

[54] **HARMONIC SYNTHESIS ORGAN SYSTEM**

[76] Inventor: **Richard H. Peterson**, 11748 Walnut Ridge Dr., Palos Park, Ill. 60464

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[58] Field of Search. 84/1.01, 1.17, 1.18, 84/1.19, 1.21, 1.23, DIG. 22, 1.11, 1.22

[56] **References Cited**

UNITED STATES PATENTS

1,213,804	1/1917	Cahill.....	84/1.17
3,309,454	3/1967	Cutler et al.....	84/1.18

Primary Examiner—Lewis H. Myers

Assistant Examiner—Stanley J. Witkowski

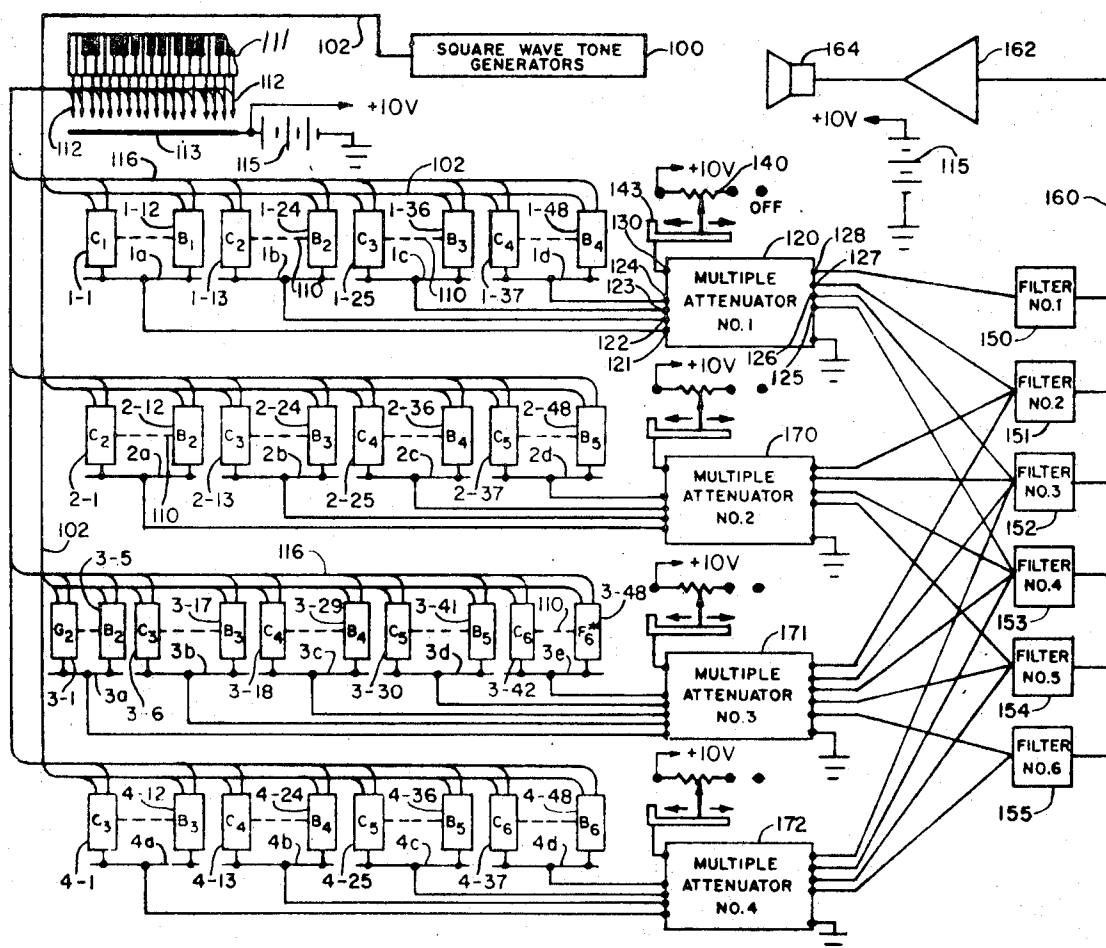
Attorney—Harris C. Lockwood

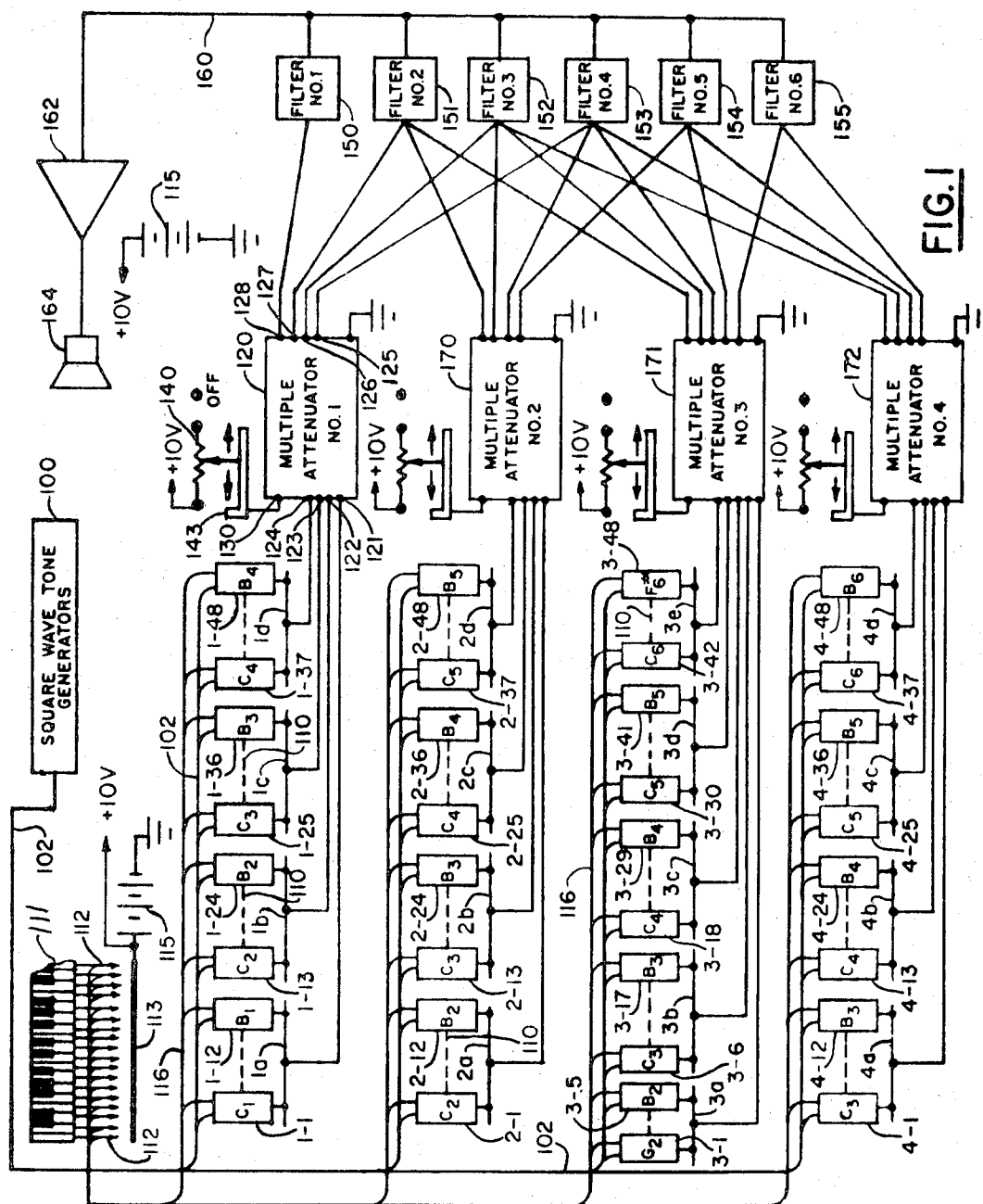
[57] **ABSTRACT**

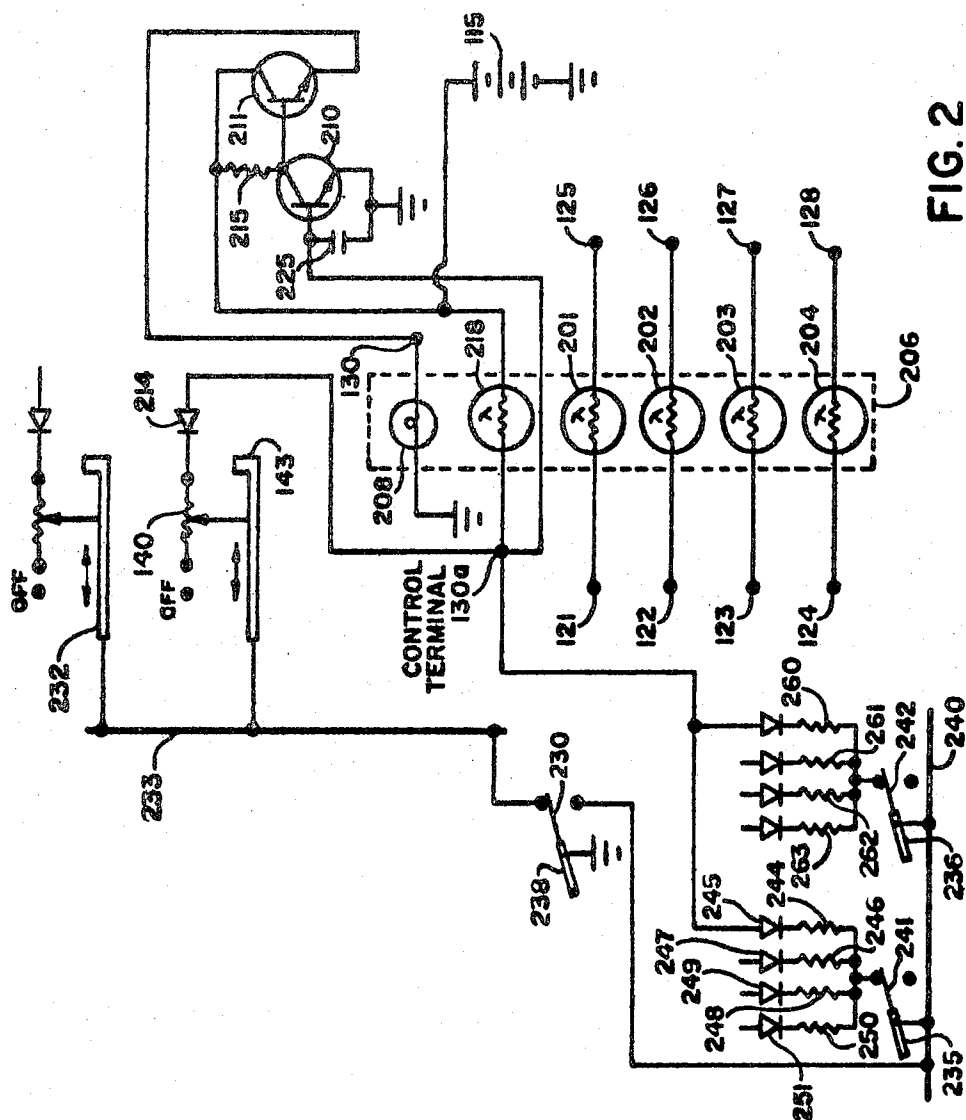
A harmonic synthesis organ in which a complex wave

tone generator generates signals corresponding to the frequencies of the fundamentals and harmonic partials. The complex tones are gated and are collected on a plurality of headers, each header corresponding to a particular harmonic partial. The