Aug. 29, 1933. I. EREMEEFF 1,924,713

SYNTHETIC ELECTRICAL MUSICAL SYSTEM

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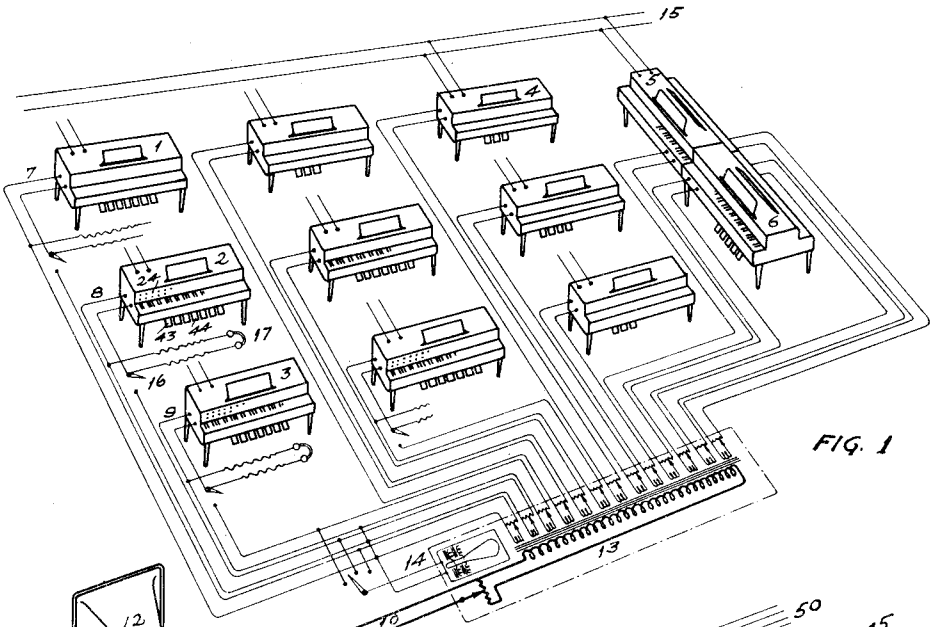
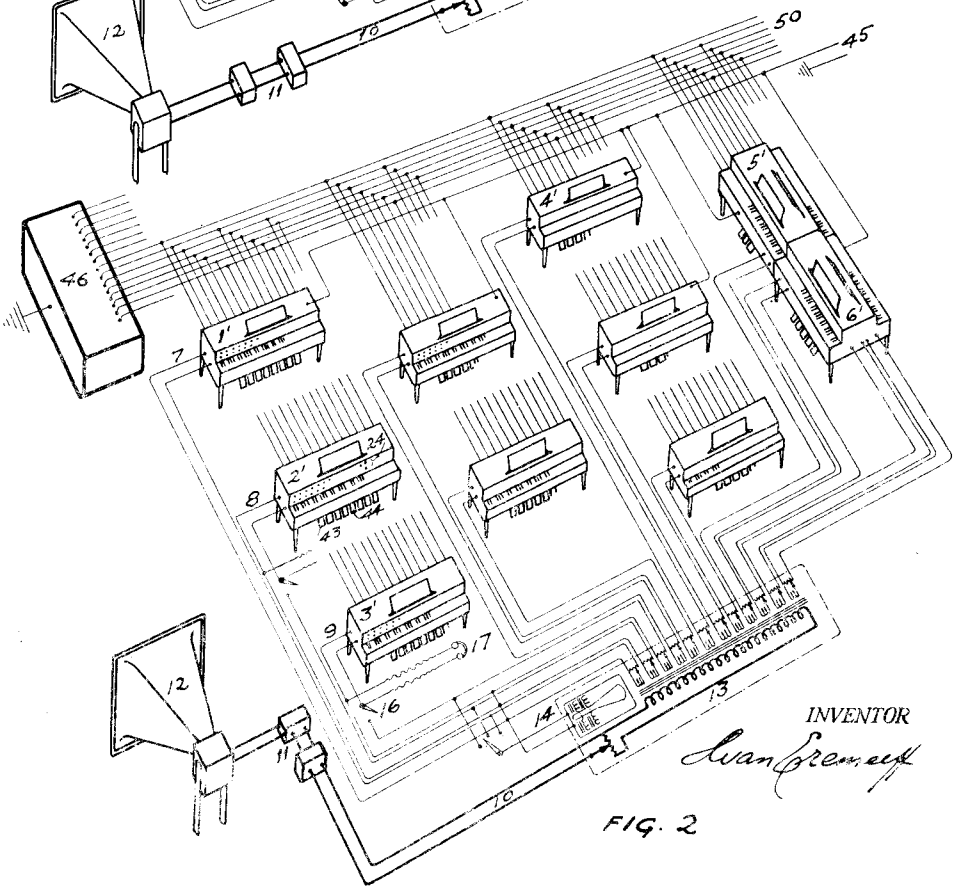


FIG. 1



INVENTOR

Ivan Eremeeff

FIG. 2

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SYNTHETIC ELECTRICAL MUSICAL SYSTEM

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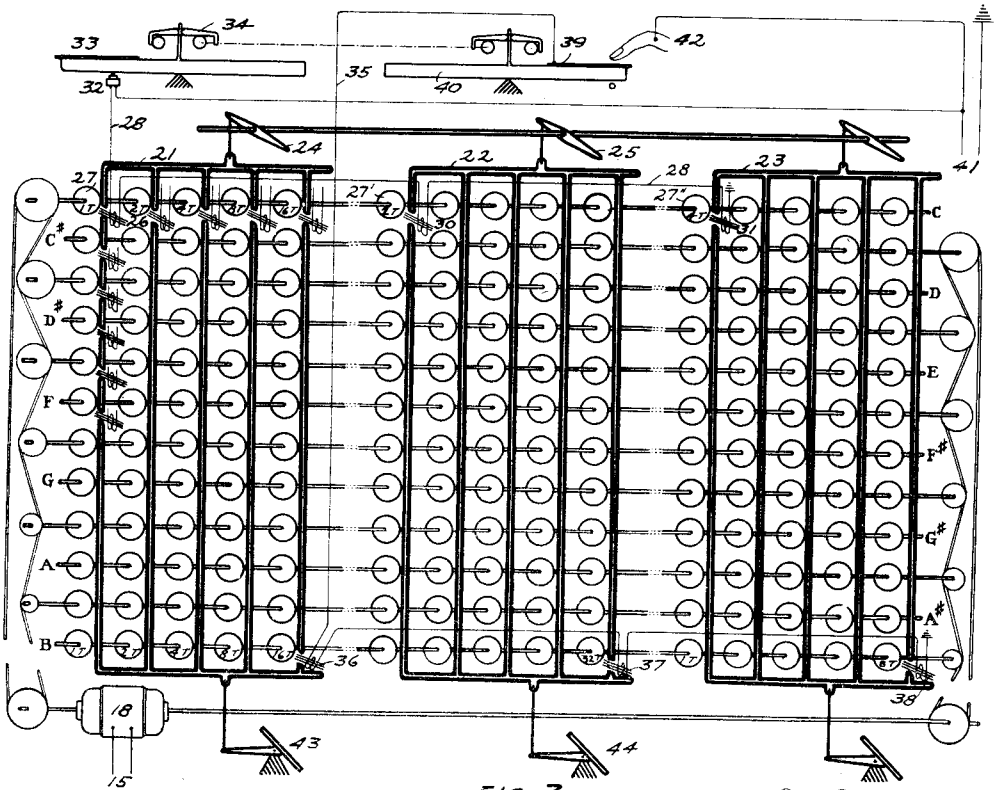

