to the terminals 376 and 377, so that the motor begins to turn when the switch 375 is closed, and simultaneously therewith a commutating system 390 is rotated in the direction shown by the arrow at a speed corresponding to the rate of change of the effective energy from the amplifier between the two above named predetermined limits. However, where desired, and where the loss of energy due to the continual running of the motor is without objection, the switches 374 and 375 may be closed at all times and the tremolo effect appropri-

ately controlled in a manner as will herein-
 after appear, so that the tremolo may be "on"
 or "off" at the will of the operator. The ter-
 minal of the switch 374 connected at one ter-
 5 minal with the conductor 373 is adapted to be
 connected at its other terminal with a brush
 379 contacting with one of the three sections
 of the commutating system 390. To the out-
 side segment of the commutating system 390
 10 is connected a second brush 380 which,
 through conductor 381, connects to the plate
 electrode of a tube, which I will hereinafter
 term the "robber tube", for the purpose of
 regulating the tremolo. While not shown for
 15 convenience of illustration, the multi-ring
 commutator 390 may be provided with one
 ring, for example, the ring to which the
 brush 379 is connected, which is a solid con-
 ducting ring, and the other rings of which
 20 are part conducting and part non-conducting,
 such, for example, that the middle ring there-
 of is provided with, for example, two con-
 ducting and two non-conducting segments,
 while the outside ring thereof, to which the
 25 brush 380 is connected, is provided with four
 conducting and four non-conducting seg-
 ments. Thus, if the conducting segments of
 all portions of the commutator are connected
 and the non-conducting segments are formed
 30 by providing recesses in the cylindrical com-
 mutator and filling these recesses with insu-
 lating material, the brushes 379 and 380 are
 at certain periods of time both resting on
 conducting segments, while at other periods
 35 of time the brush 380 is resting upon a non-
 conducting segment. Thus, the current flow-
 ing in the output circuit of the tube 382 is
 cyclically interrupted at a predetermined and
 desired rate. For example, where the brush
 40 380 rests upon a commutator ring provided
 with the larger number of conducting and
 non-conducting segments, the plate circuit
 of tube 382 is opened and closed at a more
 rapid rate than when the brush 380 is resting
 45 on the middle segment of the commutator
 provided with a lesser number of conducting
 and non-conducting segments. The rate of
 the tremolo is thus controllable.

Plate current for the tube 382 is supplied
 50 from the source of potential connected to the
 terminals 360 and 361 and flows through the
 portion of the resistor 359 between the ter-
 minal 360 and the point of connection 365
 through the conductor 364, the choke 363, the
 55 armature 300 moved over against its left
 side contact from the position shown, and the
 resistor 353, the conductor 373, the switch 374
 and the brushes 379 and 380, as well as the
 rings of the commutator 390 when both
 60 brushes are resting upon conducting seg-
 ments. At periods when the commutator
 segments beneath the brushes 379 and 380
 are both conducting so that current can flow
 through the commutator between the two
 65 brushes, the tube 382 functions to draw a por-

tion of the plate current which would nor-
 mally be supplied to the amplifiers 298 and
 299, and the plate current output of the am-
 plifiers is reduced.

However, in order to derive a more de-
 70 cided tremolo effect, and to increase the limits
 between maximum and minimum effective
 current flow from the amplifier to the sound
 reproducers, provision is made for control-
 ling the bias potential on the grid electrode
 75 of the tube 382 so that it may be more strong-
 ly positive or more strongly negative, as de-
 sired. Of course, with the more strongly
 positive grid, the tremolo effect is more de-
 cided than where the grid is more strongly
 80 negative, due to the fact that in the first in-
 stance the flow of plate current is consid-
 erably greater. For controlling the potential
 on the grid electrode of the "robber" tube
 382, I have connected the grid through a
 85 conductor 383 to a potentiometer 384. The
 position of the adjustable contact of the po-
 tentiometer 384 may be controlled in any
 manner desired. Where it is desired to ap-
 ply a decided negative bias upon the grid
 90 electrode of tube 382, so that the tube will at
 all times be blocked, it is unnecessary to open
 and close the switch 374 in order to apply
 and remove the tremolo effect, because of the
 fact that the tube 382 can at no time draw
 95 plate current under such conditions. A
 source of potential is connected to the ends
 387 and 388 of the resistor element 385 of
 which the positive side of the source is con-
 nected at 387 and the negative side at 388.
 100 One end of the potentiometer 384 connects
 at all times to the negative side of the resis-
 tor 385 and the other end is provided with
 a variable tap at 386 to vary the potential
 drop occurring in the resistor 385 between
 105 the point of connection 387 of the positive
 potential and the point of connection of the
 contact 386.

By Fig. 1—A of the drawings, I have
 110 shown one of several forms of set-ups which
 may be used for producing the different
 tones, such as the fundamental and the ap-
 propriate harmonics. By this figure, I have
 chosen to illustrate tuning forks which are
 115 extremely accurate as to each tone, although
 it has been found to be rather difficult to ar-
 range a complete set-up where all forks as-
 sume like characteristics and are free from
 changes due to temperature, mountings, etc.
 120 Therefore, according to the showing of Figs.
 4—a and 4—b, I have provided what I have
 termed "tone wheels", generally designated
 at 391. The tone wheel 391 is provided with a
 plurality of teeth 392 which extend radially
 125 from the center thereof and which are
 adapted to rotate, in the direction shown by
 the arrow, about the shaft 393.

A plurality of tone wheels of the type
 shown by Figs. 4—a and 4—b, when mounted
 130 on a single shaft and rotated in any desired

manner, are adapted to function as simple low-power alternators. The main consideration in the design of these alternators is to produce pure sine waves of a few volts. However, it is practically impossible to obtain an absolutely pure sine wave, and, therefore, in accordance with the tone wheels shown by Figs. 4—*a* and 4—*b*, a compromise is made to provide a tone wheel in which the noise and harmonic effects are reduced to such a low level that they never become audible, and, at the same time, have a negligible modulating effect. As shown by Fig. 4—*a* more particularly, the single unit tone wheel is preferably of steel construction and the teeth thereof are rotated before the magnetic pick-up 394 and 395. The magnetic pick-up 394 and 395 is formed from a strong permanent magnet 400 shaped at its outer end to conform to the peripheral shape of the individual teeth of the tone wheels, and the pick-up portions 394 and 395 are of a length substantially equal to the length of each of the teeth of the wheels on their periphery. As the tone wheel 391 revolves about the shaft 393, the various teeth thereof as they come beneath the pick-up portions 394 and 395 of the magnetic pick-up system are adapted to change the reluctance between the pick-up points 394 and 395 from a very high to a very low value. This gives the effect of a changing magnetic field through the conductors on the coils and causes the conductors 396 and 397 to generate an electromotive force of a frequency determined by the speed of rotation of the tone wheel and the number of teeth therein.

The current which is generated by the rotation of the tone wheel 391 is kept as pure as possible by generating a maximum amount of the fundamental frequency, which may be done by making the magnet 400, and thus the field, as strong as possible; also, by using many conductors in the coils so as to increase the voltage output; also, by cutting the teeth in the tone wheels as deep as possible, as shown; and also by eliminating vibration of the pick-ups as far as possible, such as, for example, by using shock-absorbers and reducing the inertia of moving parts. Energy generated in the coils 396 and 397 is utilized by making appropriate connections to the conductors 398 and 399 connected thereto.

By the well-tempered scale to which most musical systems are designed, the octaves are the only perfect tone intervals, and all tones in between the octaves are purely arbitrary and governed in accordance with what might be termed a give-and-take process, so as to produce the most pleasing sound effect from the actuation of all keys. In the octaves, each note is twice the frequency, or the 1st harmonic, of the same note an octave below it. Therefore, this leads to a design of an alternator of the type shown by Figs. 5 and 6, wherein a plurality of tone wheels having a

progressively different number of teeth, such as 1, 2, 4, 8, 16, 32, etc., may be mounted on the same shaft so as to each give a tone exactly one octave away from the adjacent tone wheel. In order to produce the tones desired, it is necessary to set the speed of rotation of the shaft upon which the tone wheels are mounted at such a speed that the notes of the well-tempered scale may be produced. For instance, if it is desired to have one generator give all of the notes corresponding to "C" in as many octaves as there are tone wheels, the desired speed of rotation of the shaft carrying all the tone wheels may be calculated from the formula:

$$R. P. M. = \frac{60 F}{T},$$

where R. P. M. is the revolutions per minute, F is the frequency of the note to be produced, and T is the number of teeth on the tone wheels. Thus, to assume a concrete example, if it is desired to have a single-tooth wheel produce the note "C" corresponding to 16.35 cycles, the formula may be written

$$R. P. M. = \frac{60 \times 16.35}{1} = 981.0,$$

so that if the shaft is turned at 981 R. P. M., the various tone wheels will give all of the "C's" on the keyboard, and all these particular notes will be tuned to perfect concert pitch.

However, if it is desired to use more than 64 teeth per wheel, it has been found that difficulties are encountered because of the fact that the larger wheels in order to conform to the standard above set must be so large that the inertia and vibration is considerably increased; the wheels are expensive if made accurately; considerable room is required; or where these difficulties are avoided, the teeth must be so shallow and small that it is impossible to produce a fundamental voltage wave enough above the noise and harmonic level to be usable.

Therefore, in accordance with the showing of Fig. 5, I have provided two shafts each carrying a predetermined number of tone wheels, and have chosen an appropriate gear ratio between the speeds of each shaft. To take the note "C" again for example, as in the previous case, and assuming that the shaft carrying the tone wheels is revolving at 981 R. P. M., in accordance with the example previously given, if tone wheels corresponding to 1, 2, 4 and 8 teeth are placed upon this shaft, frequencies of the order of 16.35, 32.70, 65.41 and 130.8 cycles may be produced, and if it is assumed that a second shaft is driven from this shaft or that a second shaft is used to drive this shaft at a reduced speed so that the relationship between the speed of the shaft previously described as 981, and the other shaft is eight times 981, for example, 7848 R. P. M., it has been found that by hav-

ing still a further plurality of tone wheels, such as might be formed from 2, 4, 8, 16, 32 and 64 teeth, it is possible to obtain frequencies therefrom corresponding to 261.7, 523.3, 1046.3, 2093.0, 4186.0, and 8372.0 cycles per second. In other words, I have provided an arrangement whereby ten complete octaves of the "C" note are developed.