headers are subdivided into groups of approximately one octave of contiguous tones and the groups are individually attenuated by a multiple attenuator controlled by a control element which may be a manually operated draw bar. The outputs of the attenuators are connected to sharp cut off filters which remove all of the natural harmonics from the complex waves, and pass to the amplifier sine waves corresponding to the various partials. A preferred multiple attenuator system employs a plurality of photo resistors associated with a lamp, the intensity of which is controlled by a related draw bar. A lamp control circuit is provided to improve the responsiveness of the lamp to changes in draw bar position. Additional stop control means are provided for controlling the attenuators from either draw bars or from an alternate control system. In the embodiments shown, only a single key contact is associated with each playing key of the organ.

3 Claims, 2 Drawing Figures







HARMONIC SYNTHESIS ORGAN SYSTEM

SUMMARY OF THE INVENTION

This invention relates to an electronic musical instrument of the harmonic synthesis type. Harmonic synthesis organs differ from so called formant organs in that all of the tone frequencies reproduced by the output system are sine waves rather than complex waves having natural harmonics. Typically in harmonic synthesis organs, control means are provided whereby sine waves corresponding to fundamentals and to a plurality of harmonic partials may be selectively combined in different amplitudes to synthesize complex tones. An early tone synthesis organ is described in the patent to Thadus Cahill, U. S. Pat. No. 1,213,804 issued Jan. 23, 1917. A more highly developed form of the instrument that has enjoyed wide commercial acceptance is based on the patent issued to Laurens Hammond, U.S. Pat. No. 1,956,350 dated Apr. 24, 1934.

