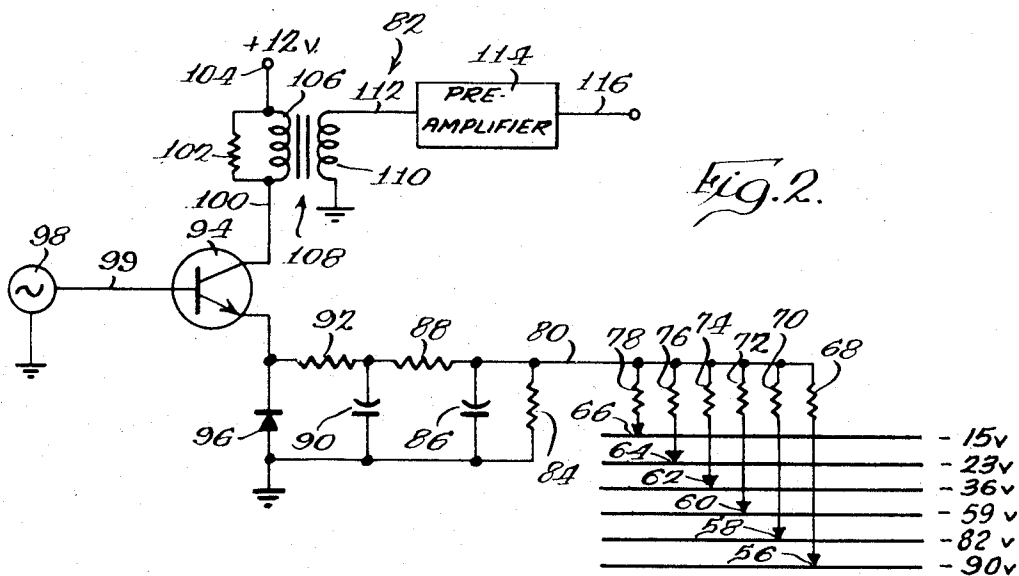


R. B. SCHRECONGOST ET AL

ELECTRIC ORGAN AND PROPORTIONAL KEYING SYSTEM THEREFOR

Sheet 1 of 2



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April 22, 1969

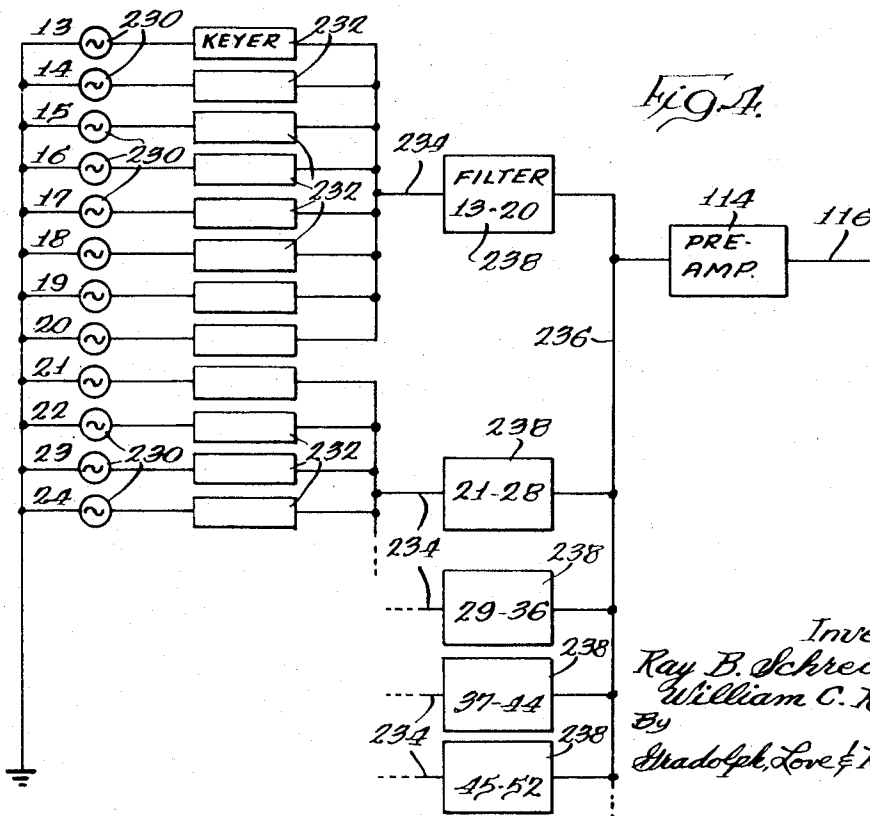
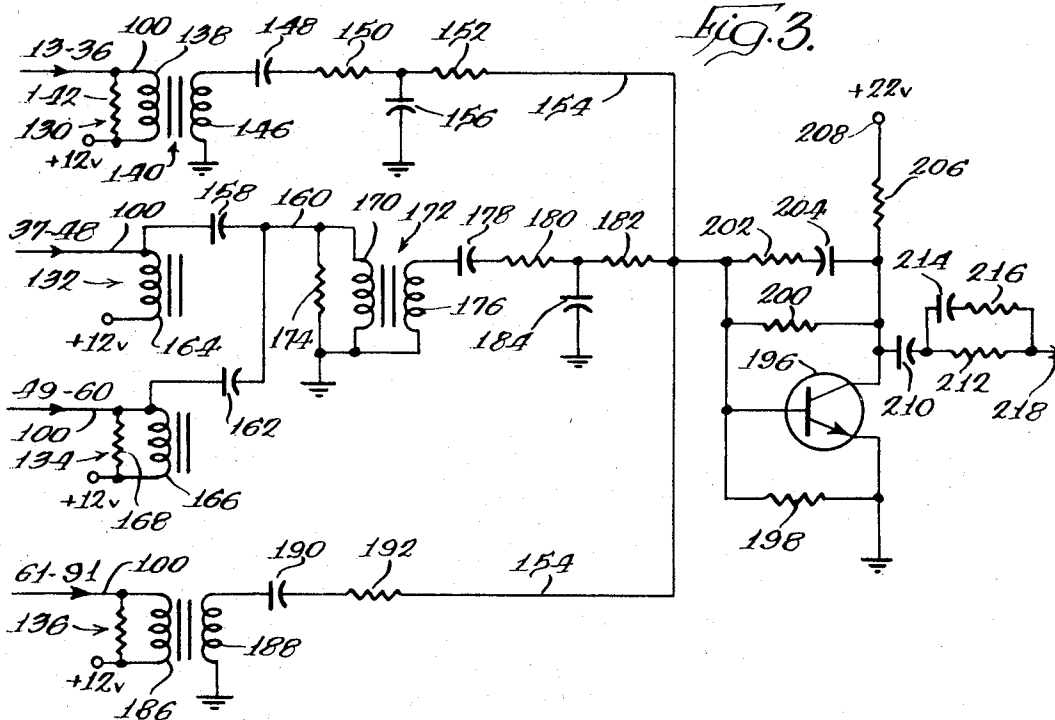
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Filed Oct. 1, 1965

Sheet 2 of 2



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3,440,324

ELECTRIC ORGAN AND PROPORTIONAL KEYING SYSTEM THEREFOR

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9 Claims

ABSTRACT OF THE DISCLOSURE

A synthesis type organ in which the individual tone generators are connected to the output through proportional keyers and in which the conduction or gain through the keyers depends upon the potential applied thereto. The keyer potential depends in turn upon the additive voltage effect of the combinations of playing keys simultaneously actuated, each of the playing keys having multiple contact connections to various voltage buses which when keys are actuated contribute additively to the instantaneous keyer voltages.

This invention relates to electric organs operating upon the synthesis principle, and particularly to an arrangement for D.C. keying a multiplicity of tone signal sources, each upon a proportional basis, so as to achieve a properly balanced output from the several generators that may be called upon simultaneously according to the instantaneous requirements of the musician.

By way of introduction, it should be understood that the usual synthesis organ provides a group of sine wave generators, one for each note to be sounded throughout the range of the instrument, plus some additional generators to provide overtone structure above the fundamental limit of the keyboard. As a refinement it is also possible to provide still additional generators to supply certain harmonics—such as the seventh, for instance—which may not be provided by the basic group of generators. Whether such refinements are use is immaterial to the present invention, since it is the basic organization that is of concern.