To refer more particularly to Fig. 5 of the drawings, I have shown the tone wheels 450 to 455 inclusive as being mounted upon a shaft 456 and driven from a turbine 457 such that the shaft 456 may be what is termed the "high-speed shaft", or, in other words, to refer to the previously given example, a shaft rotated at a speed of 7848 R. P. M. Associated with each of the tone wheels 450 to 455 inclusive, I have provided the energy pick-up systems of the type shown in connection with Figs. 4-a and 4-b, and, for convenience of illustration, have only identified one of these sets of pick-ups by numerals. The shaft from the turbine upon which the tone wheels are carried is appropriately mounted and supported in bearings 459 and 460. Toward one end of the shaft 456, I have provided a gear reduction system, conventionally shown as 461, through which the shaft 468 may be rotated at a speed equal to one-eighth of that of the shaft 456, as above set forth for speed requirements. The tone wheels 463 through 466 inclusive are supported upon the shaft 468, so as to produce the lower frequency tones. The tone wheels 450 to 455 inclusive carried on the high speed shaft 456 produce the higher frequency tones. If it is assumed that this showing represents all of the notes corresponding to "C" on the musical scale, the values above given may be assumed as those frequencies which are generated by the rotation of the tone wheels.

At the end of the turbine shaft 456 there is a governor, conventionally shown and generally designated as 469, which is adapted to control the speed of the turbine in a manner to be hereinafter set forth.

The turbine 457 is preferably driven with air, since it is easier to generate and use a steady air pressure than a stream pressure or a hydraulic head, although the latter are fully within the scope of my disclosure and may be used where desired. The turbine which has been found especially suitable for the purpose herein disclosed is one of the three stage pressure-compounded reaction type, such that the normal speed under a load of only a single tone wheel and about three to five pounds pressure of air is approximately 9000 R. P. M.

In order to control the speed of rotation of the shaft and of the turbine, the governor 469 carrying the weights 470 supported therefrom by means of a plurality of pairs of arms 471 and 472 is adapted to rotate with the shaft. As the speed of the shaft 456 increases

and overcomes the pressure of the spring 473 contained inside the governor and tending to pull the weights 470 toward the shaft, the weights tend to fly outwardly due to the centrifugal force of rotation. As this happens, the end 474 of the governor is moved to the left from the position shown, and the follower 475, mounted on a separate shaft 486 carried by the bearing 476, is also adapted to move to the left due to the spring pressure derived from the spring 485, to be hereinafter explained.

The air supply, assuming air is used for driving the turbine 457, is adapted to enter into a control valve, generally designated 477, through the intake port 478 and flows within the chamber 477' to either side of the baffle plate 479 mounted closely adjacent the intake.

Also carried by the shaft 486 and adapted to move therewith simultaneously with the movement thereof, due to the changing position of the follower 475 with respect to the lower end 474 of the governor, are the valves 482 which, when closed, are adapted to fit over the ports 481 at the lower end of the baffle plate 479. In the position shown, with the shaft 486 moved approximately to the end of its right hand movement, looking at Fig. 5, the valves 482 are open and air flowing into the valve 477 through the intake port 478 is adapted to flow on either side of the baffle 479, thence through the ports 481 and out of the valve through the outlet port 480 from which it is directed through an appropriate pipe or flexible tube to the turbine 457 as a driving force therefor.

As the turbine 457 approaches its desired or normal speed, the weights 470 of the governor tend to fly outwardly and the follower 475 due to the action of the light spring 485, supported within the housing 483 carried on the end of the valve chamber 477 resting against the end of the housing and the collar 484 carried on the shaft 486, also moves to the left, and thus partly closes the ports 481 of the valve to a position of equilibrium. Now, should the intake air pressure rise, the turbine connected to the outlet from the valve 477, through any appropriate form of air connection, speeds up, and thus the weights 470 will tend to fly outwardly. As this happens, the valves 482 move to the left to close the ports 481 so that the turbine is slowed down. The shaft 486 will then move to the right due to control action from the governor to slightly open the ports 481 and once more compensate for the change in the air pressure supply.

As is seen from the showing of Fig. 5, a valve arrangement for controlling the speed of a turbine tone generator system for producing different tones has been provided, and the speed control or synchronization medium for the system is a means which controls the

speed of the prime-mover functioning as a driving force in such manner that there is practically no change in the speed thereof irrespective of pressure fluctuations, due to the free floating action of the valve. When it is borne in mind that the spring 485 is just sufficient to overcome friction, so that the valve rod 486 floats freely in the bearing 476 and the bearing contained within the housing 483 so as to respond instantly to any motion of the governor carried by the turbine shaft, it will be recognized that the system is especially sensitive to speed changes so as to apply correction and maintain all tones of constant frequency.

However, in many cases, it is highly desirable to resort to an electric drive for the tone producers so that it is unnecessary to use air or the like as a driving force, and because of the fact that convenience often demands that electric drives be substituted for other forms of mechanical drives.

Therefore, by Fig. 6 of the drawings, I have shown a preferred form of electric drive wherein the motor 490, which may be of the 110 volt A. C. type, is adapted to turn the shaft 493, and through the use of a pair of gears 491 and 492, drive a shaft 468 similar to the shaft 468 of Fig. 5. The shaft 468 is mounted in bearings 462 and 467 and carries therewith tone wheels 463 through 466 inclusive, which were previously designated as the tone wheels revolving on the low speed shaft. In order to provide for a high speed shaft for generating the higher frequency tones, I have provided a similar gear system 461 to that shown by Fig. 5, and rotate therefrom a similar shaft 456 for the purpose of turning the tone wheels 450 through 455 inclusive, each provided with a similar pick-up system to that described in connection with Figs. 4-a and 4-b.

At one end of the motor shaft 493 there is arranged a governor 469 (which is the same as that shown by Fig. 5) for responding to changes in motor speed. Controlled from the end 474 of the governor 469 is a pair of contacts 495 and 496 adapted to control the synchronizing system in a manner to be hereinafter explained in connection with Fig. 7. On the other end of the motor shaft 493 there is positioned a commutator, generally designated 494, for serving as a further control element in controlling the speed of the motor 490 which will also be explained in connection with the description of Fig. 7, wherein I have shown a preferred form of synchronizing element for rigidly maintaining constant speed with substantially no hunting from the motor 490 used for driving the tone wheel shafts.

Now to refer more particularly to the synchronizing system, the motor 490 as it rotates is adapted to control the position of the weights 470 on the governor previously de-

scribed, and when the motor is at rest, the weights 470 are drawn towards the shaft 493 by pressure of the spring 473 contained within the governor so as to move the end 474 thereof to the right as shown by Fig. 7. Under such conditions, the contact arms 495 and 496 provided with contact points 510 and 511 respectively are brought together and moved to the right from the position shown so that the contact 512 of the contact arm 496 rests against the contact 497 which is connected through a conductor 498 and switch 499 to a terminal 500 to which is supplied positive potential of appropriate strength and value. In order to start the motor 490, the switch 499 is closed so that positive current connected to the terminal 500 may flow through the switch 499, the conductor 498, the terminal 497, the contact 512 of the contact arm 496, the contacts 511 and 510, which are now pressed together due to the fact that the motor has not yet started, the contact arm 495 and conductor 501 through to the winding of the relay R_{50} and thence through the conductor 502 and resistor 503 to the terminal 504 to which the negative side of the source of current is connected. Thus, with the closure of switch 499, the relay R_{50} is energized and acts to move the armatures 505, 506 and 507 upward from the position shown so that they rest against the contacts 549, 514, 509 and 521 respectively. The armature 505 now serves to close the motor circuit by short-circuiting the resistor 555 through the conductors 554, the armature 505, the contact 549, the conductor 553 and the point of connection thereof to the terminal 551 to which the impressed voltage for driving the motor 490 is impressed. Current may now flow from the positive source connected to the terminal 500 through the conductor 498, contacts 497 and 512, the contact arm 496 and the conductor 508 to the relay contact 509. As current is supplied to the relay contact 509, it then flows through the armature 506 and the contact 514 through the conductor 515 where it divides and flows through the conductor 516' to the contact 517 adjacent one tine of the fork 518, and also through the conductor 516 to the middle slip ring 532 of the commutating system 494. The slip ring 532 is connected preferably to one half of the commutator ring 558 which is divided into two separate portions 533 and 534 separated by a strip of insulating material 535 on each half of the commutator. This connection of the slip ring 532 to the segment 533 of the commutator ring 558 is by way of a conductor 559. Current supplied from the source connected at 500 may now flow from the brush connected with the slip ring 532 through the conductor 559 to the commutator segment 533 and upward through the brush connected thereto and the conductor 537 to the armature 507 and from there through the contact 521 and the conductor

523 to the winding 524 and thence to the negative side of the source of potential through the conductor 527, the resistor 529 and the terminal 530. The fork speed control 518 is now started in vibration. By virtue of the fact that a source of positive potential is connected to the terminal 520 and through the conductor 519 to the fork, as the fork times swing or vibrate a connection of the source of positive potential is made upon vibrational movement of the fork time through the contact 556 and the conductor 557 to the slip ring 531. Similar to the slip ring 532, the ring 531 is connected with the second half of the commutator ring 558 through the conductor 560 so that as the fork vibrates and as the commutator is turning, due to the rotation of the motor, current will next be supplied to the actuating winding 524 through the same conductor 537 now having the brush connected thereto bear upon the commutator segment 534 so as to drive the fork. Simultaneously with this action, positive current connected to the terminal 520 is also supplied to the opposite time of the fork, and as the time comes to bear upon the contact 526, the positive current is likewise supplied through the conductor 525 to the fork actuating coil 524 so as to produce a further aid in driving the fork.

As the motor 490 tends to reach the desired speed, and this speed should be a slight amount greater than that desired, for the purpose of providing simpler synchronization, the weights 470 of the governor 469 tend to fly outwardly from the shaft and this then breaks the connection between the contact 512 of the contact arm 496 and the contact point 497, so that current from the source connected to the terminal 500 through the contact point 497 is interrupted. Thus the holding current for the relay R_{50} which initially originated from the source connected at 500 is now interrupted, but simultaneously with this operation, now that the relay has once been actuated, the source of holding current originates at the source of positive potential connected to the conductor 513 and the relay armature 506 so that through the contact 509 of the conductor 508, the contact arm 496 and contacts 511 and 510, current can flow through the contact arm 495 and through the conductor 501 connected to the negative side of the source of potential 504 to operate the relay R_{50} .

However, as the motor speed further increases the pressure of the end 474 of the governor 469 decreases against the contact arm 495 by reason of the governor weights moving further out from the shaft due to the centrifugal force of revolution of the governor, and this causes the contacts 510 and 511 of the contact arms 495 and 496 to also separate. Under such conditions, there is an open circuit between both the source of posi-

tive potential connected to the terminal 500 and the source of positive potential connected at 513 to the negative side connected at 504, so that the relay R_{50} is open and all of the armatures 505, 506 and 507 drop to the lower position against the contacts 548, 515 and 522 respectively. As this happens, the fork 518 tends to control the motor directly and without the aid of the starting relays.