The present invention relates to an improved harmonic synthesis organ in which all of the fundamental and harmonic partial frequencies are derived from complex wave electrical tone generators. Square wave tone generators are economical to manufacture and square waves are easily gated, or keyed, by low cost gating systems. There are important advantages, therefore, in being able to use this type of tone generator in a harmonic synthesis organ. In the present invention means are provided for generating a series of square waves having fundamental frequencies corresponding to the notes of a musical scale over a range of several octaves. A series of gates equal in number to the number of keys is provided for each fundamental or partial which may be desired. Typically, a keyboard may be associated with from four to nine or more sets of gates, with corresponding gates in each set controlled from a single key contact associated with each playing key. Signals from the outputs of the gating circuits are collected on a series of headers, each header collecting frequencies corresponding to the fundamental frequency, or to one of the partial frequencies, of whatever keys are played. The headers are subdivided into groups of twelve or less adjacent semi-tone frequencies. A multiple section attenuator is provided for each header and includes as many sections as there are octaves of notes. The attenuator passes a selected portion of the signals appearing on the header to a system of sharp cut off filters which change the square waves into sine waves by sharply attenuating all frequencies above the fundamental frequency of the highest note in the group.

A preferred multiple attenuator system employs a photo resistor for each section; the plurality of photo resistors being associated with a single lamp whose intensity is varied by the control device which may be of the draw bar type as disclosed in the aforementioned Hammond patent. Alternate and/or additional means are provided for controlling the attenuators from conventional stop tablets or from combination pistons.

It is the primary object of the invention to provide an improved electronic organ of the harmonic synthesis type.

Another object of the invention is to provide an instrument of the character described in which all of the signals are generated and gated as square waves and are subsequently changed to sine waves, or near sine waves, before being transduced to sound.

Another object of the invention is to provide an instrument in which control of the harmonic partials is by means of photo electric attenuating circuits employing "draw bar" control.

It is another object of the invention to provide means for controlling the variable attenuator by either draw bars or alternately by stop tablets or combination pistons.

Still another object of the invention is to provide an improved photo electric attenuator in which the response to changes in adjustment are relatively instantaneous.

It is a further object of the invention to provide a harmonic synthesis organ wherein only a single switch contact is required for each playing key of the instrument.

These and other objects of the invention will become apparent from the detailed description which follows. In the accompanying drawings:

FIG. 1 is a block diagram of an organ according to the invention, and

FIG. 2 is a schematic circuit diagram of an attenuator and a control system suitable for use with the system of FIG. 1.

Referring first to FIG. 1, 100 is a square wave tone generating system which includes a separate square wave generator, or frequency divider, for each note of the musical scale over a range of several octaves. Connected to the tone generators are a plurality of sets of gates for gating the various partial frequencies of a tone to be synthesized. 1 — 1 through 1 — 48 are a set of gates for gating the fundamental components of tones to be produced. To avoid needless complication of the drawing, not all of the gates are shown; it being understood that the dotted lines 110 indicate a series of gates starting and ending with those shown. A second set of gates 2 — 1 through 2 — 48 are for the purpose of gating signals corresponding to the second harmonic partial of the tones to be produced, and in like manner, gates 3 — 1 through 3 — 48 and gates 4 — 1 through 4 — 48 are for the purpose of gating the third and fourth partials respectively. In many cases, more than four sets of gates are employed, nine being a typical number. The input of each individual gate is connected to an appropriate output terminal of the square wave tone generating system by way of cable 102. Each gate that is shown is identified with the name of the note, and with the octave number, of the generator to which it is connected. A keyboard 111, which may be one of several in an actual instrument, has a single contact key switch 112 associated with each playing key. Upon depression of any key its respective contact is pressed into contact with the bus bar 113 which is connected to a source of gate energizing potential 115. 116 represents a connecting cable connecting each key contact to a respective gate in each of the sets of gates. Thus key contact 112 — 1 is connected to gates 1 — 1, 2 — 1, 3 — 1, and 4 — 1. Each set of gates is connected to an output header which is subdivided into octave group headers; each octave group header collecting the gated signals from 12 gates, except in the case of the third harmonic partial, where in some cases less gates are associated with some of the group headers. As an example, when key 111 — 1 is depressed, contact 112 — 1 energizes gates 1 — 1, 2 — 1, 3 — 1, and 4 — 1, and each of these gates connects an appropriate signal from the tone generator to its respective octave header 1a, 2a, 3a or 4a. In like manner, any key that is depressed will cause output signals to