For those unfamiliar with the synthesis approach to organ design, such as is fully described in Patent No. 1,956,350, issued in the name of Laurens Hammond, it may be stated that, briefly, the principle is to have each playing key operate a rather large number of contacts—nine, for instance—individually against an equal number of bus bars. One of these bus bars is representative of the tone fundamental; another the second harmonic; a third, the third harmonic, and so on. Similarly, the appropriate key contacts are connected to the appropriate generators supplying the fundamental, the second harmonic, and so on, for the particular key. Thus, the key for international A, for instance, will have its fundamental contact connected to the generator supplying a frequency of 440 c.p.s., its second harmonic contact connected to the 880 c.p.s. generator, its third harmonic contact connected to the generator for 1320 c.p.s., and so on. Whenever a key is played, therefore, each of the bus bars will have appropriate tone signals applied thereto, such that collectively the bus bars contain the fundamentals, and each of the desired harmonics of all of the keys being held down. To complete the system, the various bus bars are connected to the output system by taps arranged across a resistor mesh or across a transformer primary, so that by adjusting the individual bus bar connections to any one of the several taps, the relative strength of the fundamental and any of its harmonics in the output can be whatever is desired.

Although usually in such a system the generators are of the sine wave type, this is, of course, not necessarily basic to the system.

It is important to understand that in a system of this character, the output of any single generator may appear, depending upon the key or keys being played, and upon the harmonic mixture desired, as a strong fundamental for one note, a less strong second harmonic of another, a still weaker third or fifth of a third, and so on. The output of a single generator will appear as a mixture of several of these effects if more than one key is played simultaneously, as will usually be true, and thus at any instant the mixture in the output may include several contributions of various effectiveness from the same generator leading to the output over multiple paths. In the system described in the previously mentioned Hammond patent the scheme used is comparatively straightforward in that the signals from the generators pass through multiple contacts to the various bus bars. This arrangement is commonly called AC keying, since the contacts make and break the AC signal circuits.

AC keying has several basic deficiencies that are difficult to suppress or eliminate, such as the development of keying transients, the low signal voltage at the key contacts if low impedance generators are used, or the problems with cross-talk between the signal circuits if the generators have high impedance, and so on.

A more advantageous type of system generally is known as DC keying. With this approach, actuation of the playing keys makes and breaks a plurality of DC circuits at a voltage which can be selected so as to be more compatible with keying requirements, and the DC circuits are then used to control individual gate or equivalent circuits for the generators. Thus, there are no AC signals at the key contacts, and the characteristics of the gates can be selected so that transients do not develop in the tone signals.

The difficulty is that DC keying does not lend itself well to the synthesis principle and has not, so far as is known, been used in practice. The principal reason for this is that in an ordinary electronic organ, operating on the format principle, it is necessary only to have one keying circuit for each of the generators, since the generators each supply a mixed signal of high harmonic content, whereas applying the same keying circuits to a synthesis organ would require a keying circuit for each generator times the number of connections between each generator and the output system. Appreciation of this makes immediately apparent the commercial impossibility of supplying this excessive number of keyer circuits at reasonable cost.

It is the principal object of this invention to provide a novel DC keying system for synthesis type organs which overcomes the inherent difficulty set forth above.

An additional object is to provide a novel DC keying system for synthesis organs which requires only one keyer circuit for each generator without sacrificing the synthesis principle.

Another object is to provide a novel DC keyer system for synthesis organs which requires about the same number of keyers as do organs operating on the format principle.

Still another object is to provide a novel DC keying system for synthesis organs which supplies a single keyer circuit for each signal source and controls the individual keyers, such that the strength of the tone signals passed through the keyers is proportional to the demand upon the individual generators necessary to supply the input requirements of the organ output system, which in turn is fixed by the requirements of the musician.

Another object is to provide a novel synthesis organ in which the tone signals from the individual generators need not be sine wave signals, but in which the ultimately synthesized complex tone signal is substantially the same as it would be if the generator signals were true sine waves.

Yet another object is to accomplish all of the above at low cost.

Other objects and advantages will become apparent from the following description of a preferred embodiment of the invention which is illustrated in the accompanying drawings.

In the drawings in which similar characters of reference refer to similar elements throughout the several views:

FIG. 1 is a simplified circuit diagram showing the general keyer arrangement for connecting a tone signal generator to a common output system, and a control system for the keyer;

FIG. 2 is a diagram illustrating one of the keyer circuits;

FIG. 3 is a circuit diagram showing a transient suppressing arrangement for connecting the keyers for a multiplicity of signal generators to a common output system; and

FIG. 4 is a circuit diagram illustrating a system for a synthesis type organ which may use signal generators of the non-sine wave type.

