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ELECTRICAL MUSICAL INSTRUMENT

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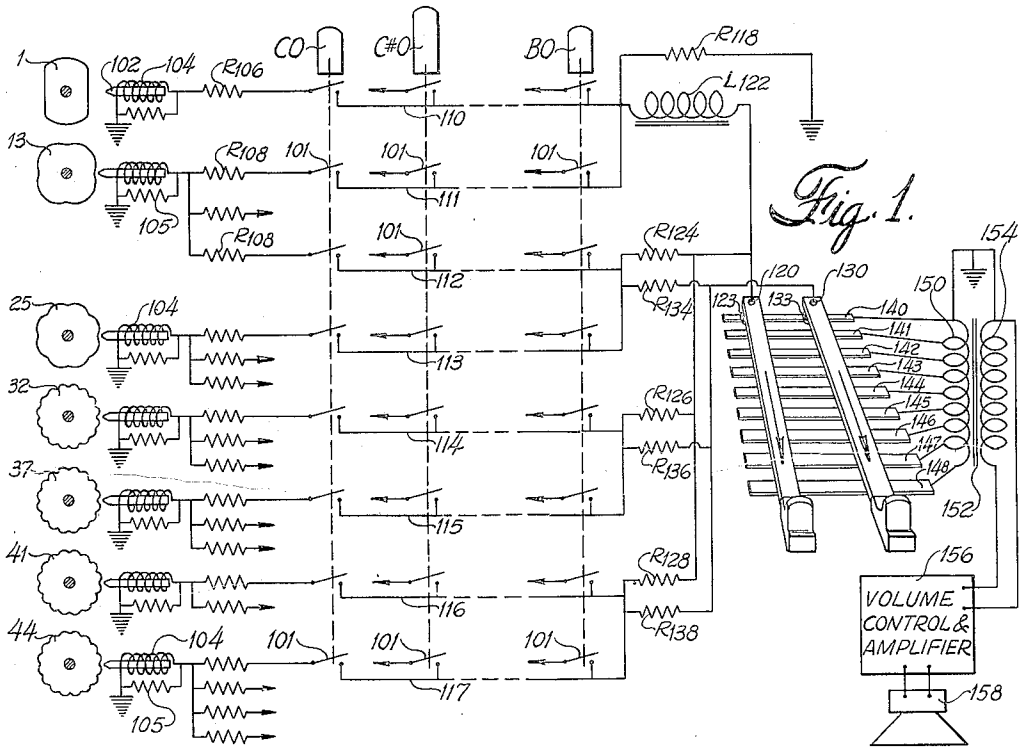


Fig. 1.

PEDAL NOTE DESIGNATION	ODD HARMONIC GENERATOR No.	FREQUENCY (f) OF FUNDAMENTAL - CPS	NUMBERS OF SINE WAVE GENERATORS					
			2f	4f	6f	8f	10f	12f
C0	1	32.692	13	25	32	37	41	44
C#0	2	34.634	14	26	33	38	42	45
D0	3	36.712	15	27	34	39	43	46
D#0	4	38.888	16	28	35	40	44	47
E0	5	41.194	17	29	36	41	45	48
F0	6	43.636	18	30	37	42	46	49
F#0	7	46.250	19	31	38	43	47	50
G0	8	49.000	—	32	39	44	48	51
G#0	9	51.891	—	33	40	45	49	52
A0	10	55.000	—	34	41	46	50	53
A#0	11	58.260	—	35	42	47	51	54
B	12	61.714	—	36	43	48	52	55

Fig. 2

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ELECTRICAL MUSICAL INSTRUMENT

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Our invention relates generally to electrical musical instruments and more particularly to an improved system and apparatus for generating electrical tone signals in the bass register.