Under such conditions, the fork is driven entirely by means of the current supply connected to the terminal 520 and the conductor 519 to the fork so that the current then flows through the time of the fork against the contact 526 and the conductor 525 through to the negative side of the potential source by way of the fork actuating coil 524, and positive potential derived from the source connected to the terminal 520 then alternately flows through the conductors 516 and 557 by way of the contacts 517 and 556 adjacent the opposite time of the fork from the driving side. Thus, current is alternately supplied to the slip rings 531 and 532 at the period of the fork so that it may flow alternately through the commutator segments 533 and 534 in accordance with the speed of rotation thereof as is in turn governed by the motor speed. As this is happening, the resistor 555 is no longer short-circuited because of the fact that the armature 505 has dropped to its lower position and an auxiliary control impedance for controlling the motor speed is connected across the input terminals to the motor by way of the same conductor 554 connected to the armature 505 and the conductor 550 connected to the opposite side of the motor leads, the windings 546 and conductor 547 connected to the lower terminal 548 of the relay armature 505 so as to complete the circuit.

With the commutator 494 revolving and current thereby being supplied to the two commutator segments 533 and 534, the current is carried through the conductor 537 and the armature 507 to the lower contact 522 and thence through the conductor 538 to the motor control circuit, generally designated 539. The motor control circuit includes a pair of windings 540 and 541 serving as the primary windings of a saturation reactance or transformer 561. In shunt with windings 540 and 541 is a resistor 542 and a capacity 543 which are connected to the negative side of the source of potential connected at 545 through the conductor 544. The capacity 543 is intended as a smoothing capacity for smoothing the current flow through the control circuit and also for reducing the effect of sparking by the commutator due to the rapid rotation thereof. At time periods when current is supplied to the commutator, and in turn to the motor control circuit 539, if the current strength flowing through the control winding 539 increases due to the fact that the rate of rotation of the commutator 494 is

out of step with the vibration of the fork, the impedance in the secondary winding 546 is materially increased, and thus a greater load is placed across the motor circuit and consequently more current is supplied in the winding 546 so as to reduce the speed of the motor and cause it to approach the fork speed. However, if the fork 518 and the motor 490 are exactly in step so that the current supply from the source connected at 520 and connected through the conductors 516 and 557 to the slip rings 531 and 532 is exactly in step with the rotation of the motor so that the commutator segments 533 and 534 are energized at exactly the same time that the current from the source connected to the fork is supplied through conductors, the impedance of the coil 546 is reduced to a minimum and thus the motor tends to assume its own natural speed, but where the current supplied is out of step with the rotation of the commutator, then, due to the fact that the motor is slightly over-speed, and due to the fact that the impedance in the winding 546 is increased, the motor speed will be reduced and approach that which is desired.

In order to provide for the different speeds of rotation of the various shafts driving the plurality of tone wheels, as is apparent due to the above outlined requirements, it is advisable to procure motors of different speeds and to then control these motors from forks or the like having different vibrational characteristics so that the fork for controlling all of the motor shafts corresponding to all of the notes "C" on the scale will be of a different frequency from the fork used to control the motor driving all notes corresponding to "B" on the scale, and, similarly, the motors themselves will be of different speed characteristics, although preferably motors of the type to which the same source of power may be connected for driving purposes. Therefore, in accordance with the arrangement herein disclosed by Figs. 5 and 6, which are controlled as to their speed by the valve control for the turbine drive of Fig. 5 and by the fork control of Fig. 7 for the electric drive of Fig. 6, it is now necessary to assume that the pick-up coils 398 and 399 of the tone producing system, as shown by Figs. 4-a and 4-b, are connected in the manner shown by Fig. 1-a, and, therefore, to the ends of the conductors 398 and 399, assuming that the tone wheel shown by Figs. 4-a and 4-b represents the note "C" assumed to be produced by the fork 2 of Fig. 1-a, connect the conductor 398 to ground as at 6 of Fig. 1-a and the conductor 399 to the conductor 105 which connects to the tone terminal 100 of Fig. 1-a. Likewise, in connection with the showing of Figs. 5 and 6, I connect all of the tone pick-ups from the tone wheels to similar terminals in a manner similar to that shown by the various parts of Fig. 1, so that all of the tones

produced in the entire system may be coordinated with various keying relays of the type conventionally shown by R_{11} , R_{21} , R_{31} , etc. until the entire tone producing system is coordinated with various keying relays. As was above stated in connection with the description of the various parts of Fig. 1, the tones produced by the individual tone wheels of Fig. 4, 5 or 6 may in some instances form the fundamental frequency for some notes, and especially the fundamental for the note which they represent, but that they may also form the harmonics of some other note in the entire musical scale, and, therefore, it should be understood that each of the tone wheels is capable of a double use as were the forks of Fig. 1-a, of producing the fundamental for one note and the harmonics for one or more notes.

Thus, from the above description, it readily appears that I have provided a system for producing musical sounds in which there is a plurality of tone producing alternators of a number equal to the number of independent and individual tones on the scale, and with these tones I have coordinated a number of independent amplifiers of a lesser number than the notes on the entire musical scale, and at the same time of a number equal to the maximum number of notes to be played simultaneously. Also, it should be recognized that one independent amplifier is keyed to each of the tones or notes played, and that this amplifier produces at its output end a tone corresponding to the fundamental and the partials of each of these notes, although, of course, in accordance with the intensity of the sound desired, and in accordance with the particular type of note which it is desired to represent, as was described in connection with Fig. 1-e and Fig. 2, wherein the various resistors or potentiometers were shown for controlling the intensities of the various partials or harmonics with respect to the fundamental so that the percentage of each of the partials or harmonics with respect to the fundamental was controlled.

Also, it should be understood that the invention is intended to cover a system wherein there is a definite selection of the various amplifiers in accordance with the position of the note on the scale, and, further, that I have provided a means whereby the tones are keyed to the keying contacts, and thus to the input circuit of the coordinated amplifier, at a time period just prior to the time of keying the particular amplifier which is selected to these individual tones so as to reduce noise effects. In addition to the above features, the invention covers, at the same time, an electrical music system having a plurality of tone amplifiers so arranged that each amplifier at one instant is capable of producing only one particular note, and a means whereby the notes played on the con-

sole keyboard an instant prior will not be heard simultaneously with any new notes to be coordinated with the particular amplifier.

It should be noted in connection with the method and apparatus herein described that it is not always necessary to produce the fundamental for each note in order to produce a characteristic tone. This is particularly true in connection with the low frequency notes in the lower portion of the register where it is possible to obtain the characteristics of a lower tone only through the use of the selected upper partials or harmonics of that tone. However, for the purpose of this description and for the purpose of definition throughout the claims, I have referred herein to the use of the fundamental frequency plus any or all selected and predetermined partials or harmonics as representing each note of the musical scale.

While I have herein shown and set forth, and particularly described, the use of tone generators in the form of tone wheels, tuning forks, photo cell pick-ups and the like, it should also be borne in mind that I may substitute any form of tone generator known in the art; for example, a vacuum tube oscillator of the type disclosed by Patent No. 1,376,288 granted April 26, 1921 to F. E. Miller. Such substitution, of course, would involve only the changing of the connections of the outputs to appropriate contacts of the selection relays of the system, as described in connection with the illustrated examples of the tuning fork and tone wheel generators, and not otherwise produce any material change in the arrangement.

While the invention has now been described in connection with one of its preferred embodiments, it is, of course, to be recognized that many modifications and changes may be made therein such as to adapt the system to pianos as well as organs, or to provide in combination with the system herein disclosed a record sheet or surface having markings, perforations, or other identifying characteristics so as to provide for automatic operation, either through air or electrically controlled means, for example. Also, in a similar manner my system herein disclosed readily adapts itself to use in connection with musical reproducers of the types used to resemble orchestra effects. This may be done, for example, by coordinating the various amplifiers with one of the selected instruments so as to represent each of the desired tone or quality effects. Many other changes and modifications will at once suggest themselves to those skilled in the art to which my invention relates. Therefore, I believe myself to be entitled to make and use any and all of the modifications such as fall fairly within the spirit and scope of my invention as defined by the hereinafter appended claims.

Having now described my invention what I claim and desire to secure by Letters Patent is the following:

1. In an electrical music system, a plurality of tone generators, a plurality of sound reproducers of a number less than the number of tone generators, and means for coordinating one of said sound reproducers with tone generators for a single note only at any instant.

2. In an electrical music system, a plurality of tone generators, a plurality of sound reproducers of a number less than the number of tone generators, means for coordinating one of said sound reproducers with the said generating means for a single tone, and means for limiting the number of notes on one sound reproducer to one at any given instant.

3. In an electrical music system, a plurality of tone generators, a plurality of sound reproducers of a number less than the number of tone generators, and means for limiting the number of notes on one sound reproducer at any one instant.

4. In an electrical music system, a plurality of generators for producing electrical energy of frequencies corresponding to each note of the musical scale, sound reproducers of a number equal to the notes to be played simultaneously, means for causing the reproduction of sound corresponding to fundamental and selected harmonic frequencies of coordinated notes of the musical scale impressed upon said sound reproducers, and means for singly connecting the said sound reproducers with the generators corresponding to the desired notes to be reproduced at any one instant.

5. In an electrical music system, a plurality of tone generators of a number equal to the number of notes in the musical system, amplifying systems of a number corresponding to the number of musical notes to be produced simultaneously, means for independently keying said amplifiers at any instant with tone generators corresponding to a single musical note only, and a sound reproducer connected with each of the amplifiers.

6. In an electrical music system having a keyboard with keys assigned to each note of the musical scale, a plurality of tone generators for generating electrical energy of frequencies corresponding to the fundamental and predetermined harmonics of each fundamental note of the musical scale, a plurality of sound reproducers of a number equal to the maximum number of notes to be played simultaneously, means for supplying tones from tone generators to said sound reproducers as keys corresponding to desired notes are depressed on the keyboard, and means for limiting the number of tones in each sound reproducer at any one instant to the selected

fundamental frequency plus the predetermined and chosen harmonic frequencies.