Referring to FIG. 1 of the drawings, a -90 v. source is indicated at 10, and this source is connected to ground through a voltage dividing resistor of about $2K$ shown at 12. This resistor is tapped so as to give voltages of -90 , -82 , -59 , -36 , -23 , -15 , -9 , -6 and 0 in this particular embodiment. These voltage taps are connected respectively to voltage buses 14, 16, 18, 20, 22, 24, 26, 28, and 30 which are so arranged that drawbar slides 32, 34, 36, 38, and 40 can be moved individually across the buses to pick up any one of the desired voltages. The drawbar slides are in turn connected individually to a group of bus bars arranged beneath the playing keys.

These bus bars are indicated at 44, 46, 48, 50, 52, and 54, and cooperate respectively with playing key contacts 56, 58, 60, 62, 64, and 66 which are for obtaining a generator output when the particular generator frequency is required respectively for the fundamental, or the second, third, fourth, fifth, or sixth harmonic.

In the interest of simplifying the drawing and description, FIG. 1 shows drawbars, harmonic bus bars, and key contacts available only for the fundamental and harmonics to the sixth, but it will be understood that this is representational only and that in a practical organ additional harmonics will be made available to the musician by providing additional drawbars, bus bars, and key contacts as may be required for a specific design.

In any event, the key contacts 56, 58, 60, 62, 64, and 66, or whatever number are provided are connected through resistors 68, 70, 72, 74, 76, and 78 respectively to a common lead 80. The resistors serve an isolating function, and also differ in value between about $220K$ to $390K$ for the fundamental 68 down to about $150K$ for the highest harmonics for scaling purposes. That is, it is useful to preemphasize the higher harmonics, somewhat, so that they can subsequently be rolled off at the amplifier as an aid to click suppression.

The common control lead 80 is connected to the keyer 82 which is shown in greater detail in FIG. 2. In this figure, in the interest of completeness, the bus bars 44, 46, 48, 50, 52, and 54, together with the key contacts 56, 58, 60, 62, 64, and 66, and resistors 68, 70, 72, 74, 76, and 78 have been repeated. Also for convenience, the particular voltages applied to the particular bus bars by the specific drawbar arrangement of FIG. 1 have been indicated.

In FIG. 2 the lead 80 is connected to ground through resistor 84 so that the potential on lead 80 depends upon

the several voltages upon the several bus bars, the values of the resistors 68, 70, 72, 74, 76, and 78 and the value of the resistor 84. Thus, any change in the drawbar positions is reflected in a change in voltage at 80. Note also, that because of the almost infinite combinations possible of drawbar settings, the voltage at 80 can be almost anything from -90 v. to zero.

The lead 80 is connected to ground through capacitor 86 and through resistor 88 and a second capacitor 90 to ground, the junction between resistor 88 and capacitor 90 being connected through resistor 92 to the emitter of a transistor 94. The emitter is also connected to ground through a diode 96 oriented to pass current whenever the emitter is sufficiently negative relative to ground. The capacitors 86 and 90 and resistors 88 and 92 remove DC transients from the keyer control terminal, the emitter potential being determined by the forward characteristics of the diode. Resistor 92 determines maximum degeneration in the emitter circuit, and therefore has an effect upon keyer linearity.

The tone signal generator 98 is connected by a lead 99 directly to the base of the transistor, and the collector thereof is connected to a lead 100 which connects in turn through a resistor 102 with a terminal 104 supplied with current at a potential of 12 v. The resistor 102 is bridged by the primary 106 of an output transformer 108, the secondary 110 of which is connected by a lead 112 to a preamplifier 114. The preamplifier output lead 116 is connected in turn to the organ output system 118 and speaker 120 (see FIG. 1).

In a particular embodiment of this invention resistors had the following values: 84, $47K$; 88, $10K$; 92, $33K$; and 102, $2.7K$. The capacitors 86 and 90 vary somewhat depending upon the frequency of the generator signal keyed by the circuit as would be expected. Using customary generator designating nomenclature, and assigning generator number 13 to C at a frequency of about 65 c.p.s. and using successively higher numbers to denote successively higher semitones, generators for frequencies 13 to 18 have a capacity at 90 of $.68 \mu f.$, those higher than 18 have a capacity at this location of $.47 \mu f.$ Generators for frequencies from 13 to 36 have a capacity at 86 of $1 \mu f.$, from 37 to 60 a capacity at 86 of $.82 \mu f.$, and from 61 to 91 or above a capacity of $.47 \mu f.$

Silicon alloy diodes are preferred at 96, those shown being type 1N461A, although others have been used without difficulty. The transistors 94 are of type 2N2926, and to promote linearity of response it is preferred that they be confined to a limited variation at a medium beta. These transistors may be had already color coded into beta groups and we have found that the group with betas from 90 to 180 is satisfactory for the purpose and promotes substantially universal interchangeability.