appear on one of the octave headers associated with each set of gates. The signals appearing on any header will be square waves having fundamental frequencies corresponding to the frequency of a particular partial. Thus, signals having fundamental frequencies corresponding to the fundamental partial of a tone to be produced are collected on octave headers labeled 1a, 1b, 1c, and 1d. Signals having fundamental frequencies corresponding to the second harmonic partial are collected on headers 2a, 2b, 2c and 2d, and signals having fundamental frequencies corresponding to the third harmonic partial are collected on headers 3a, 3b, 3c, 3d, and 3e. Finally, signals having fundamental frequencies corresponding to the fourth partial are collected on headers 4a, 4b, 4c, and 4d.

Associated with each header is a multiple section attenuator such as multiple attenuator number 1 shown at 120, which has input terminals 121, 122, 123, and 124 connected respectively to the octave group headers 1a, 1b, 1c, and 1d. Each input terminal has a corresponding output terminal 125, 126, 127, 128. Also connected to each multiple section attenuator is a control terminal 130, the potential of which determines the attenuation of signals transmitted between the respective input and output terminals. 140 is an adjustable resistor connected to the source of potential 115 and to the draw bar 143. The attenuation between the respective input and output terminals is determined by the setting of the draw bar 143. Multiple attenuator number 1 thus controls the amplitude of the fundamental component of a tone to be synthesized. Multiple attenuators number 2, number 3 and number 4 in like manner control the amplitude of the second, third and fourth partials.

150 is a filter designed to sharply attenuate frequencies above its pass band of approximately 65 hz to 130 hz. Filters 151, 152 153, 154 and 155 are similar but are designed to pass bands of 130 hz to 260 hz, 260 hz to 520 hz, 520 hz to 1,040 hz, 1,040 hz to 2,080 hz, and 2,080 hz to 4,160 hz, respectively. The outputs of all of the filters are connected via conductor 160 to the output system including amplifier 162 and loudspeaker 164.

Referring now to FIG. 2, photo resistors 201, 202, 203, and 204 are cadmium sulphide or other photo resistive cells whose resistance is a function of the light intensity falling upon them. Each cell has an input terminal and an output terminal and the cells shown have their input and output terminals numbered to correspond to the numbers shown on FIG. 1, in connection with attenuator 120. All of the cells are enclosed in a common light tight enclosure 206 and are arranged to be illuminated by the lamp 208. Voltage applied to terminal 130 controls the brightness of the lamp. By varying the potential of terminal 130 the brightness of lamp 208 is varied, and accordingly the impedance of all of the photo resistors is varied. However, if the voltage to the lamp is controlled by a simple variable resistor as shown in FIG. 1, the response of the resistance of the photo resistors to changes in voltage applied to terminal 130 is very sluggish due to the thermal inertial of the lamp and to the intrinsic time constants of the photo resistors. To overcome this very serious objection, the lamp is arranged to be controlled by an "accelerator" circuit consisting of transistors 210 and 211, resistor 215, and photo resistor 218 which is enclosed in the same light tight enclosure 206 as are the other photo resistors 201 through 204. A manually operated

draw bar 143 adjusts the resistance of resistance element 140. The photo resistor 218 is connected between the source of potential 115 and the base of transistor 210. The emitter of transistor 210 is grounded, and the collector is connected to the source of potential 115 through resistor 215 which may have a value in the order of 10,000 ohms. Transistor 210 is a very high gain amplifier that also operates as a switch. In the absence of base-emitter current the transistor is switched "off" and its collector voltage will equal the potential of source 115. With a relatively small amount of base emitter-current the transistor saturates, and its collector voltage will be substantially zero. Transistor 211 is an emitter follower. It includes the lamp 208 in its emitter circuit and couples the potential on the collector of transistor 210 to the lamp.