In most musical instruments, the tones in the bass register are more highly developed harmonically than the tones in the treble register and listeners have become accustomed to expect such high harmonic development in bass tones, substantially irrespective of the source. In electrical musical instruments of the type described in Hammond Patent No. 1,956,350, wherein the tones are synthesized by combining sine-waves of the frequencies corresponding to the various partials of the tone there are certain mechanical and cost limitations which make it unfeasible to produce bass tones having more harmonic development than the tones in the middle pitch range of the instrument. In the manufacture of electric organs of the type disclosed in said Hammond patent, it has been found that it is desirable, in the pedal division of the organ, to provide independent 16ft. and 8ft. complex tones. It has also been found important to provide these two complex tones in octave coupler relations of various degrees of coupling intensity. The 16ft. coupler tone should provide a musically desirable series of partials consisting of fundamental and a complete and relatively long series of harmonics as high as the twelfth harmonic. Similarly, the 8ft. complex series, while it need not be as bright as a 16ft. series, should include at least the fundamental and the second, third, fourth, fifth, sixth, and eighth harmonics. If the method of synthetic build-up of tone quality were followed as disclosed in said Hammond patent, it would require a very large number of pedal contacts to meet the above requirements. Inasmuch as the tone quality, or harmonic structure, of the 16ft. and 8ft. tones ordinarily need not be altered, a system which involves the use of complex tone generators is indicated.

However, it is important to take into consideration the fact that the bass pedal tones may contain harmonic frequencies, particularly the second harmonics, which are the same as the frequencies of the fundamental of other tones which may be produced at the same time under control of keys of the manuals, and these same frequencies may be of comparable amplitude.

Therefore, if the second or other even order harmonics of the bass pedal tones were derived from a different source than for the tones controlled by the manuals, serious cancellation effects would frequently occur unless elaborate and

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costly apparatus were provided for accurately maintaining these generators in phase, to insure phase addition. On the other hand, hidden in the practical playing of musical compositions, the above mentioned phase problem would not be present to any great extent with respect to the odd harmonics of the bass pedal tones. This is because the intensity of the third harmonic in the pedal tones is relatively low and also because the simultaneous playing of this frequency under the control of the manual keys is relatively infrequent.

It is therefore one of the primary objects of this invention to provide an improved bass tone generating system in which these phasing problems are not present. This is accomplished by having the bass generating system for the lower bass pedal controlled tones provide complex tones composed of the fundamental and odd harmonic series and having the other generating system provide individual sinusoidal even harmonic frequencies for the bass tone, and also for the synthesizing of the tones which are controlled by the manuals, in the manner described in the aforesaid Hammond patent. By this means a single contact under each of the bass pedals may be effective to switch the entire odd harmonic series for the 16ft. bass pedal tones, which results in economy when the pedal switch is used to provide both a complex 16ft. and an 8ft. series. It is however desirable to have the musical instrument adjustable to provide complex 16ft. and 8ft. pedal tones at will, in any desired octave coupler combination, and it is therefore one of the fundamental objects of our invention to provide an electrical musical instrument having a bass tone generating system which without increasing the number of key operated switches or generators makes it possible to produce such bass tones. If the bass tone wheels generated signals which included the even harmonics such partials would very likely not be in phase with the same frequencies produced by the octavely related generators and thus there would be a partial or complete cancellation of the even harmonics whenever the bass note was played with a note an octave or two octaves higher in the scale. This would occur very frequently in the rendition of organ music, and it is therefore a further object of the invention to avoid such cancellation effects.

A further object of our invention is to provide an electrical musical instrument having a bass tone generating and control apparatus which may be utilized to produce complex tones in the 8ft. or 16ft. register, or both, at the will of the player.

Other objects will appear from the following description reference being had to the accompanying drawings, in which:

Fig. 1 is a circuit diagram of representative parts of the bass pedal generators, key operated switches and harmonic control apparatus of the invention; and

Fig. 2 is a chart tabulating the connections to the switches operated by the pedals of the lowest octave.