7. In an electrical music system having a keyboard with keys assigned to each note of the musical scale, a plurality of tone generators for generating electrical energy of frequencies corresponding to the first partial fundamental and other predetermined partial frequencies of each note of the musical scale, a plurality of sound reproducers of a number equal to the maximum number of notes to be played simultaneously, means for supplying tones from tone generators to said sound reproducers as keys corresponding to desired notes are depressed, means for limiting the number of tones in each sound reproducer to the selected fundamental frequency plus the predetermined and chosen partial frequencies at any one instant, and means for separately controlling the intensity of each of the fundamental and other predetermined partials reproduced by said sound.

8. In an electrical music system, a plurality of tone generators for generating the fundamental frequency and harmonics for each note throughout the musical scale, a plurality of sound reproducers for audibly reproducing the fundamental and harmonic frequencies of the generated notes as desired, means for amplifying the fundamental and harmonic frequencies of each of the generated tones as desired, means for selectively coordinating individual fundamental and harmonic frequencies corresponding to desired notes of the scale to be reproduced with said amplifiers and sound reproducers, and means for keying the said sound reproducers with each of the amplifiers with a predetermined time delay after desired tone frequencies are impressed thereon.

9. In an electrical music generating system, a plurality of tone generators for both fundamental and other predetermined partial frequencies of the notes throughout the musical scale, a plurality of amplifying systems of less number than the number of tone generators, means for selectively keying the amplifiers with the tone generators, a sound reproducer associated with each of said amplifiers, and means for limiting the tones on each of said amplifiers at any one instant to the first partial fundamental and predetermined selected partial frequencies corresponding to a single note selected.

10. In an electrical music system, a plurality of generators for producing electrical frequencies corresponding to each note throughout the musical scale, a plurality of sound reproducers of a number less than the number of generators, and means for selectively coordinating each of said sound reproducers with generators producing frequencies corresponding to a predetermined musical note so as to produce from each sound reproducer at any instant frequencies corre-

sponding to a single note only and independent of the frequencies produced from each other sound reproducer.

11. In an electrical music system, a plurality of generators for producing electrical energy tone frequencies corresponding to the fundamental and predetermined overtones of each note of the musical scale, a plurality of sound reproducers of a number equal to the number of notes on the musical scale to be played simultaneously, means for individually coordinating one of said sound reproducers with the frequency generating means for a single musical note in accordance with desired tone reproduction, means for limiting the number of tone frequencies on one sound reproducer to frequencies corresponding to a single musical note at any given instant, and means for successively coordinating other desired tones with other of said sound reproducers.

12. In an electrical music system, a plurality of tone generators for generating electrical energy of frequencies corresponding to each note of a musical scale, a plurality of sound reproducers of a number equal to a predetermined number of tones to be played simultaneously, means for successively and individually associating said sound reproducers with said generators for audibly reproducing the generated tones, and means for limiting the number of tones on one sound reproducer at any one instant.

13. In an electrical music system, a plurality of tone generators for producing electrical energy of the various frequencies representing each note of the musical scale, a separate sound reproducer for each of the several notes to be played simultaneously, means for causing the reproduction of sound corresponding to fundamental and other partial frequency tones of coordinated notes of the musical scale impressed upon said sound reproducers, and means for separately connecting one of said sound reproducers with the generators corresponding to each of the desired notes to be produced at any one instant.

14. In an electrical music generating system, a plurality of tone generators for generating electrical tones corresponding to both the fundamental and other partial frequencies of the notes throughout the musical scale, a plurality of amplifying systems of less number than the number of tone generators, means for selectively keying each of the amplifiers with the tone generators for a single note at any instant, a sound reproducer associated with each of said amplifiers, and means for keying the sound reproducer with the amplifier system upon selecting the desired note.

15. In an electrical music generating system, a plurality of tone generators for both fundamental and partial harmonic fre-

quencies of the several notes throughout the musical scale, a plurality of amplifying systems of a number corresponding to the number of notes to be reproduced simultaneously, means for selectively keying the said amplifying systems with the said tone generators, a sound reproducer associated with each of said amplifying systems, means for keying the said sound reproducer with its associated amplifier upon selecting the desired note, and means for limiting the number of notes reproduced by each of said sound reproducers to a single note composed of the fundamental frequency and chosen harmonics at any one instant.

16. In an electrical music generating system a plurality of simple tone frequency generators for electrically producing the fundamental and other partial frequencies of each of the several composite notes throughout the musical scale, a plurality of thermionic amplifying systems of a number equal to a predetermined number of composite notes to be reproduced simultaneously, means for selectively keying the said thermionic amplifying systems with the frequency generators, a sound reproducer associated with each of said amplifier systems, means for keying the said amplifying systems with appropriate frequency generators upon selecting each desired composite note, and means for keying the said amplifying systems with the associated sound reproducers by control of the plate current flow through a portion of said thermionic amplifying systems.

17. In an electrical music generating system, a plurality of tone generators for generating the fundamental and other predetermined partial frequencies for each note throughout the musical scale, a plurality of sound reproducers of less number than the number of tone generators, a plurality of amplifying systems of equal number to the sound reproducers, means for coordinating one of said sound reproducers with a single fundamental and the other predetermined partial frequencies corresponding to a chosen note at any one instant, means for keying an amplifier system with selected tone generators in accordance with the note to be played, and means for limiting the keying of each selected note at any instant to a single amplifier of the system.

18. In an electrical music generating system, a plurality of tone generators of a number equal to the number of notes of a musical system, a plurality of sound reproducers of a number equal to the predetermined number of notes to be simultaneously reproduced, a plurality of amplifying systems of a number equal to the number of sound reproducers, means for coordinating each of said sound reproducers through an associated amplifying system with a single tone generator at any one instant, means for keying the tones

generated to a portion of the amplifiers in the system in accordance with the selection of a note to be played, means for keying each sound reproducer with its associated amplifying system, and means for delaying the keying of the sound reproducer to a time after the tone has been keyed to the amplifying system coordinated therewith.

19. In an electrical music system, a plurality of tone generators for generating the fundamental and other partial frequencies of each note throughout the musical scale, a plurality of tone selection relays for selecting the notes to be played in accordance with the manual selection of keys coordinated therewith, a plurality of sound reproducers of a number less than the number of tone generators, and tone keying relays for coordinating each of said sound reproducers with a single tone generator for each selected note.

20. In an electrical music system, a plurality of tone generators for generating the fundamental and harmonic frequencies of each note throughout the musical scale, a plurality of sound reproducers of a number equal to the number of notes of the scale to be simultaneously played, a plurality of amplifying systems of a number equal to the number of sound reproducers, tone selection relays for selecting various tone generators in accordance with manually selected keys coordinated therewith and for associating the selected tones with predetermined amplifying systems, and means for keying the sound reproducer with its associated amplifying system at a time after the tones have been keyed thereto.

21. In an electrical music generating system, a plurality of generators for producing electrical frequencies of a number equal to the number of notes of a musical system, a plurality of sound reproducers of a number equal to the number of notes to be simultaneously reproduced, a plurality of amplifying systems of a number equal to the number of sound reproducers, means for coordinating at any one instant one of said sound reproducers with a generator corresponding to a single musical tone, means for keying the tones generated to a portion of the amplifiers in the system and their associated sound reproducers in accordance with the selection of a note to be played, and means for quickly rendering each of said amplifiers inoperative after the desired tones have been reproduced for the predetermined desired time duration.

22. In an electrical music generating system, a plurality of electrical tone generators of a number equal to the number of notes of a musical system, a plurality of sound reproducers of a number equal to the number of notes to be simultaneously reproduced, a plurality of amplifying systems of a number

equal to the number of sound reproducers, means for coordinating one of said sound reproducers with a single tone generator at any one instant, means for keying the tones generated to a portion of the amplifiers in the system and their associated sound reproducers in accordance with the selection of a note to be played, means for quickly rendering each of said amplifiers inoperative after the desired tones have been reproduced for the predetermined desired time duration, and means for removing the previously desired tones from the selected amplifier after said amplifier has been rendered inoperative.

23. In combination with an electrical music system having a keyboard with separate keys assigned to each note of the musical scale, a plurality of generators for generating electrical tones of fundamental and other partial frequencies of each note throughout the musical scale, a plurality of sound reproducers of a number equal to the number of notes of the scale to be played simultaneously, a plurality of amplifying systems of a number equal to the number of sound reproducers, tone selection relays for selecting various tone generators in accordance with the depression of the keyboard keys coordinated therewith and for associating the tones with predetermined amplifying systems, and means for keying the sound reproducer with its associated amplifying system at a time after the tones have been keyed thereon by depression of a key and for rendering the sound reproducer inoperative prior to the removal of the tones from the coordinated amplifier by raising of a key.

24. In an electrical music system, a plurality of tone generators for generating electrical frequencies corresponding to the fundamental and selected harmonic frequencies for each note throughout the musical scale, amplifying systems of a number equal to the number of notes to be played simultaneously, a sound reproducer associated with each of the said amplifying systems, means for keying selected portions of the tone generators with one of the amplifying systems upon selection of each note of the musical scale, and means for regulating the intensity of the various harmonic frequencies as supplied to the amplifying system.

25. In combination with an electrical music system having a keyboard with separate keys representing each note of the musical scale, a plurality of tone generators for generating electrical energy of frequencies corresponding to the fundamental and other partial frequencies for each note throughout the musical scale, amplifying systems of a number equal to the number of notes to be simultaneously reproduced, a sound reproducer associated with each of the said ampli-

fying systems, means for keying selected portions of the tone generators with one of the amplifying systems upon depression of each note of the musical keyboard, and means for independently regulating the intensity of the various partial frequencies as supplied to the amplifying system.

26. In an electrical music system, a plurality of tone generators for generating electrical frequencies corresponding respectively to consecutive notes on a musical scale throughout a plurality of octaves, a plurality of amplifying systems for amplifying the tones generated in accordance with predetermined note selection, a sound reproducer coordinated with each of the amplifying systems, means for keying one of the amplifying systems with one of said tone generators upon selection of each note of the musical scale to be reproduced, and means for maintaining the generated tones in the said keyed amplifying system for a time period corresponding to the entire length of time the note is desired.

27. In an electrical music system, a plurality of tone generators for generating electrical frequencies corresponding respectively to consecutive notes on a musical scale throughout a plurality of octaves, a plurality of amplifying systems for amplifying the tones generated in accordance with predetermined note selection, a sound reproducer coordinated with each of the amplifying systems, means for keying one of the amplifying systems with one of said tone generators upon selection of each note of the musical scale to be reproduced, means for maintaining the generated tones in said amplifying system during the time period corresponding to the entire length of time the tone is desired, and means for rendering each sound reproducer inoperative prior to the removal of each of the generated tones from the coordinated amplifying system.