FIG. 3

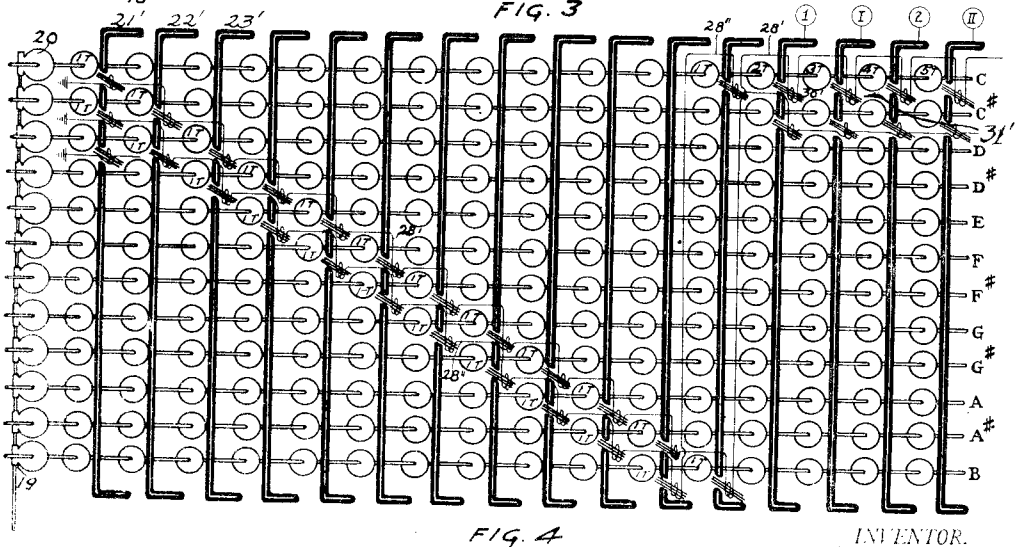

FIG. 4

INVENTOR.

Ivan Eremeeff

Aug. 29, 1933. I. EREMEEFF 1,924,713

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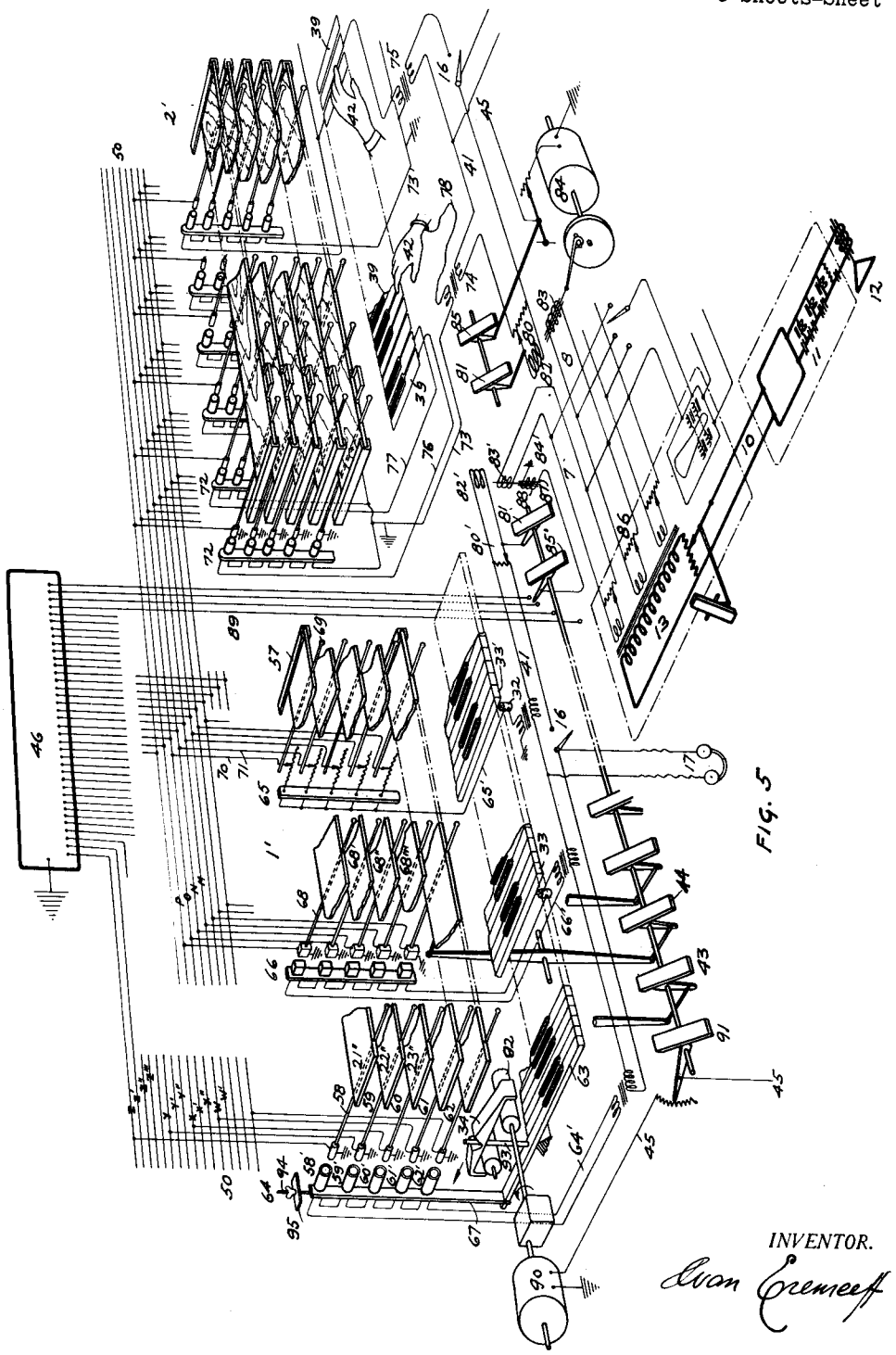

FIG. 5

INVENTOR.

Ivan Eremeeff

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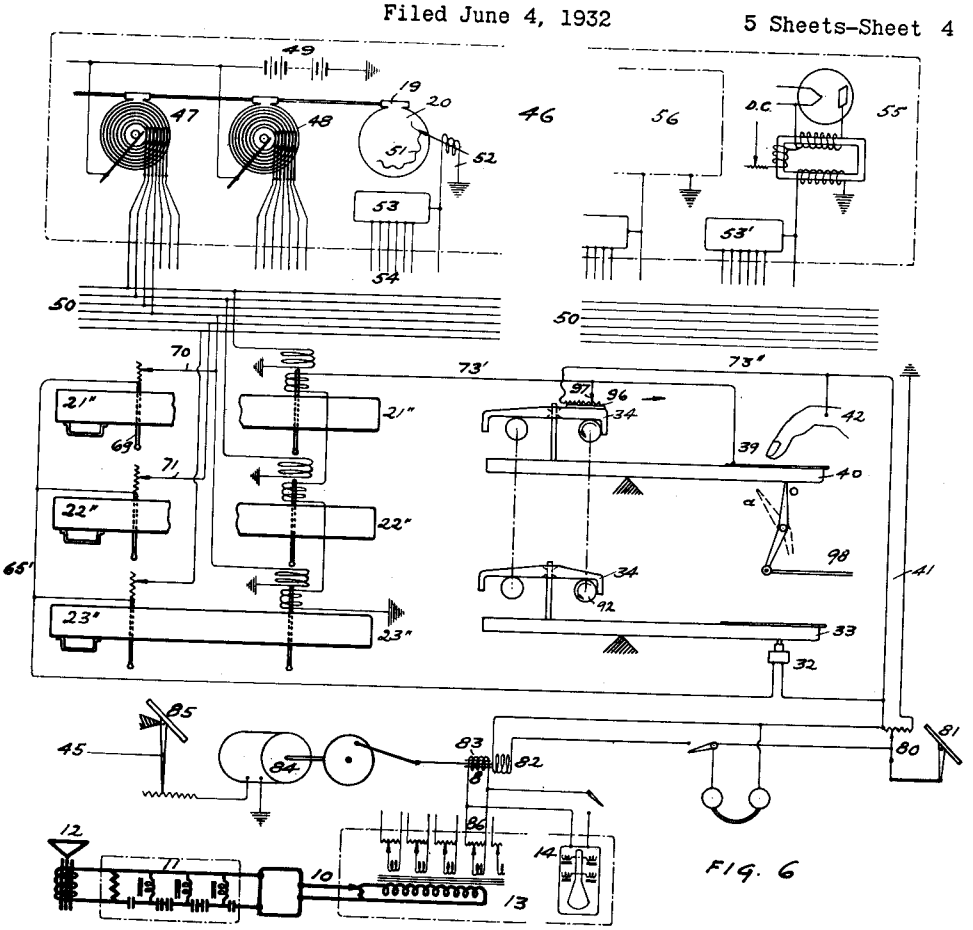

