June 23, 1942. W. F. KANNENBERG 2,287,105

ELECTRONIC ORGAN

Filed Dec. 7, 1939 6 Sheets-Sheet 1

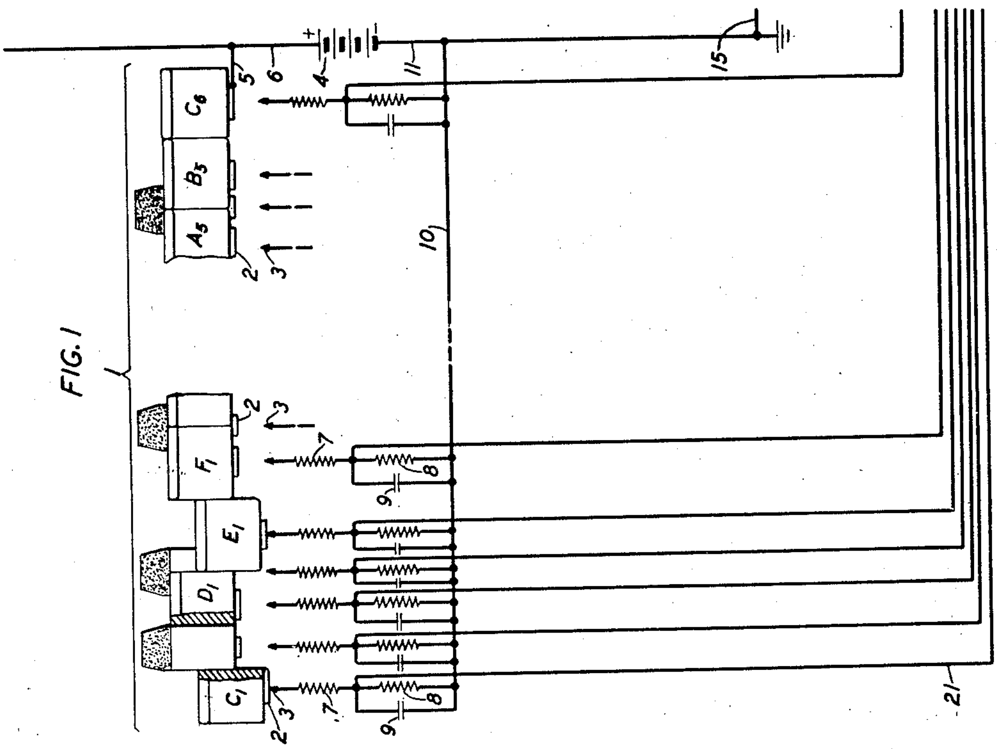

FIG. 1

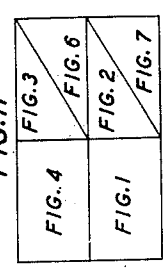

FIG. 11

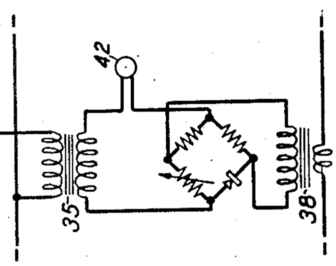

FIG. 10

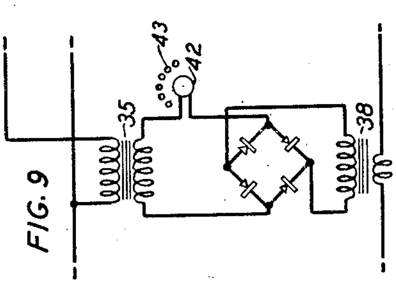

FIG. 9