Referring to Fig. 1, there is illustrated a plurality of phonic wheel generators 1, 13, 25, 32, 37, 41, and 44. These generators are driven by a synchronous motor through a suitable resilient and frictional driving gearing preferably of the type fully disclosed in the aforesaid Patent No. 1,956,350. The tone wheels above enumerated, except for tone wheel 1, are of the type disclosed in said patent, their peripheries being conformed so as to generate substantially sine-wave frequencies. The tone wheels of generators 1 to 12 are of different conformation, having two diametrically opposite parallel flat sides, the remainder of the periphery being circular. This type of tone wheel generates a complex tone comprising a fundamental (f), and a series of odd harmonics of progressively decreasing amplitude, namely, 1/3 (3f), 1/5 (5f), 1/7 (7f), 1/9 (9f), 1/11 (11f), etc. The harmonics above the 11th, although detectable, do not add much to the characterization of the tone quality. The particular shape of the tone wheel 1 is chosen because of its simplicity and low cost and although it does generate some even harmonics, these are of such low amplitude as not to have a serious cancellation effect with respect to the same frequencies provided by the sine-wave generating tone wheels. Each of the tone generators 1 to 12 is thus capable of supplying six frequencies which are of appreciable value in rendering the tone more complex.

Although only 7 tone wheels are illustrated in Fig. 1, it will be understood that the instrument may include as many as 91 tone wheels, a number of which, even though not illustrated in Fig. 1, have their reference characters included in the chart of Fig. 2. These reference characters, except for the tone wheels 1 to 12, correspond to those which are used to identify the tone wheels in said prior Patent No. 1,956,350 and operate in the same manner as described in said patent to generate substantially sine-wave frequencies corresponding closely or exactly to the semi-tone frequencies of the tempered musical scale (A= 440).

In Fig. 1, there are illustrated three pedals CO, C#O, and BO representative of the lowest octave of pedals of the pedal clavier, the reference characters also indicating the pitch of the tones capable of being controlled by these pedals.

Each of the pedals is arranged, upon depression, to close eight switches 101. Each of the generators includes a permanent magnet 102, having a wedge shaped point terminating adjacent the periphery of its associated tone wheel, each magnet being wound with a pickup coil 104, shunted by a loading resistor 105, one end of each coil 104 and resistor 15 being connected to ground and the other end of which is connected to one or more of the switches 101 through decoupling or "non-robbing" resistors R106, or R108.

Each of the pickup coils for the tone wheels 13 to 19 is connected through parallel resistors

R108 respectively to two of the switches 101 of the pedals CO to F#O respectively, while the pickup coils for tone wheels 20 to 24 are respectively connected through resistors R108 to only one switch 101 of each of the pedals GO to BO. The switches 101 which are connected to the generators having tone wheels 1 to 12 inclusive are respectively operated by the pedals CO to BO to connect these generators to a bus-bar 110. In a similar manner the switches 101 connected to the generators having tone wheels 13 to 19 are adapted to be connected to bus-bars 111 and 112 upon operation and their associated switches 101, and the generators having tone wheels 25 to 36, which represent the 4th harmonic are adapted to be connected by switches 101 to bus-bars 113. Bus-bars 114 to 117 are similarly adapted to receive the signals from the appropriate generators for the 6th, 8th, 10th and 12th harmonics upon the closure of the appropriate switches 101. The nature of the connections is indicated in the chart, Fig. 2.

Bus-bars 110 and 111 are connected together and are connected to ground through a resistor R118 which may be of value in the order of 10 ohms, and are also connected to a contactor 123 mounted on a 16ft. drawbar 120 through an inductance L122 which operates as a filter greatly to attenuate the transient high frequencies present upon closure or opening of the switches 101, and eliminates, or at least greatly attenuates, the noise usually referred to as "key click."

In addition the contact 123 of drawbar 120 is connected to bus-bars 112 and 113 by a resistor R124 which may have a value in the order of 10 ohms, is connected to bus-bars 114 and 115 by a resistor R126 of a value such as 50 ohms, and is connected to bus-bars 116 and 117 through a resistor R128 of a value such as 300 ohms. An 8ft. drawbar 130 has its contactor 133 connected to bus-bars 112 and 113 through a resistor R134, of value in the order of 5 ohms, is connected to bus-bars 114 and 115 by a resistor R136, of about 5 ohms, and is connected to bus-bars 116 and 117 through resistor R138, which may have a value of about 20 ohms.