FIG. 6

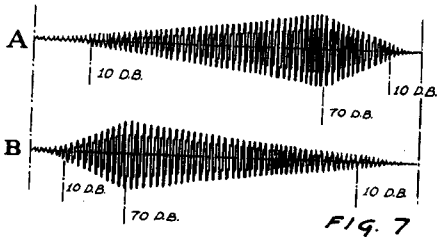

FIG. 7

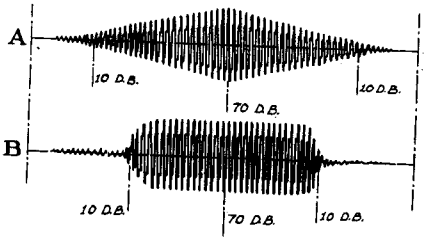

FIG. 8

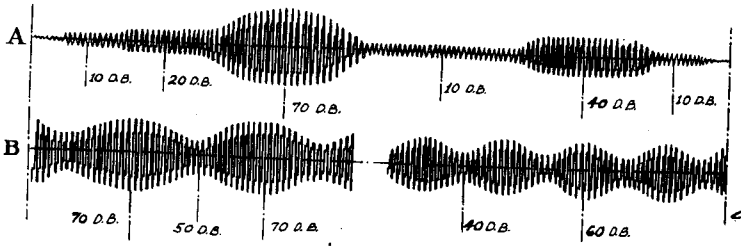

FIG. 9

INVENTOR

Ivan Eremeff

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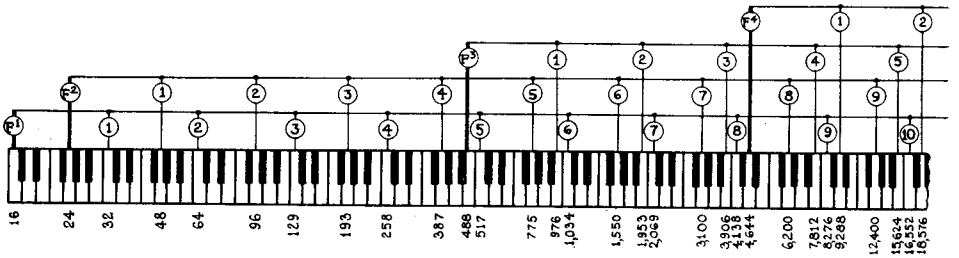


FIG. 10

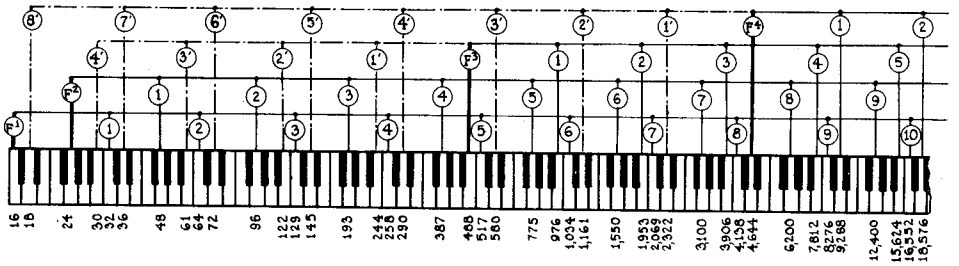


FIG. 11

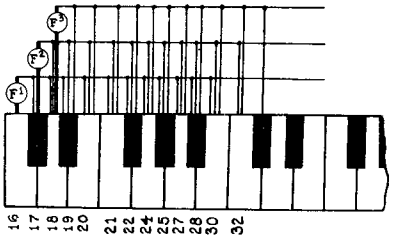


FIG. 12

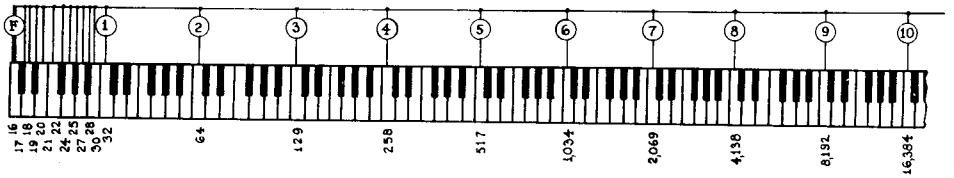
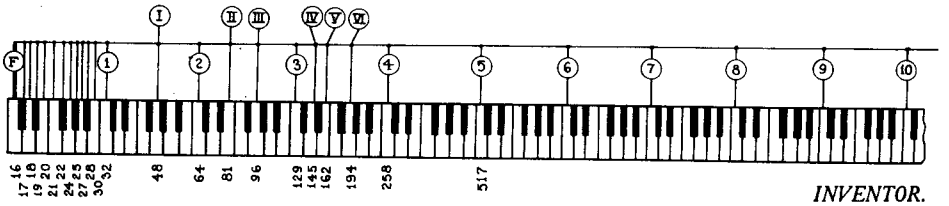


FIG. 13



INVENTOR.

Ivan Eremeeff

FIG. 14

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UNITED STATES PATENT OFFICE

1,924,713

SYNTHETIC ELECTRICAL MUSICAL SYSTEM

Ivan Eremeeff, Philadelphia, Pa.

Application June 4, 1932. Serial No. 615,307

6 Claims. (Cl. 84—1)

My invention relates to a system consisting of one or more synchronously coupled electrical musical instruments, each of which is capable of producing electrically tones of predetermined pitch, predetermined synthetic quality, and predetermined tonal expressions, the latter being produced by various keying means, with provision, if desired, for tremolo and a continuing diminishing of the tones after the keying has been discontinued. Each instrument of this system is provided with earphone attachments for the purpose of silent practise, and is also provided with individual couplings for a common line to sound emitting devices. This system also provides controlling and viewing means for aiding a conductor to direct the operators of the said instruments.

It is an object of my invention to devise a system which utilizes pulsating electric currents whose frequencies correspond to the frequencies of the tones of a musical scale. Such pulsating electric currents are either produced in each individual instrument of this system or are produced in distant central generators which supply pulsating electric current to the individual instruments. Each individual instrument is provided with means for combining at predetermined intensities, a pulsating electric current, whose frequency, which I shall call "fundamental", corresponds to that of a predetermined musical tone, with predetermined numbers of pulsating electric currents whose frequencies are multiples of said fundamental, and which I shall call "harmonics", or with predetermined numbers of its "sub-harmonics" as well as its harmonics. Provision is also made for combining currents of fundamental frequency with their harmonics, sub-harmonics, and frequencies which are fractions of the first harmonic, corresponding to the tones of a musical scale.

Another object of my invention is to devise a system of synthetic electrical musical instruments whose principal features are not to generate frequencies, as all musical instruments do, but to mix already generated frequencies according to my theory, also including what is generally known as the Helmholtz theory, in which the fundamental, or lowest, frequency is combined with a predetermined number of its harmonics which are, of course, its exact multiples. This latter theory, however, is in many cases unpractical, such as when, for example, a fundamental of very high frequency is combined with harmonics of higher frequency, which are mostly inaudible.

The main features of my invention are the mixing of fundamentals (which are not of the usual lowest frequency of a combination but of frequencies of the highest intensity) with their harmonics, with their sub-harmonics, and with fractional frequencies of the first harmonic of each fundamental, at different predetermined intensities which are readjustable during said mixing without its discontinuation, keying of rapid response, and diminishing and tremolo effects. Another feature is the application of common line currents to different instruments for the purpose of perfect tuning and for maintaining the phase occurrence of each pulsating electric current in all the instruments in such a manner that the superposed currents of the same frequencies of the individual instruments will combine correctly without destroying each other or producing beat tones.