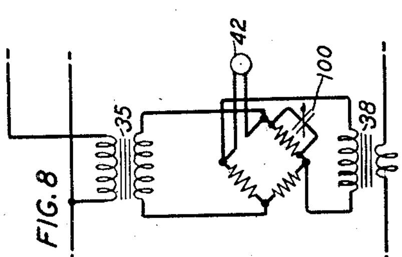

FIG. 8

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ELECTRONIC ORGAN

Filed Dec. 7, 1939 6 Sheets-Sheet 2

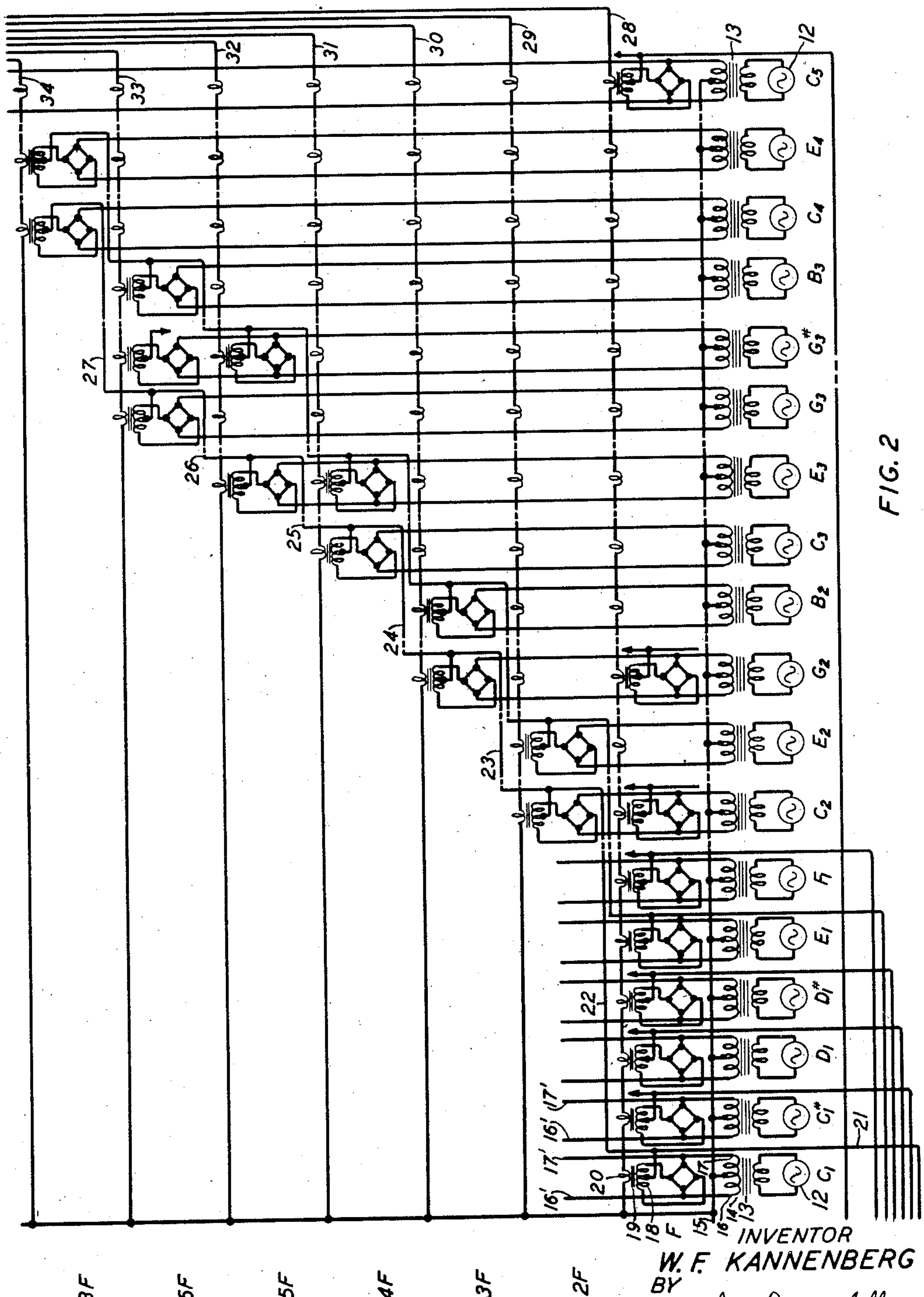

FIG. 2

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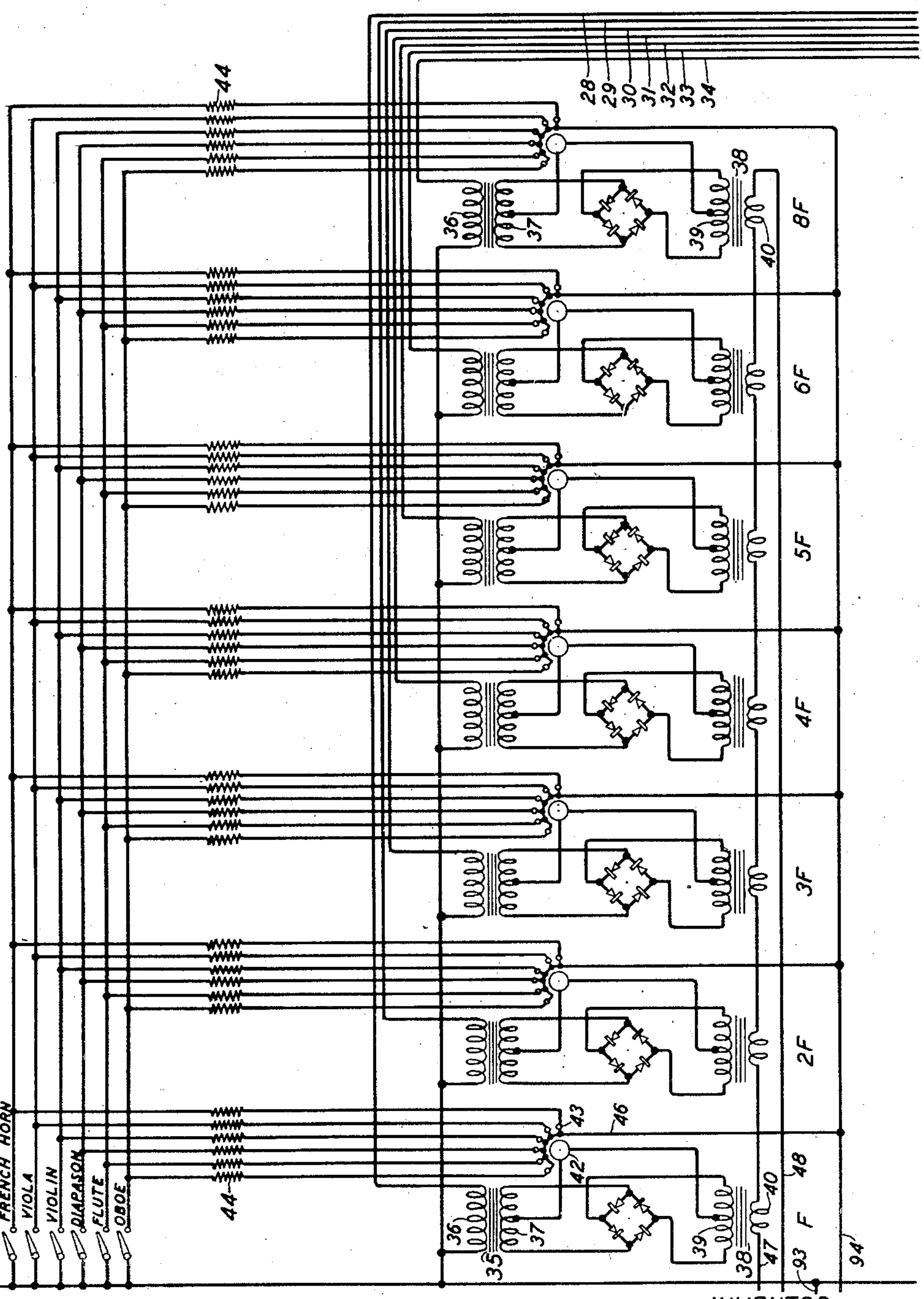
ELECTRONIC ORGAN