28. In an electrical music system, a plurality of tone generators for generating electrical frequencies corresponding respectively to consecutive notes on a musical scale throughout a plurality of octaves, a plurality of amplifying systems for amplifying the tones generated in accordance with predetermined tone selection, a sound reproducer coordinated with each of the amplifying systems, means for keying one of the amplifying systems with one of said tone generators upon selection of each note of the musical scale, and means for delaying the keying of the sound reproducer with its associated amplifying system until the generated tones have been keyed upon the said amplifying system.

29. In an electrical music system, a plurality of electrical tone generators for generating frequencies corresponding respective-

ly to consecutive notes on a musical scale throughout a plurality of octaves, a plurality of amplifying systems for amplifying the tones generated in accordance with predetermined tone selection, a sound reproducer coordinated with each of the amplifying systems, means for keying one of the amplifying systems with one of said tone generators upon selection of each note of the musical scale, means for delaying operation of the sound reproducer with its associated amplifying system until the generated tones have been keyed with the said amplifying system, and means for delaying the removal of tones from each amplifying system until the coordinated sound reproducer is rendered inoperative.

30. In an electrical music system, electrical tone generators for generating the fundamental and partial frequencies for each note throughout the musical scale, amplifying systems of a number equal to the number of notes throughout the musical scale to be simultaneously reproduced, a sound reproducer associated with each of the amplifying systems, means for supplying the generated fundamental and partial frequencies to separate amplifying systems in accordance with a manual note selection, means for controlling the intensity of each of the impressed frequencies in the amplifying system, means for locating the keying of the selected tones to particular amplifying systems in the system in accordance with the depression of keys corresponding to the desired notes, and means for keying the sound reproducers with the amplifiers at a time period after the tones have been keyed therewith.

31. In an electrical music system, means for generating electrical energy of frequencies corresponding to the several notes throughout the musical scale, a plurality of means for amplifying the generated electrical frequencies independently of each other, a sound reproducer coordinated with each amplifier for translating each of the amplified frequencies into audible energy, and means for selecting and coordinating the generated frequencies with the said amplifiers in a predetermined sequence.

32. In an electrical music system, means for generating a series of electrical frequencies corresponding to each of the notes including the fundamental and other partial frequencies thereof throughout the musical scale, a plurality of sound reproducers of a number materially less than the number of notes in the musical scale for audibly reproducing at any instant generated frequencies corresponding to a single musical note, and means for selecting the frequencies generated and coordinating the said frequencies with individual sound reproducers in a predetermined sequence.

33. In an electrical music system, a plurality of tone generators for electrically generating frequencies corresponding to the fundamental and other partial frequencies of each note throughout the musical scale, a plurality of translating elements of a number corresponding to the number of tones to be simultaneously reproduced for translating the generated frequencies into sound waves corresponding in frequency to the frequency of the generated tones, means for selecting and coordinating the frequencies generated with said translating elements in a sequence corresponding to the notes played, and means for synchronizing all of the tone generators for rigidly maintaining output frequencies from all translating elements corresponding to the ratio of frequencies throughout the well tempered scale.

34. In an electrical music system, a plurality of rotary tone generators for electrically generating frequencies corresponding to the fundamental and other partial frequencies of each note throughout the musical scale, a plurality of translating elements for translating the generated frequencies into sound waves corresponding in frequency to the frequency of the generated tones, means for selecting and coordinating the frequencies generated with said sound reproducers in a sequence corresponding to the notes played, and means for synchronizing all of the tone generators for rigidly maintaining output frequencies therefrom corresponding to the ratio of frequencies throughout the well tempered scale comprising means responsive to changes in the angular rotational speed of said generators for applying a proportionately varying load on the driving element thereof so as to compensate for speed fluctuations therein.

35. In an electrical music system, means for generating electrical frequencies corresponding to the fundamental and harmonic frequencies of each of the notes throughout the musical scale, a plurality of means for each amplifying at any instant frequencies corresponding to the fundamental and harmonic frequencies of a single selected note only in the musical scale, means for converting the electrical amplified energy into sound energy corresponding to the selected notes, means for selecting the frequencies generated in accordance with a predetermined selection of notes and coordinating each of the selected frequencies with predetermined amplifiers, and means for synchronizing the said frequency generators for maintaining a regular predetermined frequency relationship between each of the said generating means.

36. In an electrical music system, means for generating electrical frequencies corresponding to the fundamental and harmonic frequencies of each note throughout the musical scale, means for amplifying frequencies

corresponding to the fundamental and partial frequencies of selected notes throughout the musical scale, means for converting the electrical amplified energy into sound energy corresponding to the selected notes, means for selecting the frequencies generated in accordance with a predetermined selection of notes of the musical scale and coordinating each frequency selected with a separate predetermined amplifier, and electrically operated saturation reactance means variable with speed changes in the generator means for applying load changes on the generator drive means for synchronizing the said generators for maintaining a regular predetermined frequency relationship between each of the said generating means.

37. In an electrical music system, means for generating electrical frequencies corresponding to the fundamental and other partial frequencies of each of the notes throughout the musical scale, means for reproducing the generated frequencies according to a predetermined schedule, and means for introducing a tremolo effect in the reproduced tones.

38. In an electrical music system, means for generating electrical frequencies corresponding to the fundamental and other partial frequencies of each of the notes throughout the musical scale, amplifying means for amplifying the generated frequencies for reproduction according to a predetermined schedule, means for introducing a tremolo effect in the reproduced tones, said tremolo means including means for cyclically varying the output energy from the said amplifying means between a normal value and a predetermined value less than normal value.

39. In an electric music system, means for generating electrical frequencies corresponding to the fundamental and harmonic frequencies of each of the notes throughout the musical scale, amplifying means for amplifying the generated frequencies for reproduction according to a predetermined schedule, means for introducing a tremolo effect in the reproduced frequencies including means for cyclically varying the output energy from the said amplifying means between a normal value and a predetermined value less than normal value, and means for regulating and varying the predetermined energy output below the said normal value.

40. In an electrical music system, means for electrically generating, amplifying and audibly reproducing tone frequencies corresponding to the several notes throughout the musical scale, and means for varying the intensity of the audibly reproduced tone frequencies between predetermined maximum and minimum intensities for producing a tremolo in the reproduced frequencies.

41. In an electrical music system, a plurality of generators for producing electrical

energy of different frequencies corresponding to musical notes of different pitches and representing the consecutive notes of a musical scale throughout a plurality of octaves, means for amplifying according to a desired selection the frequencies corresponding to those frequencies generated, means for introducing a tremolo effect in the amplified electrical energy, and means for converting the amplified electrical energy corresponding to the generated frequencies into audible energy.

42. In an electrical music system, a series of alternators for generating frequencies corresponding respectively to consecutive notes of a musical scale throughout a plurality of octaves, a plurality of amplifiers for amplifying the frequencies generated, a sound reproducer coordinated with each of the amplifiers, means for selecting the generated frequencies of each of the alternators and impressing the said frequencies upon one of the said amplifiers in accordance with the selection of a note desired to be reproduced, means for synchronizing all of the said generators for maintaining a constant frequency ratio therebetween, and means for introducing a tremolo effect in the said amplified energy.

43. In an electrical music system, a series of alternators for generating electrical frequencies corresponding respectively to consecutive notes of a musical scale throughout a plurality of octaves, a plurality of amplifiers for amplifying the frequencies generated, a sound reproducer coordinated with each of the amplifiers, means for selecting the generated frequencies of each of the alternators and impressing the said frequencies upon one of the said amplifiers in accordance with the selection of a note desired to be reproduced, and means for delaying the keying of the sound reproducer with the amplifier until the generated frequencies have been keyed thereto.

44. In an electrical music system, a series of alternators for producing electrical frequencies corresponding to the consecutive notes of a musical scale, a plurality of amplifiers for amplifying the various produced frequencies in accordance with a predetermined selection thereof, means for controlling the intensity of each of the frequencies impressed upon the said amplifiers in accordance with the quality desired, a sound reproducer coordinated with each of said amplifying systems, and means for keying the frequencies generated with said amplifiers in accordance with the selection thereof on an associated manual keyboard.

45. In an electrical music system, a series of alternators for producing electrical frequencies corresponding to the fundamental and harmonics of consecutive notes of a musical scale, a plurality of amplifying systems for amplifying the various produced frequencies

quencies in accordance with a predetermined selection thereof, means for controlling the intensity of each of the frequencies for each note impressed upon the said amplifying systems in accordance with the quality desired, and a sound reproducer coordinated with each of said amplifying systems.

46. In an electrical music system, a series of alternators for generating electrical frequencies corresponding to the fundamental and other partials of consecutive notes of a musical scale, a plurality of amplifiers for amplifying the various generated frequencies for each note in accordance with a predetermined selection thereof, means for controlling the intensity of each of the frequencies impressed upon the said amplifiers in accordance with the sound quality desired, a sound reproducer coordinated with each of said amplifying systems, means for keying the tones generated with said amplifiers in accordance with the selection thereof on an associated manual keyboard, and means for maintaining synchronization between all of said tone generators whereby a predetermined frequency ratio is maintained between generated frequencies of all of the said generators.

47. In an electrical music system, a series of alternators for generating electrical frequencies corresponding to the fundamental and other partial frequencies of the consecutive notes throughout the musical scale, a plurality of amplifiers for amplifying at any instant the various produced frequencies of a single note only in accordance with a predetermined selection thereof, means for separately controlling the intensity of each of the fundamental and partial frequencies for each note impressed upon the said amplifiers in accordance with the tone quality desired, a sound reproducer coordinated with each of said amplifying systems, and means for keying the generated frequencies for each note with said amplifiers in accordance with the selection thereof on an associated manual keyboard so that each of a plurality of notes simultaneously played are reproduced from separate amplifiers.

48. In combination with an electrical music system having a keyboard provided with separate keys to designate each note of the system and amplifiers for amplifying electrical tone frequencies generated by suitable tone generating systems for each note, means for selecting the electrical tones generated in accordance with manual depression of the keys representing the various notes on the scale comprising means for keying the tones corresponding to each of the notes selected with separate amplifiers in the system independently of each other.

49. In combination with an electrical music system having means for separately distinguishing each note of the musical scale and amplifiers for amplifying electrical fre-

quencies corresponding to the fundamental and other partial frequencies of each note as generated by suitable tone generating systems for each note, means for selecting the tones generated in accordance with various predetermined and selected notes on the scale which include means for keying the tones corresponding to each of the notes as selected to separate amplifiers in the system independently of the other, and means cooperating therewith for independently controlling and regulating the intensity of the various fundamental and partial frequencies of each note impressed on the said separate amplifiers.