The nature and objects of my invention will be more fully understood from the following specification and claims, reference being had to the accompanying drawings, in which:

Fig. 1 represents a view of a system of synthetic electrical musical instruments which include their own electrical generators.

Fig. 2 shows a system in which a distant central generator supplies a plurality of instruments.

Figs. 3 and 4 represent detail views of what is shown in Fig. 1, illustrating individual electrical musical instruments comprising generating, mixing, keying, etc. units.

Fig. 5 is a diagrammatic view of synthetic electrical musical instruments which are supplied from a distant common generator.

Fig. 6 represents details of what is shown in Figs. 2 and 5, illustrating synthetic electrical musical instruments being supplied from a distant common generator.

Figs. 7, 8, and 9 represent oscillograms depicting keying effects and tremolo.

Figs. 10, 11, 12, 13, and 14 are diagrams illustrating the theory of synthetic combinations which my electrical musical instruments are made to perform, and which are included among the objects of my invention.

In Fig. 1, 1, 2, 3, 4, 5, and 6 represent musical instruments which have means to generate, mix, and control by key, pulsating electric currents which are transmitted by the output lines as 7, 8, 9 to the common line 10 into the amplifying and filtering system 11, which is optional, and into

the sound emitting device 12. The control cabinet 13 is operated by a conductor for the purpose of switching on and off and combining the outputs of lines 7, 8, 9, etc. in the common circuit 10 at different degrees of intensity. The oscillograph 14, with taps for each of the output lines at 7, 8, 9, permits the conductor stationed at cabinet 13 to analyze the wave forms of the pulsating electric currents produced by each instrument such as 1, 2, 3, 4, 5, 6. While otherwise similar to the instruments 1, 2, 3, 4, etc., the instruments 5 and 6 are dual, which may, perhaps, be more convenient at times.

The power line 15 supplies alternating electric current of suitable frequency to the synchronous motors in the instruments 1 to 6, etc. for the purpose of keeping them in tune, as will be explained later. Switches such as 16 and earphones as 17 are provided for each instrument for the purpose of allowing each operator to practise upon his instrument without disturbing the others, the switches providing for connection to the common circuit when so desired. Details of construction of these instruments are to be found in Figs. 3 and 4.

In Fig. 3, 18 represents a synchronous motor which drives a plurality of shafts as designated by C, C♯, D, D♯, E, F, F♯, G, G♯, A, A♯, and B, whose speed is proportional to the frequencies of the corresponding tones of a musical scale. The said shafts are driven by motor 18 with the aid of an endless uniform, non-slipping belt, or belts. Fig. 4 shows the same shafts driven by worms as 19 and worm gears as 20, in which a small increase in speed is obtained by changing the diametral pitch in said worms and gears without changing their actual diameters. In view of the fact that the art of generating pulsating electric currents is well-known, I will not repeat a means for this purpose unless in explanation of mixing or keying means, and throughout this specification I will use means of generating which are most suitable for my purpose, although these are not the objects of my invention.

The non-magnetic grilles 21, 22, 23, etc., which are made to support a plurality of iron and permanent magnet core magnets with coils against co-operative phonic wheels on shafts C, C♯, D, etc. slide toward and away from the phonic wheels by graduated movement with the aid of the handles such as 24, 25, etc., for the purpose of engaging said magnets such as 26, with their co-operative phonic wheels such as 27, for generating pulsating electric current in the coils of said magnets, the intensity of said current increasing as the gaps between the phonic wheels and the magnets in the grilles decrease.

The line 28 connects in series the magnet 26 of grille 21, the magnet 30 of grille 22, and the magnet 31 of grille 23. The variable resistance 32 permits of increase in the passage of pulsating electric current at slight pressure upon key 33. 34 represents a device for releasing key 33 at a predetermined speed for producing a continued diminishing in the intensity of said pulsating electric current to its original value. The operation of these parts will be more fully described in following pages. Line 35 connects the magnets 36, 37, 38 of grilles 21, 22, 23, respectively, to plate 39 of key 40, which is also provided with an attachment for diminishing the intensity of the pulsating electric current. The transmission of current from plate 39 to the common circuit 41 is made by a conductor as 42, the intensity of the pulsating electric current depending upon the pressure of said conductor on plate 39, and the passage of pulsating electric current increasing as the pressure of said conductor causes an increase in the area of contact with plate 39. The grilles 21, 22, 23, etc. are also controlled by foot movement, if desired, with the aid of the pedals 43, 44, etc.

The grilles 21', 22', 23', etc., of Fig. 4 are similar to the grilles 21, 22, 23, etc. of Fig. 3, there being only a single vertical bar for supporting magnets in Fig. 4 instead of several as in Fig. 3, due to lack of space. The number of teeth of the phonic wheels, the wiring of the magnets, and the movements of the grilles in both Fig. 3 and Fig. 4 will be explained in following pages. Also, complete explanation of designs and operation can be found in my co-pending application Serial Number 544,821, filed June 16, 1931.

The movements of the handles and pedals which control the grilles are graduated and calibrated for the purpose of correctly setting the grilles for generation of currents of predetermined intensities.

Returning to Fig. 2, the instruments 1', 2', 3', 4', 5', 6', etc. represent the types which are supplied with pulsating electric current from a distant common generator, and have mixing and keying means for producing such combinations as outlined in Figs. 10, 11, 12, 13, and 14. The line 45 is provided with current for driving suitable motors for tremolo and diminishing effects, which will be described later, more complete detail views being shown in Figs. 5 and 6. In Fig. 2, the instruments 5' and 6' are dual, and the remaining parts with similar symbols to those of Fig. 1, represent the same parts as shown in both figures, such as 10, 11, 12, 13, 14, 16, and 17.

In Fig. 5 the distant common generator 46, which is shown in detail in Fig. 6, consists of a plurality of generator units which produce pulsating electric current at suitable intensities in order that amplification is optional. As already mentioned, the generation of pulsating electric currents is not new, and therefore I will show only the necessary means which are provided for this purpose. Generation, for example, can be obtained by the application of vacuum tubes, phonic wheel or magneto methods, for generating pulsating electric current, electrical pick-ups driven by grooves, or commutators with different numbers of segments running at different velocities. The selection of suitable generators such as 46, depends on the output of its units at predetermined frequencies, and also depends on phase occurrence. The latter is so regulated as to avoid overlapping which produces beat tone effects. However, a novel feature in the art of generating pulsating electric currents can be found in the form of gearing illustrated as 19 and 20 in Fig. 4, which, as stated, makes possible the driving of a plurality of shafts with any fractional ratios between each other.

47 and 48 of Fig. 6 represent a plurality of commutators which produce and transmit pulsating electric currents of predetermined frequencies from the battery 49 into the supply lines 50, each of said lines having its own predetermined number of cycles. For producing in a sound emitting device such as 12 tones of a musical scale of, for example, seven octaves, twelve compound commutators as 47, 48 are required, since each compound commutator produces seven frequencies which are multiples of each other, or,

speaking in terms of music, octaves. The same can be obtained by using twelve members such as 20, each having a groove as 51 and a pick-up as 52, producing a frequency from each member. 53 represents a frequency multiplier of any conventional type, whose design is not the object of my invention. If each pick-up as 52 produces a frequency of for example 16 cycles per second, the frequency multiplier 53 will produce in circuits 54 six frequencies which are multiples of each other, in addition to the frequency generated in the circuit 52. 55 may be a vacuum tube oscillator or a gaseous diode oscillator as shown, using, for example, a rectifying tube whose size depends on the amount of output current required, the circuit of which is shown in the diagram. Such a unit generates currents of considerable strength, which makes amplification optional.

53' represents a multiplying frequency converter similar to 53, and may be of any conventional type, the construction of which is not among the objects of my invention. 56 represents one of a plurality of vacuum tube oscillators similar to 55 which produces currents whose frequencies correspond to the frequencies of the tones of a musical scale in the form of octaves beginning with the lowest and ending at the highest.