Filed Dec. 7, 1939 6 Sheets-Sheet 3

FIG. 3



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ELECTRONIC ORGAN

Filed Dec. 7, 1939 6 Sheets-Sheet 4

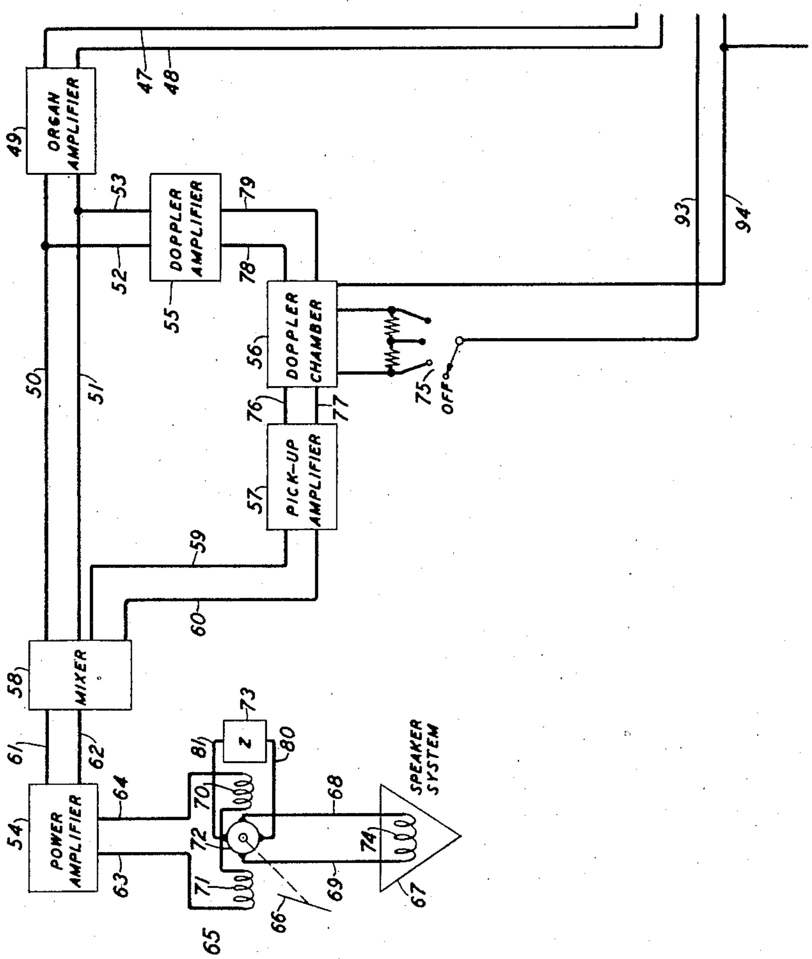

FIG. 4

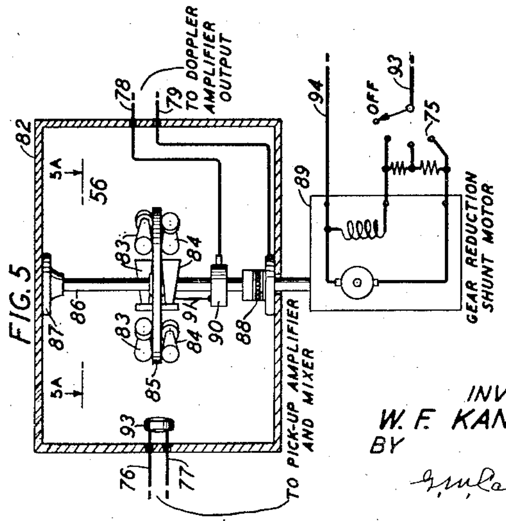

FIG. 5

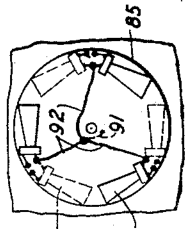

FIG. 5A

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ELECTRONIC ORGAN

Filed Dec. 7, 1939 6 Sheets-Sheet 5

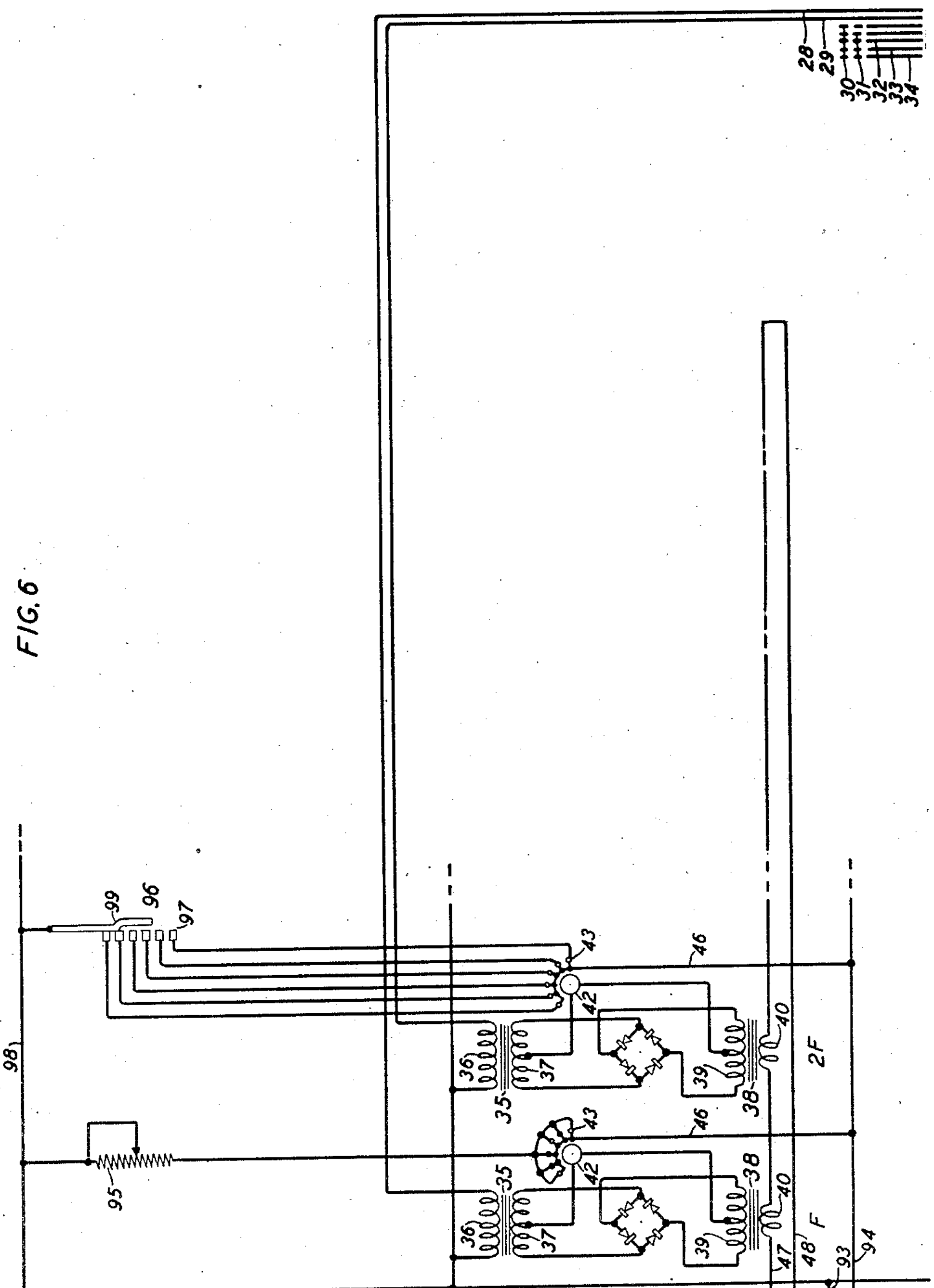

FIG. 6

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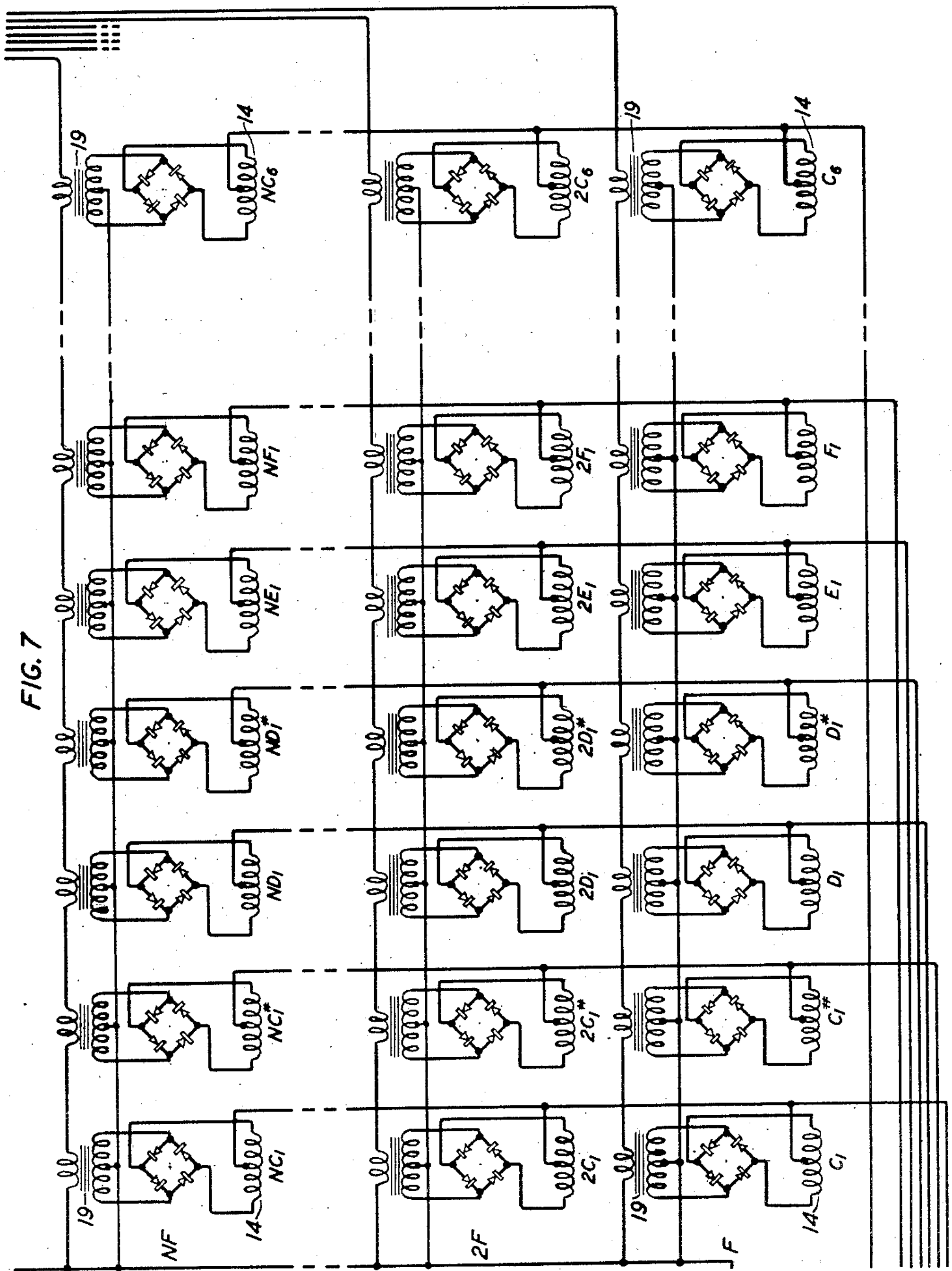
ELECTRONIC ORGAN

Filed Dec. 7, 1939 6 Sheets-Sheet 6

FIG. 7



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Patented June 23, 1942 2,287,105

UNITED STATES PATENT OFFICE

2,287,105

ELECTRONIC ORGAN

Walter F. Kannenberg, Rutherford, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application December 7, 1939, Serial No. 308,037

13 Claims. (Cl. 84—1.17)

This invention relates to electronic organs of the type adapted to synthesize complex musical tones from a plurality of relatively pure sine wave sources.

The object of this invention is to provide an improved means for controlling the tone quality or timbre of the synthesized complex sound waves and to further embellish these synthesized complex waves by the addition of combined celeste, chorus and reverberation effects.

The foregoing object is attained by the apparatus of this invention which comprises in combination an electronic organ, a quality control means for modifying the quality of its output and a means based on the Doppler principle for further modifying the output by introducing under control such special effects as have been variously termed "chorus," "celeste" and "reverberation" effects.