50. In combination with an electrical music system having amplifiers and coordinated amplifiers and sound reproducers for amplifying and reproducing musical tones generated by suitable tone generating systems and keys for designating each of the tones on the musical scale, means for selecting the tones generated in accordance with manual depression of the keys representing the various notes on the scale which include means for keying the tones as selected independently to one of the amplifiers in the system, and means for keying the sound reproducer coordinated with each of the amplifiers with the said amplifier.

51. In combination with an electrical music system having amplifiers and coordinated amplifiers and sound reproducers for amplifying and reproducing musical tones generated by suitable tone generating systems and a keyboard provided with separate keys to designate each note of the musical scale, means for selecting the tones generated in accordance with a selection of the keys representing the various notes on the scale which include means for keying the tones as selected independently to one of the amplifiers in the system, means for keying and rendering the sound reproducer coordinated with each of the amplifiers operative, and means for rendering the sound reproducers inoperative after maintaining tones thereon for a predetermined time period while continuing to impress said tones on said amplifiers.

52. In combination with an electrical music system having amplifiers and coordinated amplifiers and sound reproducers for amplifying and reproducing tones generated by suitable tone generating systems, means for selecting the tones generated in accordance with manual depression of the keys representing the various notes on the scale which include means for keying the tones as selected independently to each of the amplifiers in the system, means for keying the sound reproducer coordinated with each of the amplifiers with the said amplifier, and means for delaying the sound reproducer keying until tones are keyed to the said amplifier.

53. In combination with an electrical mu-

sic system having a keyboard corresponding to the notes of the musical scale, means for generating electrical tone frequencies corresponding to each note of the musical scale, and amplifiers and sound reproducers for audibly reproducing the generated tone frequencies, the combination of tone selection relays, and means for operating said tone selection relays to coordinate generated tone frequencies with predetermined amplifiers upon depression of keys corresponding to the desired notes.

54. In combination with an electrical music system having a keyboard with separate keys representing each note of the musical scale, means for electrically generating tone frequencies corresponding to the frequency of each note of the musical scale, and amplifiers and sound reproducers for audibly reproducing the generated tone frequencies, the combination of tone selection relays, means for operating said tone selection relays to coordinate generated tone frequencies with predetermined amplifiers upon depression of keys corresponding to the desired notes, and means for keying the amplifiers and sound reproducers with the chosen generated tones after selection thereof.

55. In combination with an electrical music system having a keyboard with a plurality of keys representing the various notes of the musical scale cooperating with means for electrically generating tone frequencies corresponding to each note of the musical scale, and amplifiers and sound reproducers for audibly reproducing the generated tone frequencies, the combination of tone selection relays, and means for operating said tone selection relays to coordinate generated tone frequencies with predetermined amplifiers upon depression of keys corresponding to the desired notes, means for keying the amplifiers and sound reproducers with the chosen generated tone frequencies after selection thereof, and means for holding and maintaining the generated tone frequencies in the amplifiers and sound reproducers during the entire period of depression of the keys.

56. In combination with an electrical music system having a keyboard with manually depressible keys representing the various notes of the musical scale and cooperating with means for electrically generating tone frequencies corresponding to each note of the musical scale, and amplifiers and sound reproducers for audibly reproducing the generated tone frequencies, the combination of tone selection relays, means for operating said tone selection relays to coordinate generated tones with predetermined amplifiers upon depression of keys representing desired notes for reproduction, means for keying the amplifiers and sound reproducers with the chosen generated tone frequencies after selection thereof, means for holding and main-

taining the generated tone frequencies in the amplifiers and sound reproducers during the entire period of depression of the keys, and means operable upon release of selected keys for rendering said sound reproducers inoperative prior to removing the released tone frequency from the coordinated amplifier.

57. In an electrical music system having a keyboard representing the various notes of the musical scale, tone generators for generating electrical tone frequencies corresponding to each of the notes, and amplifying and reproducing means for converting the generated tones into audible frequency energy, the combination of tone frequencies selection relays of a number equal to the notes played simultaneously coordinated with each of the keys representing the various notes, and means for causing a response from one of said selection relays upon depression of each of the said keys.

58. In an electrical music system having a keyboard representing the various notes of the musical scale, tone generators for generating electrical tone frequencies corresponding to each note throughout the scale, and amplifying and reproducing means for converting the generated tone frequencies into audible frequency energy, the combination of tone selection relays of a number equal to the notes played simultaneously coordinated with each of the keys representing the various notes, means for causing a response from one of said selection relays upon depression of each of the said keys, and holding relays coordinated with each tone selection relay for maintaining tone frequencies thereon during the entire period of depression of each of the keys.

59. In an electrical music system having a keyboard representing the various notes of the musical scale, generators for generating the electrical tones corresponding to each of the notes, and amplifying and reproducing means for converting the generated tones into audible frequency energy, the combination of tone selection relays of a number equal to the notes played simultaneously coordinated with each of the keys representing the various notes for selecting one of said amplifying and reproducing systems to audibly reproduce the selected tones, means for causing a response from one of said selection relays upon depression of each of the said keys, holding relays coordinated with each tone selection relay for maintaining tones thereon during the entire period of depression of each of the keys, and means coordinated with each of said selection relays for providing a locking effect on the said holding relays for preventing other tone selection relays from operating to key, whereby only a single amplifier system reproduces any selected note at any particular instant.

60. In combination with an electrical music system having a keyboard formed from keys each representing a note on the musical scale, and tone generating, amplifying and reproducing means for reproducing the notes, a relay associated with each of the keys, starting relays and tone selection relays, and means operable upon depression of each key for initiating an operation of one of said starting relays for causing an operation of said tone selection relays coordinated with a key representing the desired note to be played.

61. In an electrical music system, a generator system for producing electrical energy of fundamental and partial frequencies corresponding to each note of a musical scale, a plurality of amplifiers of a number corresponding to the number of notes of the musical scale to be played simultaneously, and means operable upon the depression of keys on the musical keyboard for supplying generated electrical energy corresponding to each chosen note to one of said amplifiers only.

62. In an electrical music system, a generator system for producing electrical energy of fundamental and partial frequencies corresponding to each note of a musical scale, a plurality of amplifiers of a number corresponding to the number of notes of the musical scale to be played simultaneously, means operable upon the depression of keys on the musical keyboard for supplying generated electrical energy corresponding to a chosen note to one of said amplifiers only and means for associating other desired frequencies corresponding to other desired notes with others of said amplifiers so as to permit amplification of the fundamental and chosen partial frequencies of one note only in each of said amplifiers during the period when each note is reproduced.

63. In an electrical music system, a generator system for producing electrical energy of fundamental and partial frequencies corresponding to each note of a musical scale, a plurality of amplifiers of a number corresponding to a predetermined number of notes of the musical scale to be played simultaneously, means operable upon the depression of each key on the musical keyboard for supplying generated electrical energy corresponding to the chosen note to one of said amplifiers only, and means for associating other desired frequencies corresponding to other keys representing other desired notes with others of said amplifiers, and means to limit the tones impressed on each amplifier to a fundamental and selected partial frequencies of a single note only at any one instant.

64. In an electrical music system, a generator system for producing electrical energy of fundamental and partial frequencies corresponding to each note of a musical scale, a

plurality of amplifiers of a number corresponding to a predetermined number of notes of the musical scale to be played simultaneously, means operable upon the depression of each key on the musical keyboard for supplying generated electrical energy corresponding to the chosen note to one of said amplifiers only, and means for associating other desired frequencies corresponding to other keys representing other desired notes with others of said amplifiers, means to limit the tones impressed on each amplifier to a fundamental and partial frequencies of a single note only at any one instant, and means for varying the intensity ratio between the simultaneously impressed frequencies on each amplifier for producing varying quality effects therefrom.

65. In an electrical music system, electrical generators for generating frequencies corresponding to the fundamental and partial frequencies of each note of a musical scale as represented by notes of a musical keyboard, a plurality of amplifiers corresponding in number to the maximum number of notes desired to be played simultaneously, means responsive to the depression of a key on the musical keyboard for impressing frequencies corresponding thereto on one of said amplifiers, and means for limiting the frequencies to be amplified by any of said amplifiers to a single fundamental and associated partial frequencies at any one instant.

66. In an electrical music system, electrical generators for generating frequencies corresponding to the fundamental and partial frequencies of each note of a musical scale as represented by notes of a musical keyboard, a plurality of amplifiers corresponding in number to the maximum number of notes desired to be played simultaneously, means responsive to the depression of a key on the musical keyboard for impressing frequencies corresponding thereto on one of said amplifiers, means for limiting the number of frequencies to be amplified by any of said amplifiers to a single fundamental and associated partial frequencies at any one instant, and means for placing succeeding tones played upon separate amplifiers for amplification of generated energy.

67. In an electrical system, electrical generators for generating frequencies corresponding to the fundamental and other partial frequencies of each note of a musical scale as represented by the notes of a musical keyboard, a plurality of amplifying systems corresponding in number to the maximum number of notes desired to be played simultaneously, means responsive to the depression of a key on the musical keyboard for impressing frequencies corresponding thereto on one of said amplifying systems, means for independently impressing the fundamental and partial frequencies corresponding to the

selected note upon the input circuit of the said amplifying system, and means for limiting the number of tone frequencies to be amplified by any of said amplifying systems to a single fundamental and associated partial frequencies at any one instant.

68. In an electrical music system, electrical generators for generating electrical frequencies corresponding to the fundamental and other partial frequencies of each note of a musical scale as represented by notes of a musical keyboard, a plurality of multi-stage amplifiers corresponding in number to the maximum number of notes desired to be played simultaneously, means responsive to the depression of a key on the musical keyboard for impressing frequencies corresponding thereto on one of said multi-stage amplifiers, means for impressing the fundamental and partial frequencies corresponding to the selected note upon the primary stage of the amplifier independently, means for limiting the number of tone frequencies to be amplified by any of said multi-stage amplifiers to a single fundamental and associated partial frequencies at any one instant, and means for placing frequencies corresponding to succeeding notes played upon amplifiers not in use for amplification of generated energy.

69. A tremolo control for an electrical tone producer of the type described comprising a motor, means for controlling the motor, and means operable from said motor for causing a variation of a resistance connected in the audio amplifier stage of said tone producer.

70. A tremolo control for an electrical tone producer of the type described comprising a motor, means for controlling the motor, mechanical means for causing the said motor to periodically short-circuit a resistance connected in the audio amplified stage of said tone producer.

71. In combination with an electrical tone producer amplifying system, a tremolo control including means for controlling the output energy from the system at a variable rate.

72. The combination with an electrical tone producer and an amplifying system, for amplifying the produced tones of, means for cyclically varying the output energy from the system.