Say, for example, there are twelve tubes, the first producing a frequency of 16.17 which corresponds to C_{-1} of a musical scale, also supplying the circuits 50 with six additional frequencies which correspond respectively to C_0, C_1, C_2, C_3, C_5, of a musical scale, with the aid of a frequency multiplier such as 53', the next tube producing a frequency of 17.13 which corresponds to $C\#_{-1}$ of a musical scale, also supplying circuits 50 with additional frequencies corresponding to $C\#_0$, $C\#_1$, $C\#_2$, etc., with the aid of a frequency multiplier similar to 53', and so forth, thus producing frequencies which correspond to the frequencies of an entire musical scale. The number of octaves does not necessarily have to be limited to seven, and as shown in the graphs of Figs. 10, 11, 13, and 14, there may be as many as for example, ten.

In Fig. 5, the two instruments 1' and 2' are shown having connection to the common circuits 50 as in Fig. 2, the details of which are illustrated in Fig. 6. The non-magnetic sliding panels 21'', 22'', 23'', etc., have graduated movements as have the grilles 21, 22, 23, etc. shown in Figs. 3 and 4. These panels slide to and fro in the channels such as 57, independent of each other, and are provided with rods as 58, 59, 60, 61, 62, etc. which carry on their ends suitable coils, each of which is supplied with a pulsating electric current of predetermined frequency from a distant common generator as 46. Opposite to said coils are placed receiving coils as 58', 59', 60', 61', 62', etc., which individually receive pulsating electric currents from the coils on the ends of the graduated rods 58, 59, 60, etc. at predetermined intensities depending on the adjustable gaps between said transmitting and receiving coils. The gaps between said coils are adjusted by individually sliding each panel as 21'' toward and away from the coil as 58' or by adjusting each individual rod as 58 in panel 21'' without moving said panel.

Each of the keys as 63, 33, and the plates such as 39, has a bank of transmitting and receiving coils as 64, or resistances as 65, or other mediums such as 66, which permit of the transmission of pulsating electric current from the power circuits connecting to the circuits 50 into the key circuits such as 64', 65', 66', etc. The construction of the mediums as 66 is not among the objects of my invention. Key 63 does not employ resistances as does the key 33 for the purpose of increasing and decreasing the intensity of the pulsating electric current since all the receiving coils as 58', 59', 60', 61', etc., are securely mounted on the bracket 67 and are lifted upward and aligned with the transmitting coils on the rods 58, 59, 60, 61, etc., when key 63 is depressed to the limit. The receiving elements of the keys 33 and 33' are stationary and the transmitting elements are commonly or individually adjusted by the panels 21'', 22'', 23'', etc., or by the rods as 68, 68', 68'', etc. The bank of transmitting and receiving elements 66 is mounted rigidly and said elements may be of any suitable design as long as they perform transmission of current from one circuit to another. The bank 65 comprises variable resistances which are suitably distributed throughout their length, and are adjusted, as said, by individual and by common means.

For example, all of the panels as 21'', 22'', 23'', etc., may be brought forward to a definite zero position. The graduated rods 58, 68, or 69, are then adjusted for transmission of, for example pulsating electric current of 50% intensity, from circuits 50, by, for example, lines 70 and 71, of the key circuit 65. By sliding the panels as 21'' toward the banks of receiving elements, all of the rods in said panels will be automatically advanced, thus increasing the intensity of the pulsating electric current in the circuits of the receiving elements of the key circuits as 64', 65', 66', etc.

Each bank, such as 64, is merely a collector of currents from its co-operative transmitting elements, receiving complex pulsating electric current which is the combination of a plurality of simple pulsating electric currents of predetermined frequencies and adjustable intensities. The intensities can always be varied during the combination, as well as during the keying action, by the rods as 58, 59, 60, 61, 62, etc., and by the panels as 21'', 22'', 23'', etc., as stated. Details concerning the wiring of the banks and the mixing of currents of various intensities individually and commonly will be given in following pages.

The instrument 2' of Fig. 5 is similar to instrument 1'. However, the instrument 2' shows different keying, such as the arrangement of plates as 39 and conductors as 42, which were explained in regard to Fig. 3. The wiring of the arrangement 39, 42, as in Fig. 5, shows application for multiple arrangements providing for many keys in place of the single arrangement of Fig. 3. It can be seen that all the receiving units as 72 are wired in parallel to a common circuit 73 which connects to one side of the primaries of transformers 74 and 75, while the lines 76 and 77, leading from two different banks, are connected at will by conductors such as 42, which have flexible connections as 78, in order to complete the circuit.

The output of the banks, which are selectively controlled by the conductors 42, is combined in the common circuit 41, the intensity of whose current is increased or decreased by a potentiometer as 80 with a volume control pedal as 81. Current from the coil 82 is transmitted to the movable coil 83 and circuit 8 at an intensity which depends on the position of the coils 82 and 83.

By moving coil 83 into coil 82 with the aid of

the device 84 at a predetermined fraction of time, controlled by pedal 85, variation of current is produced such as represented in Fig. 9 by the oscillograph curve B, which shows two forms of intensity variations, fast and slow. This periodical variation of intensity of the current in circuit 8 produces a tremolo effect when said current is converted into sound energy. The intensity of said current is regulated by potentiometer 86 in the cabinet of the conductor. The output of banks as 64, 65, 66, etc. in instrument 1' is also combined in the common circuit 41, the volume control pedal 81' and potentiometer 80' varying the intensity of the current in coil 82'. Transmission of current from coil 82' into coil 83' and into circuit 7 is made by device 84' which works without a motor, unlike the device 84. Variation of current in circuit 7 is obtained by the moving of coil 83' into coil 82' by means of the plunger 87 inside the coil 88, which has connection to oscillatory currents of different suitable frequencies supplied from the distant common generator 46 by lines 89. The tremolo pedal 85' selectively connects coil 88 to different taps on the lines 89 for permitting plunger 87 to vibrate at different speeds depending on the number of cycles of that particular line to which the switch of pedal 85' is connected.

Continuous diminishing effects are obtained as follows: motor unit 90, whose speed is controlled by the diminisher pedal 91, drives roller 92 at any suitable speed in the direction indicated by arrow. Sliding weight 34 moves by friction in the direction indicated by arrow, and pushes pin 93 of key 63 until said key resumes a normal resting position, and bank 64 with bracket 67 is lowered. No transmission of current from the transmitting coils on rods 58, 59, etc. to receiving coils as 58', 59', etc., occurs since the gap between them is increased.

Sliding weight 34 is then held stationary, with slippage on the roller 92, which continues to revolve at a speed controlled by diminisher pedal 91. When key 63 is depressed to the limit, pin 93 pushes weight 34 forward against the friction of roller 92 in a direction reverse to that shown by arrow, and bracket 67, which is hinged to key 63, is lifted, steadying itself by means of the sliding pin 94 in the stationary support 95. Current is transmitted from the transmitting elements as on rods 58, 59, etc. to the receiving elements as 58', 59', etc. as long as key 63 is held depressed. When key 63 is released, said key will not return to its resting place immediately, but will return at a speed which depends on the position of the diminisher pedal 91 and on the speed of the roller 92. Said roller picks up sliding weight 34 (which slips on roller 92 during the time of depression of key 63) and carries said weight by friction in the direction indicated by arrow at a speed already regulated by pedal 91, until said key resumes its resting position after a certain length of time. This diminishing action gradually discontinues the reception of current from said transmitting elements, producing a gradual fading effect when said current is converted into sound energy.

Instrument 2' of Fig. 5 is also provided with a diminishing means for the key arrangements 39, 42, which is similar to that of the keys 63, 33, 33', etc. of instrument 1'. Details of means for producing diminishing effects as in the case of instrument 2' of Fig. 5 can be found in Fig. 6. The diminishing mechanism as applied to instrument 2' of Fig. 5 is similar to that of instrument 1'; however, as in Fig. 6, a resistance 96 is placed upon the weight 34 over an insulating plate in such a manner that the stationary contact point 97 rests on resistance 96 in such a way that current is not permitted to pass from line 73' into 73'' unless conductor 42 is placed on 39 at a predetermined degree of pressure, provided that the stopping device 98 does not permit key 40 to be depressed.