The invention may be better understood by referring to the accompanying drawings in which:

Fig. 1 discloses a part of a conventional electronic organ manual;

Fig. 2 is one form of frequency generating system based on the utilization of equal-tempered harmonics;

Fig. 3 is a preferred form of harmonic or quality control adapted for fixed stops;

Fig. 4 shows in block form a suitable output system including means for introducing special effects based on the Doppler principle;

Fig. 5 discloses a Doppler chamber in its preferred form;

Fig. 5A is a plan view of a section taken within the Doppler chamber shown in Fig. 5;

Fig. 6 discloses two modified forms of quality control which may be substituted for the form shown in Fig. 3;

Fig. 7 discloses another form of frequency generating system based on the utilization of individual harmonic generators for each note on the keyboard;

Figs. 8, 9 and 10 disclose other specific forms of harmonic control bridge elements based on well-known principles which may be substituted for the form shown in Fig. 3; and

Fig. 11 is a key to assembling the several drawings into an integrated whole.

Referring now to Fig. 1 wherein a conventional keyboard 1 is disclosed, each key thereof having a movable contact 2 normally separated from a stationary contact 3. Upon playing a key the contacts are engaged as indicated for keys C_1 and E_1. All of the movable contacts 2 are electrically connected together and to one pole, for example, the positive pole, of a direct current source of supply 4 via conductors 5 and 6.