The drawbar contactors 123 and 133 are adapted to make contact with collector bars 140—148, being manually adjusted to the desired position. These collector bars 140—148 are respectively connected to taps on the primary winding 150 of a transformer 152, the taps being spaced in logarithmic gradations so that as each of the drawbars is pulled outwardly, step by step, the tone sounded will be perceived as increasing in intensity in approximately equal steps. The terminal of the transformer primary 150 which is connected to the collector bar 140 is connected to ground as is the corresponding end of the secondary winding 154 of this transformer. This secondary winding is suitably coupled to volume control apparatus and an amplifier 156, which in turn is coupled to a speaker 158.

From the foregoing, it will appear that upon depression of any of the pedals CO to BO its eight switches 101 will be closed and the fundamental and odd harmonic series generated by one of the tone wheels 1 to 12 will be impressed on the 16ft. drawbar contact 123 and will be transmitted to the output system of the instrument in an amplitude dependent upon the position of this drawbar. A portion of the output of the second harmonic tone generator 13—19 will be transmitted with the odd harmonic series by virtue of the connection of bus-bars 110 and

111. In addition, some of the second and fourth harmonic frequencies will be impressed upon the drawbar contact 123 through R124; some of the sixth and eighth harmonic frequencies will be impressed on the contact 123 due to its connection with bus-bars 114 and 115 through R126; and some of the tenth and twelfth harmonic frequencies will similarly be impressed due to the connection of bus-bars 116 and 117 to the contactor 123 through R128.

It will be noted that only the second, fourth, sixth, eighth, tenth and twelfth harmonics of the fundamental pitch represented by the pedal depressed will be supplied to the 8ft. drawbar contactor 133 due to its connection with bus-bars 112 and 113 through R134, its connection with bus-bars 114 and 115 through R136 and its connection with bus-bars 116 and 117 through R138. It will be noted that these even harmonics of the fundamental pitch correspond to the first six harmonics of a tone having a fundamental pitch one octave higher than the nominal pitch of the depressed pedal. The drawbar 130 thus performs the function of an octave coupler in which the intensity of the octave tone relative to that of the fundamental pitch may be varied at will by selective positioning of the drawbars 120 and 130.

The generators 13 to 91 are used not only to provide the even harmonics for the lowest octave of bass tones but are also used to supply the necessary sine-wave frequencies for the manuals and for the pedals above the lowest octave, all as more fully disclosed in said Patent 1,956,350.

In the chart of Fig. 2 the first column sets forth the reference characters of the pedals which correspond also to their musical pitch designation. The second column shows the reference characters of the tone wheels providing the fundamental and odd harmonic series which are connected to the output system upon depression of the pedals. The third column sets forth the frequencies, in cycles per second, of the generators having tone wheels 1 to 12 respectively, while the fourth to the ninth columns set forth the numbers of the tone wheel generators which supply the second, fourth, sixth, eighth, tenth and twelfth harmonics, respectively. This chart thus provides the information necessary for making the wiring connections between the generators and the switches operated by the lowest octave of pedals.

It will be understood that the generators 13 to 55, in addition to supplying even harmonics for the lowest octave of bass tones, are also used to supply the substantially sine-wave signals utilized in the remaining bass pedal controlled tones and in the tones controlled by keys of the manuals.

From the foregoing, it will be apparent that a large number of harmonically related frequencies may be transmitted to the output of the instrument upon the depression of a single key having a smaller number of key switches and key switch completed circuits. The instrument is thus capable of producing much more pleasing bass tones without substantially increasing the cost of production, as compared with the instrument disclosed in said Patent No. 1,956,350.

While we have shown and described a particular embodiment of our invention, it will be apparent to those skilled in the art that numerous modifications and variations may be made in the form and construction thereof, without departing from the more fundamental principles of the invention. We therefore desire, by the following claims, to include within the scope of our invention all such similar and modified forms of the apparatus disclosed, by which substantially the results of the invention may be obtained by substantially the same or equivalent means.