The reason for current not being permitted to pass, is that the point 97 rests on resistance 96 in such a position that no direct transmission from line 73' to 73'' takes place. If there were transmission, sound would be heard in the output. The resistance of 96 at the resting point of 97 is very high, and the resistance 96, after sliding in the direction indicated by arrow, is gradually lowered as the pointer 97 takes different positions on said resistance. Where there is no resistance, current from line 73' easily passes into line 73''. This resistance has been described, and is used for producing diminishing effects, and is in use only when it moves in the direction opposite to that indicated by arrow, since direct connection is made between line 73' and plate 39 and conductor 42 to line 73''. In other words, when the finger touches the plate 39, (when lever 98 permits of rocking key 40), current from 73' passes either through the finger or the moving resistance. When the finger leaves the plate, current passes only through the already lessened resistance of 96.

This arrangement provides complete finger touch, without having to move a heavy mass for transmitting currents into the circuit 41. For producing the diminishing effects, stop 98 is placed in the position of (*a*) permitting the conductor 42 to transmit current and to depress key 40, at the same time moving resistance 96 in the direction indicated by arrow, while contact point 97 is stationary. Current from line 73' is transmitted either through the lessened resistance 96 or by conductor 42, into circuit 73'', but when conductor 42 leaves plate 39, resistance 96 is moved in the opposite direction from that indicated by arrow, with the aid of roller 92, at a speed which is controlled by a diminisher pedal as 91 in Fig. 5. Said resistor continues to move back until contact point 97 has resumed its original position.

It is to be understood that the arrangement for producing diminishing effects as shown can be applied to all of the keys of each instrument, and certain parts, such as sliding weight 34, have been shown in simplified form for the sake of explanation. Similar features for producing diminishing effects have been disclosed in my copending patent application Serial Number 486,391, filed October 4, 1930, and allowed May 24, 1932.

Figs. 7, 8, and A of Fig. 9 illustrate the results of various keying effects which can be obtained by such arrangements as 32, 33, 39, 40, and 42, of Figs. 3, 5, and 6. A of Fig. 7 shows the effects of slow increase and rapid decrease in intensity of current obtained by the various keying means mentioned above, while B of Fig. 7 illustrates rapid increase and slow decrease of current, depending upon the various pressures and contacts given to the keys. If the current represented by A of Fig. 7 is converted into sound energy, the 10 decibels as indicated would produce a tone about as loud as a whisper, gradually increasing to the loudness of 70 decibels, which is suitable in an auditorium. From 70

decibels, the current represented by A again decreases to about 10 decibels; however, the decrease being much faster than the increase, as can readily be seen in A of Fig. 7. The rapid decrease of A to zero from 10 decibels is produced either by releasing the key as 33, shown in Fig. 6, rapidly, or disconnecting the conductor 42 from the plate 39, also shown in Fig. 6. B of Fig. 7 shows the effects of rapid increase in intensity from about 10 decibels to 70 decibels with a slow decrease again to 10 decibels and then to nothing. In Fig. 8, A illustrates a uniform increase and decrease from 10 decibels to about 70 decibels and again to 10 decibels. B of Fig. 8 shows a sudden increase from 10 to 70 decibels, held for a time at 70 decibels, and again suddenly decreased to 10 decibels. Such effects can be obtained by a short quick touch of the conductor 42, of Fig. 6, upon the plate 39, where it is held at a uniform intensity, and then suddenly lifted from it.

In Fig. 9, A shows the effects of various pressures on a key such as 33, or on plate 39 by a conductor as 42, shown in Fig. 6, varying from zero to 10 decibels, held uniform for a short period, increased to and held uniformly at 20 decibels, gradually increased and held at 70 decibels, then dropping gradually to about 10 decibels, held uniform for a time, then increased to about 40 decibels, and again dropping to 10 decibels and returning to the zero point. This illustrates the pliability of controlling the pulsating electric currents by means of my various keying systems.

B of Fig. 9 represents tremolo effects, the rapid and slow variations being produced by the tremolo pedals as 85 and 85' of Fig. 5, the numbers in decibels, of course, representing the variations in both cases. For the sake of explanation, the decibel figures were cited. These are not to be taken scrupulously.

Figs. 10, 11, 12, 13, and 14 illustrate the art of combining oscillatory matter, either in the form of electricity or sound. In view of the fact that I am describing electrical musical instruments, I will explain in electrical form, the musical scales whose frequencies correspond to the frequencies of my electrical currents. Fig. 10 represents a musical scale ranging from 16 cycles to approximately 10 octaves above F^1 represents a fundamental of 16 cycles, with its first harmonic of 32 cycles, its second harmonic of 64 cycles, its third harmonic of 129 cycles, and so forth. The fundamental F^1 has a high intensity, and when combined with its first, second, third, etc. harmonics, said harmonics having predetermined intensities, complex pulsating electric current resulting from such combination will be obtained. When such current is converted, without distortion, into sound energy, the quality of the sound will have characteristics depending on the combination. By changing the number of harmonics, and by changing the intensity of the fundamental and the harmonics, a new quality of sound will be heard from a sound emitting device without changing the pitch, which will be that of the fundamental provided that it continues to have the highest intensity. As previously stated, this is the generally accepted theory of producing different qualities of sound. However, if the fundamental has a very high frequency, such as F^4 of Fig. 10, and some of its harmonics are above the range of audibility, musical sounds cannot be produced as well as in the case of lower frequency fundamentals. F^2 and F^3 illustrate the number of harmonics available for fundamentals of 24 cycles and 488 cycles respectively. The numbers placed below the keyboard represent the frequency numbers of those keys directly above them. To those familiar with the frequencies of musical tones, it is known that the cycle numbers are generally carried at least to two decimals. For simplicity I will disregard these decimals, such as 16.17, for which I will merely use 16.

As already stated, my invention is made to conform with such combinations as illustrated in Fig. 10, as well as with my own combinations as shown in Figs. 11, 12, 13, and 14. In Fig. 11, fundamental F^1 has ten harmonics, fundamental F^2 has nine harmonics, but fundamental F^3 has nine partials, five of which are harmonics, and the remaining four are "sub-harmonics". Fundamental F^4 has ten partials, two exact harmonics, and eight subharmonics. It can be seen that the number of partials of the various fundamentals in Fig. 11 are practically the same, while in Fig. 10, the higher the frequency of the fundamental, the fewer are its partials.

In Fig. 12, each fundamental, as F^1, F^2, and F^3, has eleven partials which correspond to the tones of a musical scale. For example, the partials of fundamental F^1 are: partial no. 1, frequency 17, (17.13 to be exact) partial no. 2, frequency 18, partial no. 3, frequency 19, and so forth. Likewise, since fundamental F^2 has a frequency of 17, its first partial will have a frequency of 18, its second partial frequency 19, its third partial frequency 20, and so forth. These partials are fractions of the first exact harmonic of each fundamental, the first harmonic, of course being a multiple of the fundamental always. In other words, the first partial of each fundamental is the first fraction of the first harmonic of the fundamental.

In Fig. 13, the fundamental F, frequency 16, has eleven partials, 17, 18, 19, 20, 21, 22, 24, 25, 27, 28, and 30, as well as ten exact harmonics. Altogether, fundamental F has twenty-one partials, the first mentioned eleven partials being fractions of the first harmonic which is designated by frequency 32, which, of course, is an exact multiple of fundamental F, frequency 16.