In order to provide "thumpless" keying there is associated with the stationary contacts of each key, a potentiometer made up of two resistors 7, 8, resistor 8 being in turn shunted by a condenser 9. One end of each of the resistors 8 and condensers 9 in the entire organ is connected to ground strap 10 which is connected to the other pole of the direct current power source 4 and to ground by conductor 11. When a key is played the voltage across its associated resistor 8 will gradually rise to a fixed limit with the charge taken by condenser 9, and when the key is released it will gradually fall to zero due to condenser 9 discharging through resistor 8. The rates of rise and fall may be different and are controlled in a well-known manner by the choice of magnitudes for resistors 7, 8 and condenser 9. While this specific form of keying is disclosed for the sake of completeness, it will be obvious from what follows that any of the forms already well known in this art may be substituted therefor provided they supply a direct current voltage for controlling the keying bridges of Fig. 2 or 7 hereinafter more particularly described.

In Fig. 2 a series of tone generators 12 is shown each one generating a substantially pure sine wave of frequency corresponding with the frequency of one note in the equal-tempered scale. In the actual organ there will be as many such generators as there are equal-tempered notes of different frequencies in the organ or twelve for each chromatic octave. In addition thereto there must be as many more in the audible range above the upper end of the keyboard as are necessary to provide harmonics for the notes which appear on the keyboard but whose audible harmonics are above the notes appearing thereon. To avoid confusion only enough of these generators are herein disclosed to clearly explain the invention. The output of each sine wave generator, for example, the C_1 generator, is supplied to a two-coil transformer 13, the secondary 14 whereof is center-tapped as shown. The center taps of all these transformers are connected together and to ground by a conductor 15.

The outer terminals 16 and 17 of each secondary 14 are connected to the input terminals of an associated copper-oxide bridge essentially identical in construction and operation with the bridge disclosed in U. S. Patent 2,025,158 granted December 24, 1935, to F. A. Cowan. These individual bridges are more clearly shown in Fig. 7, the arrows being deleted in Fig. 2 for clarity. As many additional copper-oxide bridges are connected in parallel to each of these bridges as are required to provide harmonics for the other notes on the keyboard. For example, the C_2 generator must have one bridge to provide an output when its associated key is played and must have another bridge to provide an output when the C_1 key is played because the frequency of C_2 is the second harmonic of C_1. Likewise the G_2 generator must have an additional bridge to supply the third harmonic of C_1, the C_3 generator to provide the fourth harmonic, and so forth. This is true of nearly every note on the keyboard so that the number of bridges per note will vary from one to seven for an organ capable of furnishing the first to sixth and the eighth harmonics of every note played. If subharmonic content is desired, additional bridges are added in like manner. In Fig. 2 all bridges connected to the same generator are arranged in a row directly above it.

For the purposes of this invention, these bridges operate as follows: Each bridge is made up of four substantially identical arms containing non-linear, asymmetric impedance elements such as copper-oxide rectifier units poled as shown in Fig. 7 so that balance is ordinarily maintained irrespective of the alternating current input from secondary 14. There is, accordingly, no alternating current output from the bridge to the center-tapped primary 18 of output transformer 19. If, however, the center taps of secondary 14 and primary 18 are connected to a suitable direct current source, an unbalance will appear so that the bridge will deliver an alternating current output to the primary 18 of transformer 19, the magnitude of which varies with the intensity of the direct current.

For convenience of quality control, all the bridges producing the fundamental frequencies of their associated keys are arranged in one bank which may be called the fundamental bank. This is the lower horizontal row of bridges in Fig. 2. All of the bridges which supply second harmonic contents are arranged in the next higher horizontal row, etc. The output of each harmonic bank is collected by the secondaries 20 of the output transformers 19 in that bank. These are serially connected as shown and one end thereof is connected to ground while the other end of each is carried to their associated quality control bridges in Fig. 3, via conductors 28 to 34, inclusive. For the organ herein assumed, that is, one capable of supplying for each note the first to sixth, inclusive, and the eighth harmonics there will be seven horizontal rows of such bridges and, accordingly, seven groups of transformer secondaries serially connected. In Fig. 2 these are denoted F, 2F, 3F, 4F, 5F, 6F and 8F, respectively, the seventh harmonic being omitted because it does not fall nearly enough on any equal-tempered frequency to permit its inclusion without the addition of considerable equipment. There is also an objection raised when a seventh harmonic is added to an equal-tempered instrument because of inherent dissonances. If additional harmonics or subharmonics are desired, it is only necessary to provide an additional bank for each harmonic order added, the connections being made in the same manner as for the bridges shown.

The keying operation of the apparatus so far described is as follows: Assume that key C_1 of Fig. 1 is played as indicated. A voltage will gradually rise across its resistor 8 until it reaches a predetermined limit depending upon the ratio of resistances of resistors 8 and 7, the capacity of the condenser 9 and the voltage of supply 4. This voltage will be impressed via conductor 21 and ground upon the copper-oxide units of the C_1 bridge in the fundamental or F bank. It will also be impressed in like manner via conductor 22 upon the C_2 bridge in the second harmonic or 2F bank, via conductor 23 upon the G_2 bridge in the third harmonic or 3F bank via conductor 24 to the G_3 bridge in the 4F bank via conductor 25 to the E_3 bridge in the 5F bank via conductor 26 to the G_3 bridge in the 6F bank and finally via conductor 27 to the C_4 bridge in the 8F bank. Thus it is seen that when a given key is pressed all of the associated harmonic bridges are caused to deliver their full rated outputs into their output transformers. The actual control over the proportioning of the harmonic content is attained in a manner to be hereinafter described.

Fig. 1 also shows the key E_1 depressed and the circuit may be traced as before to find that the E_1 bridge of the F bank, the E_2 bridge of the 2F bank, the B_2 bridge of the 3F bank, the E_3 bridge of the 4F bank, the $G_3\sharp$ bridge of the 5F bank, the B_3 bridge of the 6F bank and the E_4 bridge of the 8F bank are all activated. Circuits for all the other keys and bridges are not shown but are arranged in the manner indicated for these two keys. If no subharmonics are desired only one bridge will be connected to each generator in the first or low bass octave. If subharmonics of upper notes are desired then additional bridges are connected to the upwardly extending conductors 16', 17' and they are arranged in suitable subharmonic banks in the same way as are the harmonic banks disclosed. In the second octave each generator will have at least two bridges because they furnish the second harmonic content for the first octave. All the generators from G_2 to B_2, inclusive, will have an additional bridge in the third harmonic bank. All the bridges are thus arranged, the largest number for any generator being 7 for the organ assumed. Of course, if the lowest note on any manual is any chromatic note other than C_1 the actual letters assigned to the generators in the circuits disclosed will have to be shifted the corresponding number of chromatic intervals, there being no essential structural differences otherwise. The total number of bridges and their arrangement in the complete organ is therefore obvious from the above description and the accompanying drawings.