73. In combination, an electrical tone frequency generator, an amplifier for amplifying the produced generated tone frequency, and means for cyclically varying the output energy of said amplifier, at a sub-audible rate.

74. In combination, an electrical sound reproducer, and means for cyclically varying the input energy thereto.

75. In combination, an electrical sound reproducer, and means for cyclically varying the input energy thereto at a sub-audible rate.

76. In combination with an electrical tone producer amplifying system, a tremolo control including a communicating system, and

means operable from the said commutating system for cyclically raising and lowering the output energy from the said system.

77. In combination with an electrical tone producer having thermionic amplifiers for amplifying produced tones, a tremolo control including means for cyclically varying the output current from said amplifying system between two predetermined values.

78. In combination with an electrical tone producer, a tremolo control including means for cyclically varying the effective output therefrom between predetermined maximum and minimum values.

79. In combination with an electrical tone producer having thermionic amplifiers for amplifying produced tones, a tremolo control including an auxiliary thermionic amplifier functioning as a robber tube, and means provided by said robber tube for cyclically effecting an increase and decrease in the effective output current from the said thermionic amplifier.

80. In combination with an electrical tone producer having thermionic amplifiers for amplifying the tones produced, a tremolo control including a thermionic tube connected with the output circuit of said thermionic amplifier, means for controlling the output current of said second named thermionic tube at a predetermined rate, and means responsive to changes in the output current of said second named thermionic tube for cyclically effecting a resultant increase and decrease in the effective plate current output of said thermionic amplifier.

81. In combination with an electrical tone producer having push-pull connected thermionic amplifiers for amplifying produced tones, a second thermionic tube functioning as a robber tube connected with the output circuit of said push-pull connected thermionic amplifier, means for interrupting at a predetermined rate the plate current supply for said second named thermionic robber tube for sequentially changing the plate current output therefrom between a minimum and a maximum value, and means provided by connection of said robber tube with the output circuit of said push-pull connected thermionic amplifiers for robbing the plate current supply to said push-pull amplifiers at periods when maximum current is being passed by the said robber tube for effecting a change in the effective plate current output from the said push-pull amplifier varying between predetermined normal strength and a value differing therefrom by a predetermined amount.

82. In combination with an electrical tone producing system having amplifying means cooperating therewith for amplifying produced tones, means for producing effective changes in the effective output from said amplifying means to cyclically change the output between two predetermined limiting

values, and means for controlling the strength of the tremolo by varying the separation of the two said limiting values in accordance with desired strengths of tremolo operation.

83. In combination with an electrical tone producing system having amplifying means cooperating therewith for amplifying produced tones, means for producing effective changes in the effective output from said amplifying means to cyclically change the output between a normal value and a value below the said normal value, and means for controlling the strength of the tremolo by regulating the amount which the output energy from the amplifying system decreases below the said normal value in accordance with the tremolo operation.

84. In combination with an electrical tone producing music system having amplifiers coordinated therewith for amplifying the produced tones, a tremolo control including a thermionic amplifier for cyclically increasing and decreasing the effective output current from the said amplifying system between a normal value and a value below the said normal value, and means for regulating the strength of the plate current output from the said control amplifier for determining the effective strength of the tremolo by regulating the amount which the effective output current from the amplifier is decreased below the predetermined normal value.

85. In combination with an electrical tone producing system having a plurality of amplifiers for independently amplifying separate tones from the tone producers as selected, a separate tremolo control for each amplifier, and means for separately controlling the strength of the tremolo on each of the said amplifiers for establishing a predetermined ratio between the strength of the tremolo on the several amplifiers whereby the tremolo strength on one amplifier is of a different value than on another amplifier.

86. An amplifying system for amplifying tones produced in electrical tone producers generating fundamental and partial frequencies corresponding to each note of the musical scale which includes independent means for supplying the fundamental and the partial frequencies corresponding to each selected note to the amplifying systems.

87. The amplifying system claimed in claim 86 including, in addition, parallelly-connected output means from the said amplifiers for utilizing the combined fundamental and partial frequencies of each note.

88. In an electrical tone producing system having generating means for producing fundamental and partial frequencies of each note of the musical scale, an amplifying system including a plurality of independent amplifier tubes, means for supplying the fundamental and each partial frequencies inde-

pendently to separate amplifier tubes of said amplifying system, and a parallel output connection from all of the said separate amplifier tubes for utilizing the combined energy from all of said amplifier tubes.

89. The combination claimed in claim 88 including, in addition, means for independently controlling the amplitude of the fundamental and separate partials supplied to the input of each of the plurality of amplifier tubes.

90. In combination with an electrical tone producer having generators for producing the fundamental and partial frequencies of each note of the musical scale, an amplifying system including a plurality of amplifiers having input circuits connected with the fundamental and separate partials of the separately produced frequencies, parallel output connections from each of the amplifiers, means for coupling each of the separate amplifiers with a plurality of push-pull connected amplifiers for preventing noise and distortion due to keying of the generated frequencies with the first named amplifiers, and means connected with said push-pull amplifiers for utilizing the amplified energy from said tone producers.

91. In combination with an electrical music system having a plurality of generators for generating tone frequencies corresponding to the fundamental and partial frequencies of each note of the musical scale throughout a plurality of octaves, amplifying means for amplifying the generated tones according to a predetermined keying selection, means for connecting the said amplifying means in push-pull fashion for avoiding noise and distortion from keying the generated tone frequencies therewith, and means for supplying plate current to said push-pull connected amplifiers in push-push manner for avoiding clicks and noises due to keying of the plate current supply therewith upon selection of predetermined tone frequencies.

92. In combination with an electrical tone producing system having generators for producing the fundamental and partial frequencies of each note of the musical scale throughout a plurality of octaves and means for selecting and keying the produced tones as desired, a vacuum tube amplifying system having push-pull connected amplifiers for amplifying the selected produced tones, a source of plate current supply for said push-pull connected amplifiers, means for rendering the said amplifiers operative upon a predetermined note selection by controlling the supply of plate current thereto, and means for supplying plate current to said amplifiers in push-push fashion for avoiding noises and clicks from keying of said amplifiers.

93. The combination claimed in claim 92 including, in addition, a choke coil connected in the supply of plate current to said ampli-

fiers for avoiding noise and distortion upon keying the plate current thereto.

94. In combination with an electrical tone producing system having tone generators for producing frequencies corresponding to the fundamental and partial frequencies of each note of the musical scale throughout a plurality of octaves which includes an amplifier for separately amplifying the fundamental and partial frequencies of each of the produced and desired notes in accordance with a predetermined selection, a push-pull connected thermionic amplifier for amplifying the combined fundamental and selected partial frequencies in accordance with a predetermined note selection, means for supplying plate current to said push-pull connected amplifiers in push-push fashion for avoiding clicks and noises upon keying of the amplifiers and rendering the amplifiers operative upon a predetermined note selection, and means for equally rendering the said push-pull connected amplifiers inoperative at time periods when the predetermined note selection is no longer desired including a ground connection from said plate current supply to said amplifier.

95. A synchronizing system for maintaining constant speed from driven rotary elements which includes vibratory means for supplying impulses to said elements for maintaining substantial constancy in the angular rotational speed of said elements, and an electrical reactance of varying value determinable by fluctuations in the speed of said elements and the rate of supply of said controlling impulses thereto for applying a supplemental fluctuating load to said driven elements for controlling the speed thereof by maintaining coincidence between the rate of supply of controlling impulses and the rate of rotation.

96. The method of audibly reproducing musical sounds from an electrical music system which includes generating a fundamental and selected partial frequencies for each note throughout the musical scale, audibly reproducing the fundamental and partial frequencies of the generated notes as desired, amplifying the fundamental and partial frequencies of each of the generated notes as desired, selectively coordinating individual fundamental and partial frequencies of each of the notes with the amplifying and reproducing systems, and keying independent sound reproducing systems with each of the amplifying mediums as desired tones are impressed thereon.

97. The method of operating an electrical music system which includes producing electrical frequencies corresponding to each note throughout the musical scale, reproducing produced frequencies independently of each other through a plurality of sound reproducing systems of a number equal to a predeter-

mined number of notes to be simultaneously heard, and selectively coordinating said sound reproducing systems with the electrically produced frequencies for a predetermined note so as to reproduce each of the desired notes independently from each other.

98. The method of operating an electrical music system which includes generating electrical energy at various tone frequencies corresponding to each note of the musical scale, reproducing generated frequencies independently of each other through a plurality of sound reproducing mediums of a number equal to the number of notes on the musical scale to be played simultaneously, individually coordinating the sound reproducing systems with electrically generated energy corresponding in frequency with desired note reproduction, limiting the number of frequencies on each sound reproducing system to frequencies corresponding to a single note at any given instant, and successively coordinating other desired note frequencies with others of the sound reproducing systems.

99. The method of operating an electrical music system which includes generating tones corresponding in frequency to the fundamental frequency and selected partials for each note throughout the musical scale, audibly reproducing the generated fundamental and partial frequencies of the generated tones as desired, amplifying the fundamental and partial frequencies of each of the generated tones as desired, selectively coordinating individual fundamental and partial frequencies corresponding to desired notes of the scale to be reproduced with the amplifying and sound reproducing systems, and keying the sound reproducing with each of the amplifying systems with a predetermined time delay after desired tone frequencies are impressed thereon.

100. The method of operating an electrical music generating system which includes generating tones corresponding in frequency to fundamental and selected partial frequencies for each note throughout the musical scale, amplifying in a selective manner the generated tones, selectively keying the amplifying systems with the tone generating sources, converting the output electrical energy from each amplifying medium into audible energy, and limiting the tones simultaneously keyed with one amplifying system at any one instant to the fundamental and partial frequencies of a selected note.

101. The method of operating an electrical music generating system having a plurality of tone generators for generating fundamental and partial frequencies assigned to each note throughout the musical scale and a plurality of thermionic amplifying systems and coordinated sound reproducers of a number equal to the maximum number of notes to

be simultaneously reproduced which includes, selectively keying the thermionic amplifiers with the tone generators, controlling the plate current flow through the thermionic amplifiers for keying each sound reproducing system with the coordinated amplifier upon selectively keying the desired tones thereon.

102. The method of operating an electrical music system having tone generators for generating the fundamental and other partial frequencies for each note throughout the musical scale, amplifying systems of a number less than the number of notes throughout the musical scale, and a sound reproducer associated with each of the amplifying systems which includes supplying the generated fundamental and partial frequencies to the amplifying systems in accordance with a manual tone selection, controlling the intensity of each of the impressed frequencies upon each amplifying system, keying the selected tones to one of the amplifying systems in accordance with the depression of keys corresponding to the desired notes, and keying the sound reproducers with each amplifying system at a time period after the tones have been keyed therewith.