We claim:

1. In an electrical musical instrument having an output system and having a plurality of bass tone controlling pedals, a plurality of generators of electrical tone signals for the bass tones, each of the tone signals comprising the fundamental frequency and predominantly a plurality of odd harmonics thereof, a plurality of producers of substantially sine-wave electrical signals of frequencies corresponding to the even harmonics of the tone signals provided by said generators, and a switching means individual to and operated by each of the pedals substantially simultaneously to connect to the output system a generator of the fundamental and its odd harmonics together with the producers of a plurality of even harmonic sine-wave signals.

2. In an electrical musical instrument having an output system, the combination of a plurality of electrical generators for the bass tone signals, each generator generating signals comprising the fundamental and a relatively long series of odd harmonic frequencies, a set of electrical tone signal producers respectively producing signals of frequencies corresponding to the even harmonics of the tones produced by the odd harmonic generators, and selectively operable means for simultaneously connecting a predetermined generator and a plurality of harmonically related tone signal producers to the output system.

3. In an electrical musical instrument having a plurality of bass pedals, the combination of a plurality of generators of bass pedal frequency signals each including the fundamental frequency and predominantly a plurality of the odd harmonics thereof, a plurality of electrical sine-wave tone signal producers respectively generating sine-wave signals corresponding in frequency to the even harmonics of the tone signals generated by the generators of the bass pedal frequency signals, a bus-bar for collecting the fundamental and odd harmonic frequency signals, bus-bars respectively for collecting the even harmonic frequencies, an output system having a plurality of input terminals, the intensity of the signal in the output system being determined by the terminals across which the signal is supplied to the output system, a plurality of switching devices adjustably to connect the bus-bars to said terminals, impedance devices respectively connecting the bus-bar receiving the fundamental and odd harmonic frequencies and certain of the even harmonic frequencies to one of the switching devices, said impedances being of graded value so as to attenuate to an increasing extent the even harmonics of higher frequencies, and a second group of impedances connecting only the bus-bars receiving the even harmonics to a second switching device, said impedances likewise attenuating to an increasing extent the higher harmonic frequencies.

4. In an electrical musical instrument having an output system provided with a plurality of input terminals for the reception of electrical tone signals, the particular terminals across which a tone signal is supplied determining the intensity of the tone produced by such signal, the combination of a plurality of bass tone elec-

trical signal generators, each generating a signal comprising a fundamental frequency and a long series of its odd harmonic frequencies, a plurality of substantially sine-wave electrical tone signal generators generating a plurality of the even harmonic frequencies for the bass tones, a plurality of bus-bars, means including playing key operated switches and decoupling resistors for selectively impressing signals produced by said fundamental and odd harmonic generators upon one of said bus-bars and impressing signals produced by the even harmonic generators on others of said bus-bars, and a pair of selectively operable switching devices for connecting the bus-bars to any one of the input terminals of the output system, one of the switching devices being connected to the bus-bars receiving the fundamental and odd harmonic frequencies, and to the bus-bars receiving certain of the even harmonics, and the other of said devices being connected to bus-bars receiving only even harmonics, each of the connections from the last named bus-bars to the switching device including a decoupling impedance.

5. In an electrical musical instrument having an output system provided with a plurality of input terminals for the reception of electrical tone signals, the particular terminals across which a tone signal is supplied determining the intensity of the tone produced by such signal, the combination of a plurality of base tone electrical signal generators, each generating a signal comprising a fundamental frequency and a long

series of its odd harmonic frequencies, a plurality of substantially sine-wave electrical tone signal generators generating a plurality of the even harmonic frequencies for the bass tones, a plurality of bus-bars, means including playing key operated switches and decoupling resistors for selectively impressing signals produced by said fundamental and odd harmonic generators upon one of said bus-bars and impressing signals produced by the even harmonic generators on others of said bus-bars, a pair of selectively operable switching devices for connecting the bus-bars to any one of the input terminals of the output system, a relatively low impedance connecting one of the switching devices to the bus-bar receiving the fundamental and odd harmonic frequencies, decoupling impedances connecting the other bus-bars to the same switching device, and other relatively lower impedances connecting only said other bus-bars to the other of said switching devices.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,956,350	Hammond	Apr. 24, 1934
2,142,580	Williams	Jan. 3, 1939