As previously stated, the outputs from the several harmonic banks are fed to harmonic or quality control bridges in Fig. 3 via conductors 28 to 34, inclusive, and ground. Referring now to Fig. 3 it is seen that there is a row of seven bridges substantially like the bridges of Fig. 2. There is one bridge for each harmonic F, 2F and so on to 8F. The input transformers 35 in this case are located above the bridges and their primaries 36 are connected to their corresponding conductors 28 to 34, inclusive, and to ground. For example, primary 36 of the fundamental bridge is connected to the serially connected secondaries 20 of the fundamental bank in Fig. 2 via conductor 28 and ground. The other bridges are similarly connected to their respective harmonic banks in Fig. 2.

The center-tapped secondaries 37 of these transformers are connected to the inputs of the copper-oxide bridges the operation whereof being the same as previously described for the bridges of Fig. 2. The direct current unbalancing potential for each bridge is supplied by a photoelectromotive force cell 42 to the center taps on secondary 37 of the input transformer 35, and primary 39 of the output transformer 38. From the previous description it is clear that so long as any given photocell 42 produces no unbalancing voltage the corresponding alternating current input voltage will not be transferred to the output circuit. Thus, if all seven photocells are dark, there will be no output even though any number of the organ keys are played.

The amount of output transferred to the secondaries 40 from any bridge will be governed by the amount of illumination received by its associated photocell 42. For this purpose a separate cluster of lamps 43 are adapted to illuminate each cell. It is evident that the harmonic content is thereby under control. Each lamp of the cluster 43 is fed from direct current source 4 of Fig. 1 via conductor 46, an individual resistor 44 and a fixed stop tablet 45 to the grounded side of source 4. To imitate the quality of a French horn, for example, the French horn tablet is operated to connect one lamp of each of the seven clusters to source 4 through their individual resistors 44, the amount of each harmonic being controlled by the size of its individual resistor. Other stops are provided for other fixed qualities and they may be used singly or in any desired combination for special effects as is well known.

The outputs from the seven output transformer secondaries 40 are collected by serially connecting these secondaries together and to an organ amplifier 49 via conductors 47, 48. The organ amplifier 49 is shown in block form in Fig. 4 and may be of any suitable design.

The description thus far describes the means for keying and the means for effecting quality control. It is evident that the quality control herein described is very flexible and exceedingly simple in its operation. The keying bridges in actual practice are of relatively small dimensions and take very little space thereby lending themselves to very compact console designs. The quality control bridges likewise are in no way bulky and obviously lend themselves to an extremely flexible control over quality. Moreover, a very important result is attained by the use of this type of control, namely, silent keying and transition from one quality to another while playing. The only switch contacts used are at the keys and stop tablets. The network formed by resistors 7, 8 and condenser 9 as well as the copper-oxide keying bridge network affords "thumpless" or "clickless" keying while the natural build-up and decay time of the lamp filament in cluster 43 affords silent quality transition while playing.

As previously stated, the collected output from the secondaries of the quality control transformers are carried to the organ amplifier 49 of Fig. 4 via conductors 47 and 48. The output of organ amplifier 49 is amplified by a power amplifier 54 and fed to a speaker system 67 by way of a swell control 65. In order to further modify and embellish the organ output, special effects variously termed as celeste, choral and reverberation are introduced by means of Doppler chamber 56. The principal output of the organ amplifier 49 is fed to a mixer 58 by way of conductors 50 and 51. A diverted portion of this output is carried to the Doppler amplifier 55 by way of conductors 52 and 53 the output whereof is fed directly to the Doppler chamber 56 by way of conductors 78 and 79. The special effects above enumerated are produced in this chamber in a manner to be explained more in detail in connection with Fig. 5.

The output of chamber 56 is amplified by pick-up amplifier 57 and fed to mixer 58 by way of conductors 59 and 60. Mixer 58 proportions the relative amounts of direct and diverted outputs from the organ amplifier 59. The output of this mixer is carried to the power amplifier 54 by way of conductors 61 and 62.

The actual volume from the power amplifier 54 to reach the speaker system 67 is under control of the swell control 65 which operates essentially on the principle of an induction regulator. Since there are no contacts to be made or broken in this type of swell control, it introduces no noise whatever in the speaker system. The output of the power amplifier 54 is connected to the field windings 70 and 71 of the swell control 65 by means of conductors 63, 64. A wound rotor 72 disposed in mutual inductive relation with field windings 70, 71 is adapted to be rotated through 90 electrical degrees by means of swell control pedal 66. Rotor 72 is preferably wound in a conventional, distributed form such as commonly used on armatures. The mutual inductive relationship between field windings 70 and 71 and wound rotor 72 is thereby made variable from substantially zero to its maximum value. The output from this rotor is carried to the speaker system by way of permanently attached conductors 68 and 69.

Since any changes in the mutual inductive relationship between wound rotor 72 and the field windings 70 and 71 changes the effective terminating impedance for the power amplifier 54, an auxiliary terminating impedance 73 is connected to rotor 72 by way of conductors 80 and 81. The impedance of auxiliary impedance 73 is substantially identical with the impedance of coil 74 in the speaker system 67. Conductors 80 and 81 are connected to wound rotor 72 in such a manner as to be displaced substantially 90 electrical degrees from the connections made by conductors 68 and 69 so that the portion of the rotor winding which is connected to conductors 68 and 69 is approaching a zero mutual inductive relationship with the field windings 70 and 71 while the portions of the rotor windings connected to conductors 80 and 81 are approaching their maximum mutual inductive relationship. This maintains the effective terminating impedance more nearly uniform throughout the operative range of swell control. While pedal 66 is shown linked to winding 72, it is obvious that field 70, 71 may be the rotor while winding 72 is the stator in which case pedal 66 would be linked to the field 70, 71.

The actual physical apparatus employed for the various amplifiers, mixer, speaker system and the swell control 65 in Fig. 4 may be of any convenient design. A preferred form for the Doppler chamber 56, however, is disclosed in Fig. 5.