In Fig. 14, as in Fig. 13, the fundamental F is combined with ten partials which are exact multiples of said fundamental, and eleven partials which are fractions of the first harmonic, frequency 32. However, in addition, Fig. 14 shows the partials designated by the numberals I, II, III, IV, V, and VI, which are so-called "in-between" harmonics of the fundamental F, frequency 16. For example, partial I represents an exact third multiple of the fundamental F, and has a frequency of 48; partial II represents an exact fifth multiple of fundamental F, and has a frequency of 81; partial III represents an exact sixth multiple, frequency 96; partial IV represents an exact ninth multiple of the fundamental, and has a frequency of 145; partial V represents a tenth multiple, frequency 162; and partial VI represents a multiple by twelve times, frequency 194. Of course, there may be as many more of such multiples of the fundamental as desired. Due to the fact that the entire decimal of each frequency number is not given, as previously explained, the frequency numbers of the various partials are not, then, exact multiples. For example, while the tenth partial of fundamental F, frequency 16, is given as frequency 162, this is really an exact multiple of the entire number 16.17, the remaining

fraction accounting for the additional "2" in 162.

It is to be noted that the frequencies of all fractions, harmonics, and sub-harmonics mentioned, can be found in a musical scale, and can be produced electrically from currents whose frequencies correspond to the frequencies of a musical scale. It is also to be understood that the conventional musical scale of tones and half-tones can be applied with quarter-tones, or scales which may be called metric, of uniform ratios of strictly multiplying frequencies can also be utilized.

For the production of musical tones by systems such as illustrated in Figs. 3 and 4, their synthesis is shown in Fig. 10. In Fig. 3, the grille 21 is brought to the position so that the gaps between the phonic wheels and their co-operative magnets permit of the production of pulsating electric current of predetermined intensity, for example, 100%. Shaft C of Fig. 3, rotates for example, 16.17 times per second. Phonic wheel 27, having one tooth on its periphery, generates one impulse per revolution, producing 16.17 impulses per second at an intensity of 100%. This is illustrated in Fig. 10 by fundamental F^1, frequency 16.17. Grilles 22, 23, etc. are brought into position for generating pulsating electric current of 100% intensity. Phonic wheel 27' has, for example, two teeth, and naturally produces 32 (fraction omited) impulses per second as illustrated by harmonic 1 of F^1 in Fig. 10. Phonic wheel 27'' of Fig. 3, has, for example, four teeth on its periphery, producing 64 impulses per second, which is illustrated in Fig. 10 as harmonic 2 of F^1. Additional phonic wheels with eight teeth, sixteen teeth, etc., produce the harmonics 3, 4, 5, etc. of F^1 in Fig. 10. The magnets 26, 30, 31, etc. are coupled by the common circuit 28, and pulsating electric current, which can be represented by the combination of fundamental F^1 and a predetermined selective number of its harmonics, all of 100% intensity, is transmitted to circuit 41 with the aid of the keying means 33 or 39, 42. By lowering grille 22 to a predetermined position, the intensity of the current in magnet 30 is lessened to, for example, 50%, producing a change in the resulting combined current, since the intensity of the fundamental is 100%, the intensity of its first harmonic is 50%, that of the second harmonic is 100%, and so forth. For more alteration in the resultant current, grille 21 may be lowered to 95% intensity, grille 22 may be lowered to 15%, grille 23 to 60% etc. so that the current in circuit 28, which will be complex, of course, will be the combination of fundamental F^1, frequency 16, key of C_{-1}; at an intensity of 95%, with harmonic 1, frequency 32, key of C_0, at an intensity of 15%, harmonic 2, frequency 64, key of C_1, at an intensity of 60%. If said grilles are, for example, adjusted to positions producing the intensities mentioned, all of the magnets and the co-operative phonic wheels of grille 21, for example, will generate current of 95% intensity, and the magnets and phonic wheels of grille 22 will generate current of 15% intensity, etc.

If the magnet 36, shown in Fig. 3, on shaft B, were placed, for example, on shaft C, which makes 16.17 revolutions per second, the frequency of the current generated would be 258, since the phonic wheel co-operating with magnet 36 has 16 teeth, as do all of the phonic wheels in the position of the beginning of the fifth octave. However, magnet 36 is really located at shaft B which revolves faster than shaft C, making 30.52 revolutions per second. Multiplying this by 16, which represents the number of teeth on the phonic wheel co-operating with magnet 36, the current generated has a frequency of 488, which is designated in Fig. 11 as the frequency of F^3. The magnet 37 of Fig. 3 co-operates with a phonic wheel having 32 teeth, generating current of 15% intensity, frequency 976, corresponding to the tone one octave higher than that represented by F^3, and this is designated in Fig. 11 as harmonic no. 1.

Magnet 38 co-operates with a phonic wheel of eight teeth, since it is made to generate the first sub-harmonic of F^3 as 1' of Fig. 11, whose frequency is one octave lower than that of F^3, being 244, and whose intensity is 60%, due to the adjustment of grille 23. The complex pulsating electric current in circuit 35 of Fig. 3 will be the combination of the fundamental current of magnet 36 at an intensity of 95%, frequency 488, with the first harmonic current from magnet 37 at an intensity of 15%, frequency 976, and the sub-harmonic current from magnet 38 at an intensity of 60%, frequency 244.

The following, or fourth grille, after grille 23, would be provided for the second harmonic of F^3, the fifth grille would be provided for the second sub-harmonic, as 2' of Fig. 11, and so forth. Each grille is adjusted for different intensities without static or without causing disconnection in the circuits.

The wiring diagram of Fig. 4 shows the magnet of grille 21' and shaft C coupled with the magnet of grille 22' and shaft C#, which are in turn coupled with the magnet of grille 23' and shaft D, and so forth on all the shafts respectively. Each phonic wheel co-operating with said magnets has one tooth, the entire row of coupled magnets and their phonic wheels producing, for example, frequencies of 16 to 30 cycles, due to the fact that each shaft revolves faster than the precedent one in accordance with the frequencies of a musical scale. For example, shaft C revolves 16.17 times per second, shaft C# revolves 17.13 times per second, shaft D revolves 18.15 times per second, shaft D# revolves 19.22 times per second, etc. All the magnets are coupled by line 28' and will produce what is illustrated in Fig. 14 as the fractions of the first harmonic of the fundamental F. Magnet 30' co-operates with a phonic wheel with two teeth, producing a frequency which is twice as high as the fundamental, which would be represented by the harmonic no. 1 of fundamental F in Fig. 14. Magnet 31' co-operates with a phonic wheel of three teeth, producing a frequenccy which is three times as high as F, designated in Fig. 14 by the numeral I. It can be said that the next magnet following 31' co-operates with a phonic wheel of four teeth, producing a frequency which is four times as high as the fundamental F, shown in Fig. 14 as harmonic no. 2, while the next magnet, co-operating with a phonic wheel of five teeth, produces a frequency which is five times as high as F, shown in Fig. 14 by numeral II, and so forth.

The magnets connected in the circuit 28'' are placed in the same respective grilles as are the magnets coupled by line 28'. The currents generated by the magnets of line 28'' are a trifle higher in frequency, by as much as the ratio between, for example 16.17 and 17.13. The intensities of the currents of all the magnets of each grille as 21', 22', 23', 1, I, 2, II, etc., are adjusted to predetermined degrees simultaneously.

For obtaining combinations such as illustrated in Figs. 10 to 14, the synthetic electrical musical instruments of my inventon operate as follows:

for combining a fundamental as F^1 in Fig. 10, with a predetermined number of its harmonics, at different predetermined degrees of intensity, rod 56, shown in Fig. 5, has a transmitting coil which is connected to line Z of circuit 50, and delivers pulsating electric current at a frequency of 16.17 cycles per second. The rods 59, 60, 61, etc. are so adjusted, by being pulled forward, that the gaps between the transmitting and the receiving coils are greatly increased, in order that no transmission occurs excepting between the coil 58' and the coil of rod 58, when key 63 is depressed. At this time, a current of 16.17 cycles is permitted to pass into the circuit 64'. Then the rods 59, 60, 61, etc. are pushed toward their co-operative receiving coils to predetermined degrees for the additional transmission of other currents with predetermined intensities. The coil of rod 59, for example, connects to line Y which carries currents of 32.33 cycles, the coil of rod 60 connects to line X, which carries currents of 64.66 cycles, the coil of rod 61 connects to line W, which carries currents of 129 cycles, and so forth.