The operation of the circuit is as follows. With draw bar 143 set in any given position, a portion of the resistance of control element 140 is placed between the base of transistor 210 and ground. This switches transistor 210 to its off state, permitting its collector voltage to rise; thus placing the full potential of 115 on the base of transistor 211, and also on the emitter of transistor 211, and therefore on the lamp 208. But as lamp 208 lights and shines upon photoresistor 218, its resistance drops until transistor 210 becomes saturated, at which time voltage to lamp 208 is cut off. When this happens lamp 208 begins to go out, causing the resistance of photo resistor 218 to again begin to increase until its value becomes such that transistor 210 again is switched off and the lamp again receives the full voltage of the power source 215. Actually, because of the time constant of capacitor 225 and the inherent time constants of the lamp and photo resistor, an equilibrium is almost instantly established where transistor 210 is partially switched on, and the photo resistor 218 assumes a stable resistance value. At equilibrium the resistance of the cell is determined almost completely by the value of control element 140 and is almost completely independent of the supply potential or of photo cell characteristics.

If the value of resistor 140 is changed by moving the position of the draw bar 143, a new equilibrium will immediately be established at a different lamp brilliance and at a different photo cell impedance. If photo resistors 201 through 204 have the same characteristics as photo resistor 218 it is apparent that the resistance of each of the other photo cells will essentially "follow" the resistance of photo resistor 218. If draw bar 143 is set in its off position, resistor 140 is open circuited and the lamp 208 will go out and the resistance of all of the photo resistors will assume a very high resistance equivalent for practical purposes to an open circuit.

232 is another draw bar associated with one of the other attenuators 170, 171, or 172, and it is connected to the bus bar 233 which is common to all of the draw bars. 235 and 236 are stop tablets which, if desired, can be used instead of the draw bars, to control the attenuators. 238 is a stop tablet, thumb piston, or similar device for switching between draw bar and stop tablet control by grounding either bus bar 233 associated with the draw bars, or bus bar 240 connected to the stop tablets.

Tablet 235 operates stop switch 241 that when turned "on" connects resistor 244 and diode 245 between attenuator control terminal 130a and ground, adjusting the level of one of the partials as determined

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by the value of resistor 244. Resistor diode combinations 246 - 247, 248 - 249, and 250 - 251, connect to the control terminals 130a of the other attenuators, allowing a single stop tablet to control the attenuators associated with the several partials.

Tablet 236 operates in the same manner, but resistors 260 through 263 ordinarily have different values than resistors 244, 246, 248 and 250 and thus adjust the partials to different levels. If a plurality of tablets are used simultaneously the tonal effects are additive.

Others may readily adapt the invention for use under various conditions of service by employing one or more of the novel features disclosed, or equivalents thereof. For example, where stop tablets have been disclosed it is obvious that other control devices such as combination pistons, or preset keys would be fully equivalent. It is also obvious for example, that simple wiring changes would permit the simultaneous use of tablet and draw bars. The terms gate and gating system, as used herein, are intended to include any means for "gating" or "switching" signals from the tone generators to the tone collecting bus bars. As at present advised with respect to the apparent scope of my invention I desire to claim the following subject matter.

I claim:

1. An organ of the harmonic synthesis type comprising: a series of tone generators for producing complex wave tone signals corresponding to the notes of a musical scale over a range of several octaves; a keyboard; a gating system comprised of a plurality of sets of gates, each set including a separate gate connected to each

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key and to a specific tone generator; a first tone collecting header, divided into group headers of approximately twelve notes, for collecting from one of said sets of gates each wave output signals corresponding in fundamental frequency to the fundamental frequencies of any notes played on said keyboard; a plurality of additional tone collecting headers, each divided into group headers of approximately twelve notes, and each connected to collect from a different set of gates complex wave signals corresponding in fundamental frequency to the frequency of a selected harmonic partial of any notes played on said keyboard; a plurality of multiple section attenuators, one for each tone collecting header, and each having a variable impedance element for each of said group headers; a plurality of sharp cut off filters are adapted to pass a band of frequencies approximately one octave wide and to attenuate sharply all frequencies above its pass band; and means connecting each said variable impedance elements between one group header and one of said sharp cut off filters.

2. The combination set forth in claim 1 in which each multiple section attenuator includes a plurality of respectively related input and output terminals; and unitary control means for simultaneously varying the transmission of signals between the said respective input and output terminals.

3. The combination set forth in claim 2 in which the unitary control means includes a terminal the potential of which determines the amplitude of signals transmitted between the respective input and output terminals.

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