Fig. 5 discloses the Doppler chamber 56 in the form of a sound insulated chamber having sound-proof walls 82. Within sound-proof chamber 82 a rotatable disc 85 is mounted on a shaft 86 adapted to be rotated by a gear reduction motor 89. Motor 89 may be supplied from source 4 of Fig. 1 via conductors 93 and 94, the former connecting to the grounded side of source 4 while the latter connects to source 4 via conductor 6 in Fig. 1. The upper end of shaft 86 is supported by a bearing 87, while the lower end of shaft 86 is supported by a thrust bearing 88. Three directional type loud-speakers 83, 83, 83 are symmetrically disposed around the outer periphery on the upper side of disc 85, while three similarly disposed loud-speakers 84, 84, 84 are mounted on the underside of disc 85. The output from the Doppler amplifier 55 of Fig. 4 is carried to these loud-speakers by way of conductors 78 and 79. Conductor 78 connects to the loud-speakers by way of conductor 91 through slip ring 90, while conductor 79 is connected to the lower thrust bearing 88 and is carried to the loud-speakers by way of shaft 86 and disc 85. In Fig. 5A immediately above Fig. 5, a plan view is shown of the connections between the loud-speakers on the disc. Here it is seen that conductor 91 branches into conductors 92, 92, 92 which connect the loud-speakers in parallel in groups of three.

Along one wall of chamber 82 and substantially in line with the edge of disc 85 there is mounted a microphone 93 adapted to pick up the direct and reflected acoustic energy from loud-speakers 83 and 84. Conductors 76 and 77 transmit the output from this microphone to the pick-up amplifier 57 as shown in Fig. 4.

In the actual use of this device, shaft 86 may be rotated at various speeds ranging from about fifty revolutions per minute to one hundred revolutions per minute, depending upon the effect desired. For this purpose the speed control device 75 of conventional design is shown for controlling the speed of the gear reduction motor 89. Moreover, should reverberation effects only be desired, the motor 89 is stopped whereupon chamber 56 acts only as a reverberation chamber in a manner well known in the art. It frequently happens, however, that the organist desires to enhance the beauty of tone by introducing such effects as are commonly termed "celeste" or "choral." These effects are produced in a unique manner by the apparatus of this invention which operates on the well-known Doppler principle.

The apparent pitch of a sound source vibrating at a constant frequency is higher when moving toward a receiver than when stationary and, conversely, is lower when moving away from the sound receiver. In Fig. 5, for example, shaft 86 may be rotated in either direction. Assume, for example, that it is rotated in the clockwise direction viewed from the top. Neglecting for the moment the effect of the reflected sound waves in the reverberation chamber, the direct sound waves received from directional loud-speakers 83 by microphone 93 will cyclically vary both in amplitude and apparent frequency as they rotate about shaft 86. As they approach microphone 93, their apparent pitch is higher and amplitude relatively high, while as they move away from microphone 93, their amplitude is relatively low and apparent pitch also low. The same effect is produced by the microphones 84 on the underside of disc 85 except that their amplitude effect is just the reverse, that is to say, as the loud-speakers 84 recede from microphone 93, their relative volume is greater due to their directional effect than when they are approaching microphone 93.

This rapid frequency shift produces what is commonly referred to as the "celeste" effect, while this effect combined with the fact that a plurality of speakers are used simultaneously produces the effect commonly termed the "choral" effect. If the inner walls of chamber 82 were totally sound absorbing, these effects would be produced without reverberation, but since a certain amount of reverberation is usually desirable, the character of the inner walls of chamber 82 are so selected and the dimensions thereof are so proportioned as to produce the desirable reverberation effect in the auditorium in which the organ is to be employed. It has been found experimentally that the introduction of the reverberation effect per se is insufficient to produce the results desired and that the introduction of a certain amount of celeste and choral effects simultaneously with the reverberation effect greatly enhances the beauty of the music. The apparatus of this invention therefore provides a convenient means of obtaining all of these effects simultaneously with a single piece of apparatus.

It is obvious that where controlled reverberation content will not be required, chamber 82 may be eliminated and the rotating speaker system may be located in the room with the main speaker system 67. In this case microphone 93, pick-up amplifier 57 and mixer 58 may or may not be used as the requirements of the particular installation dictate. If they are not used and the celeste and choral effects are obtained by direct acoustic radiation from the rotating speaker system, the swell control 65 must be coordinated with a similar device associated with the rotating speaker system. Such a modification is so obvious from a mere mention thereof as to require no further discussion.

Fig. 6 discloses two modifications of the quality control bridges disclosed in Fig. 3. The first of these modifications is shown at the left where the lamps of cluster 43 are all shown connected in parallel. These lamps as in the case of Fig. 3 are supplied with current from sourse 4 in Fig. 1. The high voltage side of source 4 is connected to the lower end of the lamp cluster by means of conductor 46 while the grounded side of source 4 is connected to the upper side of the lamp cluster by means of conductor 98 and continuously variable rheostat 95. The symbol for rheostat 95 is intended to represent a substantially stepless resistance control device so that the illumination intensity of lamp cluster 43 may be continuously varied from substantially zero brilliance to maximum brilliance.

The second modification shown on the right in Fig. 6 is adapted to successively add the several lamps of cluster 43 through separate contacts 97 of the quality control switch 96. This type of control increases the total brilliance on photocell 42 in successive, discrete steps.

The quality control scheme disclosed in Fig. 3 or either of the two modifications disclosed in Fig. 6 may be employed either singly or in combination in any particular organ. That is to say, a series of fixed stops may be employed as shown in Fig. 3, and, in addition thereto, a separate cluster of lamps and associated control means therefor in accordance with either or both of the modifications shown in Fig. 6 may also be used. The fixed stops permit the organist to rapidly change from one predetermined conventional tone quality to another while playing, while the variable quality controls shown in Fig.

6 permit him to employ a substantially infinite variety of tone colors and vary them to suit his taste and fancy.

In Fig. 7 a modified arrangement for the keying bridges of Fig. 2 is disclosed. In Fig. 2 only one set of generators were employed, these being tuned to the equal-tempered chromatic scale while the harmonics and subharmonics of any particular note in this scale were obtained on an equal-tempered basis from the other generators. In referring again to Fig. 2 it will be noted that the individual sine wave generators 12 were coupled to their associated keying bridges by transformer 13 having center-tapped secondary windings 14. In Fig. 7 these sine wave generators are used but have been deleted leaving only the center-tapped secondaries 14. Moreover, instead of having only one set of sine wave generators as in Fig. 2, Fig. 7 requires one sine wave generator for each keying bridge. There will, therefore, be for Fig. 7 one sine wave generator for each keying bridge in the fundamental bank, another sine wave generator for each keying bridge in the second harmonic bank, etc. This arrangement makes it possible to employ the true harmonics instead of the equal-tempered harmonics as is necessary for Fig. 2. All external circuit connections to and from the keying bridges of Fig. 7 are identical to those shown for Fig. 2 and Fig. 7 may be substituted for Fig. 2.