By depressing the key such as 63, complex pulsating electric current, which is the combination of a fundamental of 16.17 cycles, with a predetermined selective number of its harmonics, each said harmonic having a predetermined intensity, is transmitted into a sound emitting device as 12, given tremolo or diminishing effects if desired, and then discontinued without static or circuit breaking disturbances. By varying the number of harmonics which are combined with said fundamental, by adjustment of rods 58 to 62, etc., and by changing the intensities of said harmonics, unlimited synthetic combinations can be made, thus producing a variety of different tone qualities when said complex current is converted into sound energy.

Fig. 11 has been described in regard to the synthesis of fundamentals with harmonics and sub-harmonics. If key 33, of Fig. 5, produces current comprising of a fundamental frequency 488, shown as F^3 in Fig. 11, coil of rod 68 connects to for example, line P, which carries current of 488 cycles. The coil of rod 68', which controls connection of the first harmonic, is connected to line O, which carries current of 976 cycles. This is represented in Fig. 11 as the first harmonic of fundamental F^3. The coil of the rod 68'' is provided for the first sub-harmonic, and connects to line N, which carries current of 244 cycles, which, of course, is one half as high as that of the fundamental, whose frequency is 488. The coil of rod 68''' connects to line M which carries current of 1953 cycles, for production of the second harmonic of fundamental F^3 represented in Fig. 11 as harmonic no. 2. The next coil of the next rod connects to its own line for the second sub-harmonic of the fundamental, and so forth.

If the key 63 of Fig. 5 is depressed for producing a fundamental frequency of 16.17 cycles, shown in Fig. 14 as F, which is combined with its harmonics, sub-harmonics, and other partials, the wiring of the coils on the rods 58, 59, 60, 61, etc., will be as follows: the coil of rod 58 will connect to line Z, for frequency 16.17, coil of rod 59 connects to line Z' for the first fractional partial, which is, for example, frequency 17.13, coil of rod 60 connects to line Z'' for the second fractional partial which is, for example, frequency 18.18, and so forth, until all of the partials which are fractions of the first harmonic of fundamental F are connected in, for example, eleven lines, in the same order. The twelfth rod, for example, connects its coil to line Y, which carries current of 32.33 cycles, for the first harmonic of the fundamental, the thirteenth rod connecting its coil to line Y', which carries currents of 48.44 cycles, and which is three times as high as the fundamental, in frequency. This frequency is designated in Fig. 14 as the multiple I. The coil of the fourteenth rod would be connected to line X, which carries currents of frequency which is four times as high as that of the fundamental, and is indicated in Fig. 14 as the second harmonic of the fundamental F. Certain of the lines used in describing the connections in key 63, are used in other keys.

Having thus described my invention, what I claim as new and useful is:

1. In a synthetic electrical musical system comprising a centralized distant generator which supplies pulsating electric current to a plurality of independent electrical musical instruments, means for producing a plurality of pulsating electric currents of uniform wave forms, whose frequencies correspond to the frequencies of the tones of an audible musical range, said pulsating electric currents having definite phase relationships between each other to avoid overlapping, which produces additional frequencies, means for supplying the mixers of a plurality of said independent electrical musical instruments with a plurality of pulsating electric currents, each of said currents being predeterminedly utilized in each of said instruments as a fundamental, as the fractions of the first harmonics of corresponding fundamentals, and as the harmonics, sub-harmonics, and multiples of corresponding fundamentals.

2. In a synthetic electrical musical system comprising a plurality of independent electrical musical instruments and a distant centralized generator which supplies a plurality of pulsating electric currents to the mixer and banks of each of said electrical musical instruments, means for manually and automatically producing in the output circuit of each of said electrical musical instruments a predetermined compound pulsating electric current which is selectively received from the banks of the mixer of each of said electrical musical instruments at predetermined intensities and at predetermined fractions of time, and means for predeterminedly varying the intensities of said compound pulsating electric currents in said output circuits at predetermined variable fractions of time.

3. In a system for producing music electrically by a plurality of electrical musical instruments which are fed by a distant common generator, means for selectively and individually combining in the circuits of the individual banks of the mixers of said instruments, a predetermined number of pulsating electric currents, each said current having predetermined intensity and predetermined frequency, for producing in the circuit of each of said banks a complex pulsating electric current of predetermined wave form, the number of said pulsating electric currents, and their predetermined intensities and predetermined frequencies being predeterminedly and individually variable during said selective combining of said pulsating electric currents, for the purpose of individually altering the wave forms of said complex pulsating electric currents in the circuits of said mixer banks, means for selectively and commonly combining the pulsating electric currents in the circuits of said mixer banks into complex pulsating electric currents of predeter-

mined wave forms, and said means varying the number, intensities, and frequencies of the individual pulsating electric currents in the circuits of said mixer banks for the purpose of commonly altering the wave forms of said complex pulsating electric currents.

4. In a synthetic electrical musical system comprising a plurality of synchronously coupled electrical musical instruments, centralized means for individually and commonly controlling the intensities of the outputs of said electrical musical instruments, with provision for individually visualizing the wave forms of the outputs of said electrical musical instruments.

5. In a synthetic electrical musical system, a plurality of synchronously coupled electrical musical instruments, each of said instruments comprising a generator, a mixer, a keyboard, and diminisher and tremolo controls, each of said instruments having means to generate a plurality of pulsating electric currents of predetermined intensities, the frequencies of said currents corresponding to the frequencies of the tones of an audible musical range, graduated hand and foot operated means to combine a predetermined number of selective generated pulsating electric currents of predetermined fundamental frequencies and predetermined intensities with a predetermined number of their co-operative selective pulsating electric currents at different predetermined variable intensities, the frequencies of said pulsating electric currents corresponding to the harmonics, the sub-harmonics, the multiples, and the divisions of the first harmonics of their co-operative fundamental frequency pulsating electric currents, manually operated means for passing the resultant complex pulsating electric currents, which are the selective combinations of said fundamental frequency pulsating electric currents and predetermined numbers of their co-operative pulsating electric currents, into the output circuit of each said instrument, each said resultant complex pulsating electric current passing into said output circuit at predetermined variable intensity and at predetermined variable fractions of time, automatic means for the diminishing passage of said resultant complex pulsating electric currents after the operation of said manually operated means has been discontinued, and means for producing tremolo effects by predeterminedly varying the intensity of the compound pulsating electric current in the output of each said instrument at predetermined variable fractions of time, when said compound pulsating electric current is converted into sound energy.

6. A synthetic electrical musical system comprising a plurality of independent electrical musical instruments, each of said instruments being capable of individually producing musical tones and chords of predetermined synthetic musical quality, means for supplying said plurality of instruments with a predetermined number of pulsating electric currents from a common centralized generator, said generator producing said pulsating electric currents at predetermined intensities, which makes amplification optional, at predetermined frequencies, said frequencies corresponding to the frequencies of the tones of a musical scale, and at definite phase occurrences relative to each other, graduated hand and foot operated means for independently and selectively transmitting into a predetermined keying circuit a pulsating electric current of predetermined fundamental frequency and a predetermined selective number of pulsating electric currents whose frequencies correspond to the harmonics, sub-harmonics, multiples, and fractions of the first harmonic of said fundamental frequency pulsating electric current, each of said currents having predetermined intensity which is variable during transmission of pulsating electric current, means for combining said transmitted pulsating electric currents in a keying circuit which is provided for said fundamental frequency pulsating electric current, manual means for predeterminedly passing a resultant complex pulsating electric current into the output circuit of each of said individual electrical musical instruments at variable intensities and at variable fractions of time, automatic means for producing a diminishing passage of each said resultant complex pulsating electric current when operation of said manual means has been discontinued, means for varying the intensity of the compound pulsating electric current in the output circuit of each of said electrical musical instruments per predetermined variable fraction of time, individual guiding means for private performance of each of said electrical musical instruments, centralized means for selectively viewing the wave forms of the compound pulsating electric current in the output circuit of each of said electrical musical instruments, and selective centralized means for combining the compound pulsating electric currents from the output circuits of said electrical musical instruments at predetermined intensities, said combined compound pulsating electric currents later being converted into sound energy.

IVAN EREMEEFF.