103. The method of operating an electrical music system having a plurality of tone generators having frequencies corresponding to musical notes of different pitches and representing the consecutive notes of a musical scale throughout a plurality of octaves which includes amplifying according to a desired note selection the frequencies corresponding to those frequencies generated, introducing a tremolo effect in the amplified electrical energy, and converting the amplified electrical energy into audible energy.

104. The method of operating an electrical music system having a keyboard representing the various notes of the musical scale, tone generators for generating the tones corresponding to each of the notes of the scale, and amplifying and reproducing means for converting the generated tones into audible frequency energy, which includes selecting the generated tones in accordance with a depression of the keys of the keyboard, causing a response from one of the amplifying systems in accordance with the tone selection, and maintaining tones on the amplifying systems after selection during the entire period of depression of each of the keys.

105. The step in the method of producing a tremolo effect from an electrical tone producer having amplifying systems for amplifying produced tones which includes producing variations in the effective output energy from the amplifier at a predetermined rate.

106. The steps in the method of producing a tremolo effect from an electrical tone producer having amplifying systems selectively coordinated with tone producing mediums

which includes producing variations in the effective output energy from the amplifier at a predetermined rate, and controlling the degree of variation in accordance with the desired strength of tremolo.

107. The step in the method of producing a tremolo effect from an electrical tone producer amplifying system which comprises cyclically raising and lowering the output energy from the amplifying system at a predetermined rate.

108. The step in the method of producing a tremolo effect from an electrical tone producer which comprises cyclically varying the effective output energy from the tone producer between two predetermined values.

109. The step in the method of producing a tremolo effect from an electrical tone producer having thermionic amplifiers for amplifying produced tones which comprises robbing the current supply to the tone amplifying means at a predetermined rate for cyclically effecting an increase and decrease in the effective output current from the tone amplifying system.

110. The steps in the method of producing a tremolo effect from an electrical tone producing system having amplifying means cooperating therewith for amplifying produced tones in accordance with a predetermined selection thereof which include producing changes in the effective output from the amplifying means to cyclically change the output between a normal value and a value below the said normal value, and regulating the amount which the effective output energy from the amplifying system decreases below the said normal value for producing effective changes in the strength of the tremolo.

111. The steps in the operation of a tremolo in combination with an electrical tone producing system having a plurality of amplifiers selectively coordinated therewith for independently amplifying separate tones from the tone producers corresponding to different notes selected which comprise cyclically producing an increase and decrease in the effective output energy from each amplifier, and varying the rate of increase and decrease on each amplifier independently for accentuating the strength of the tremolo effect on the selected amplifiers as desired.

112. In combination, a plurality of generators for generating electrical energy of frequencies corresponding to the fundamental and selected harmonics of each note in a musical system, a plurality of amplifying systems, means for selecting and impressing the frequencies corresponding to each single selected note in the musical system upon a separate one of said amplifying systems at any instant for amplification, and an output circuit connected with each amplifying sys-

tem for utilizing the amplified generated energy.

113. In an electrical music system, a plurality of generators for producing electrical energy of different frequencies corresponding to the fundamental and selected harmonics of musical notes of different pitches representing the consecutive notes of a musical scale throughout a plurality of octaves, means for amplifying according to a desired selection the frequencies corresponding to those frequencies generated, means for introducing a tremolo effect in the amplified generated energy, and a utilization circuit connected with the amplifying system for utilizing the amplified electrical energy corresponding to the selected generated frequencies.

114. In an electrical music system, a series of generating means for producing electrical frequencies corresponding respectively to consecutive notes on a musical scale throughout a plurality of octaves, a plurality of amplifying systems for amplifying the frequencies generated, a utilization circuit for utilizing the amplified frequencies generated, means for selecting the generated frequencies of each of the generating means and impressing said frequencies upon one of said amplifiers in accordance with the selection of each note desired to be reproduced, and means for delaying the keying of the utilization circuits with each amplifying system until the generated frequencies have been keyed thereto.

115. In combination with an electrical music system having amplifiers and coordinated utilization circuits for amplifying and utilizing musical tones generated by suitable tone generating systems and keys for designating each of the tones on the musical scale, means for selecting the tones generated in accordance with a manual depression of the keys representing the various notes on the scale which includes means for keying the tones as selected independently to one of the amplifying systems, and means for keying the utilization circuit coordinated with each of the amplifiers with the said amplifier at a period when the tones are keyed with said amplifier.

116. In an electrical music system having a keyboard with a plurality of keys representing the various notes on the musical scale cooperating with means for electrically generating tone frequencies corresponding to each note of the musical scale and amplifiers and sound reproducers for audibly reproducing the tone frequencies, the combination of tone selection relays and means for operating said tone selection relays to coordinate generated tone frequencies with predetermined amplifiers upon depression of keys corresponding to the desired notes, means for keying the amplifiers and sound reproducers with

the generated tone frequencies after selection thereof, and means for holding and maintaining the generated tone frequencies in the amplifiers and sound reproducers during a period at least equal to the period of depression of the keys representing each note on the musical scale.

117. The method of producing a musical note which comprises vibrating a tuning fork whose natural period of vibration corresponds to the period of vibration of the desired note, producing electromagnetic energy from the vibration of the tuning fork, amplifying the electrical energy generated and applying the amplified energy to a sound reproducer to reproduce the musical note emitted by the vibrating tuning fork.

118. In a musical instrument, a tuning fork, an electro-magnet positioned adjacent one of the tines of said tuning fork, means to vibrate the said tuning fork to generate an electrical current in the winding of said electro-magnet, an amplifier for amplifying the generated currents, and a sound reproducer in cooperative relationship with the output of said amplifier to reproduce audibly the electrical energy generated by the said vibrating fork.

119. In a musical instrument, a plurality of tuning forks of natural periods corresponding to selected musical notes, an electromagnetic device cooperatively associated with at least one tine of each tuning fork, means for vibrating each of said tuning forks to cause electrical energy of a frequency corresponding to the fork frequency to be induced in each electromagnetic device, an amplifying system, means selectively operable to impress the frequencies generated by one or more of the vibrating tuning forks upon said amplifier, and a sound reproducer connected with the said amplifier to reproduce audibly the electrical energy impressed thereon.

120. In combination, a plurality of sources of electrical energy of frequencies corresponding to the fundamental and selected harmonics of each note in a musical system, a plurality of amplifying systems, means for selecting and connecting with one of the amplifying systems individually the frequencies corresponding to individually selected notes of the musical scale, and a load circuit connected with each amplifying system for utilizing the amplified generated energy.

121. A system for electrically producing music comprising a source for producing electrical energy at frequencies separated one from the other in proportion to the separation of the fundamental frequency of the musical notes of different pitches representing the consecutive notes of a musical scale throughout a plurality of octaves, means for amplifying according to a desired selection the frequencies corresponding to those frequencies produced, means for changing according to a

desired selection the tone quality of the amplified generated energy, and a load circuit connected with the amplifying means for utilizing the amplified electrical energy corresponding to the selected produced frequencies.

122. In an electrical music system, a series of generating means for producing electrical frequencies corresponding respectively to consecutive notes on a musical scale throughout a plurality of octaves, a plurality of amplifying systems for amplifying the frequencies generated, a load circuit for utilizing the amplified frequencies generated, means for selecting the generated frequencies of each of the generating means and impressing said frequencies upon one of said amplifiers in accordance with the selection of each note desired to be reproduced, and means for maintaining the load circuit inoperative to utilize the produced electrical energy until a time subsequent to keying the generated frequencies with the amplifier.

123. In combination with an electrical music system having amplifiers and coordinated utilization circuits for amplifying and utilizing musical tones generated by suitable tone generating systems and keys for designating each of the tones on the musical scale, means for selecting the tones generated in accordance with a manual depression of the keys representing the various notes on the scale which includes means for keying the tones as selected independently to one of the amplifying systems, and means for keying the utilization circuit coordinated with each of the amplifiers with the said amplifier at a time period subsequent to the time period when the selected tones are keyed with said amplifier.

124. In an electrical music system having a keyboard with a plurality of keys representing the various notes on the musical scale cooperating with means for electromagnetically generating tone frequencies corresponding to each note of the musical scale and amplifiers and a load circuit responsive to the generated tone frequencies, the combination of tone selection relays, means for operating the tone selection relays to coordinate generated tone frequencies with predetermined amplifiers upon depression of keys corresponding to the desired notes, means for connecting each amplifier with its coordinated load circuit at a time period subsequent to the impression of selected frequencies thereupon, and means for holding and maintaining the connection of tone frequencies with the load circuit through the amplifier during a time period at least equal to the period of depression of the keys representing each note on the musical scale.

125. In a keyboard electrical music system, vibratory sources for generating alternating current voltages in associated pick-up devices

electrical frequencies corresponding to the fundamental and harmonic frequencies for each note in a musical scale, means to select from the generated voltages various fundamentals and harmonics according to a predetermined selection thereof upon the keyboard, means for varying the tone quality produced from the selected frequencies by controlling the relative amplitudes of the fundamental and harmonic frequencies for each note selected on the keyboard, and a sound reproducer responsive to the amplitude controlled selected frequencies for audibly reproducing musical notes.

126. In a keyboard electrical music system, vibratory sources for generating alternating current voltages in associated magnetic coil electrical frequencies corresponding to the fundamental and harmonic frequencies corresponding to each note in the musical scale, means to select from the generated voltages various fundamentals and harmonics according to a predetermined manual selection thereof upon the keyboard, means for varying the tone color produced from the selected frequencies by controlling the relative amplitudes of the selected fundamental and harmonic frequencies, and a sound reproducer responsive to the amplitude controlled selected frequencies for audibly reproducing musical notes.

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CERTIFICATE OF CORRECTION.

Patent No. 1,901,985.

March 21, 1933.

RICHARD HOWLAND RANGER.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 10, line 98, strike out the word "tones"; page 11, line 27, for "UX-207-A" read "UX-201-A"; page 13, line 49, for "illsutrated" read "illustrated"; page 14, line 124, for "transformer secondaries" read "transformers", and line 125, for "transformers" read "transformer secondaries"; page 24, line 130, claim 15, strike out the word "partial"; page 30, line 79, claim 57, for "tones" read "tone frequencies", and line 80, strike out the word "frequencies"; page 32, line 65, claim 76, for "communicating" read "commutating"; page 34, line 83, claim 98, for "wih" read "with"; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 22nd day of August, A. D. 1933.

(Seal)

M. J. Moore.

Acting Commissioner of Patents.