Figs. 8, 9 and 10 are modifications of the quality control bridges disclosed in Figs. 3 and 6. These bridges operate on a slightly different principle, more particularly described in my prior U. S. Patent 2,169,842, granted August 15, 1939, wherein Figs. 22, 24 and 26 disclose respectively the Figs. 8, 9 and 10 of this application. Briefly, however, the bridge of Fig. 8 operates essentially like an ordinary alternating current impedance bridge in which the arms are made up of essentially pure resistances. The inherent capacity of photocell 42 is balanced out by means of a small variable condenser 100. When photocell 42 is illuminated, its resistance changes thereby unbalancing the bridge.

The bridges of Figs. 9 and 10 also operate like ordinary alternating current impedance bridges. In these cases, however, the unbalance is effected by means of the non-linear characteristic of the copper-oxide units in the bridge arms. The electrical outputs from the keying bridges of Fig. 2 enter these bridges by means of transformer 35, the output voltage whereof is sufficiently low to prevent the copper-oxide units from departing from the linear portions of their characteristics. However, when a direct current component is introduced by light falling on photocell 42 sufficient current is carried by the copper-oxide unit in opposite arms of Fig. 9 or by the copper-oxide unit in the arm of Fig. 10 to cause these units to depart from linearity thereby unbalancing the bridge.

What is claimed is:

1. In an electronic organ having an output system and a plurality of electric generators for producing a musical series of fundamental and harmonic frequencies, a means for confining each harmonic order to a separate harmonic order circuit comprising for each harmonic order a plurality of normally balanced keying bridge networks, one for each generator the frequency of which appears in that harmonic order, an input and an output circuit for each of said bridges, means permanently coupling the generators to their respective bridge input circuits, means permanently coupling the bridge output circuits together to form the said separate harmonic order circuit and a quality control means for controlling the relative harmonic energy delivered from said separate harmonic order circuit to the output system.

2. The combination of claim 1 wherein the quality control means comprises a normally balanced bridge network for each of the separate harmonic order circuits, means permanently coupling said bridge network between its associated harmonic order circuit and the output system and control means for controlling the degree of unbalance of each of the bridge networks.

3. In an electronic organ having an output system and a plurality of electric generators for producing a musical series of fundamental and harmonic frequencies, a means for confining each harmonic order to a separate harmonic order circuit, and a quality control means therefor comprising a normally balanced bridge network for each of the separate harmonic order circuits, means permanently coupling said bridge network between its associated harmonic order circuit and the output system and control means for controlling the degree of unbalance of each of the bridge networks.

4. A swell control means for an electronic organ comprising a primary winding and a secondary winding adapted for variable mutual inductive coupling, input terminals for the primary winding, output terminals for the secondary winding, an artificial impedance load having an impedance substantially equal to the output circuit to which the output terminals are to be connected, means connecting the artificial impedance load to the secondary at points substantially 90 electrical degrees from the output terminals and means for varying the mutual inductive coupling between the primary and the secondary windings.

5. A swell control means for an electronic organ comprising a primary winding, a secondary winding wound in distributed form and adapted for variable mutual inductive coupling with said primary winding, input terminals for the primary winding, output terminals for the secondary winding connected thereto at points substantially 180 electrical degrees apart, an artificial impedance load having an impedance substantially equal to the output circuit to which the output terminals are to be connected, means connecting the artificial impedance load to the secondary at points substantially 90 electrical degrees from the output terminals, and means for varying the mutual inductive coupling between the primary and the secondary windings.

6. In an electronic organ having a means for producing celeste and choral effects comprising the combination of a soundproof chamber, a disc rotatable about the principal axis thereof normal to its plane, means for supporting said disc within said chamber, a directional electroacoustic transducer means rigidly mounted on said disc to face a direction substantially tangential to the circle formed thereby as the disc is rotated and means for rotating said disc.

7. In an electronic organ having a means for producing celeste and choral effects comprising the combination of a soundproof reverberation chamber, a disc rotatable about the principal axis thereof normal to its plane, means for supporting said disc within said chamber, a directional electroacoustic transducer means rigidly

mounted on said disc to face a direction substantially tangential to the circle formed thereby as the disc is rotated, and means for rotating said disc.

8. In an electronic organ having a main electric output channel, the combination comprising a soundproof chamber, a disc rotatable about the principal axis thereof normal to its plane, means for supporting said disc within said chamber, a directional electroacoustic transducer means rigidly mounted on said disc to face a direction substantially tangential to the circle formed thereby as the disc is rotated, means for rotating said disc, means for controlling the speed of said rotating means, means for diverting some of the electric organ output from the main channel into said transducer means to be translated into acoustic energy, a pick-up means adapted to receive said acoustic energy and transform it back into electric energy, and means for combining said electric energy and the undiverted portions in said main channel.

9. In an electronic organ having a main electric output channel, the combination comprising a soundproof reverberation chamber, a disc rotatable about the principal axis thereof normal to its plane, means for supporting said disc within said chamber, a directional electroacoustic transducer means rigidly mounted on said disc to face a direction substantially tangential to the circle formed thereby as the disc is rotated, means for rotating said disc, means for controlling the speed of said rotating means, means for diverting some of the electronic organ output from the main channel into said transducer means to be translated into acoustic energy, a pick-up means adapted to receive said acoustic energy and transform it back into electric energy, and means for combining said electric energy with the undiverted portion in said main channel.

10. The combination of claim 6 wherein the transducer means comprises a plurality of directional electro-acoustic transducers each rigidly mounted on said disc to face a direction substantially tangential to the circle formed thereby as the disc is rotated.

11. The combination of claim 7 wherein the transducer means comprises a plurality of directional electro-acoustic transducers each rigidly mounted on said disc to face a direction substantially tangential to the circle formed thereby as the disc is rotated.

12. The combination of claim 8 wherein the transducer means comprises a plurality of directional electro-acoustic transducers each rigidly mounted on said disc to face a direction substantially tangential to the circle formed thereby as the disc is rotated.

13. The combination of claim 9 wherein the transducer means comprises a plurality of directional electro-acoustic transducers each rigidly mounted on said disc to face a direction substantially tangential to the circle formed thereby as the disc is rotated.

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