This keyer circuit has a substantially linear variable gain characteristic, with variation of the voltage at 80, over a control range of more than 100 to 1. This is due to the simultaneous operation of two effects. In the first place, the base-emitter bias is varied which changes the collector current, thus affecting the gain. Secondly, the amount of degenerative resistance in the emitter circuit varies. Both of these effects are obtained by passing current through the diode; that is, it is the voltage drop across the diode that biases the transistor on, and the resistance across the diode depends upon the current through it, thus increasing the gain of the transistor with increasing current through the diode. The maximum emitter circuit impedance is established by resistor 92.

This circuit works very well for the purpose intended; that is, whatever keys are played, the strength of the tone signals required from the individual generators will be determined by the D.C. voltage applied to the leads 80 of the individual generators, which is determined in turn by which of the key contacts for a particular keyer circuit are closed and the positions of the drawbars in the particular keyed circuits. Transients, such as clicks (high fre-

quencies) or thumps (low frequencies), are much reduced with this system over that with A.C. keying. The system lends itself well, however, to essentially complete removal of clicks and thumps without degradation of tone by an improvement which is illustrated in FIG. 3.

Here the outputs of the individual keyers are not all manifolded together, as in FIG. 1, by connecting the leads 100 together. Rather, the output leads 100 are collected into four groups 130, 132, 134, and 136 to form separate frequency bands, and these bands are separately filtered to remove frequencies above and below the band limits. In general, it is desirable to have the filter systems cut off sharply below the lowest frequency it is required to pass so as to suppress thumps. A slow roll-off at the upper band limit is effective to remove clicks.

In the specific system shown in FIG. 3, the outputs from the low frequency keyers for generators numbers 13 to 36 are collected and passed through the primary 138 of output transformer 140. This primary is bridged by resistor 142. The 12 v. connection for the collector is also indicated at 144; all this is similar to the transformer primary circuit of FIG. 2, except that a fewer number of keyers is connected to the output transformer in FIG. 3. The secondary 146 of transformer 140 is connected through a filter consisting of a capacitor 148 and two resistors 150 and 152 in series to a lead 154, the junction between the resistors being connected to ground through capacitor 156. Approximate values are: Capacitor 148, .33 μ f.; capacitor 156, .1 μ f.; resistors 150 and 152, respectively, 6.8K and 15K.

For filtering the midrange of tones, a two stage system is used. The outputs from keyers for generators numbers 37 to 48 are connected together and the mixed signal passes through a capacitor 158 to a lead 160. Similarly, the outputs from the keyers for generators numbers 49 to 60 are collected and passed through capacitor 162 to lead 160. The 12 v. D.C. connection is made to the lead 100 from the keyers for generators 37 to 48 by way of a choke 164 connected ahead of the capacitor 158, and, similarly, a choke 166 and resistor 168 in parallel is used to connect the 12 v. D.C. supply to the lead 100 from the keyers for the generators numbers 49 to 60.

The common lead 160 is connected to ground through the primary 170 of transformer 172, this primary also being bridged by resistor 174. Transformer 172 secondary 176 is connected to the previously mentioned filter output lead 154 by way of capacitor 178 and resistors 180 and 182, all in series. The junction between resistors 180 and 182 is connected to ground through capacitor 184. Suitable values for the components in this circuit are: resistor 168, 5.6K; capacitors 158 and 162, .2 μ f. and .1 respectively; resistor 147, 2.7K; capacitors 178 and 174, .033 μ f., and .025 μ f., respectively; and resistors 180 and 182, 6.8K and 15K respectively.

The signals in lead 100 from the keyers for generators above number 60, shown as numbers 61 to 91, are connected to a transformer primary circuit 186 which may be considered the same as that for generators numbers 13 to 36. The secondary 188 of this transformer is connected to common lead 154 by way of a .033 μ f. capacitor 190 and a 22K resistor 192 in series.

The common filter output lead 154 is connected to the preamplifier indicated at 184, which may be the same as in indicated at 114 in FIGS. 1 and 2. The input lead 154 to the preamplifier is connected directly to the base of a transistor 196 and to ground through resistor 198. Lead 154 is also connected to the collector by way of resistor 200 and also to the collector through a parallel path consisting of resistor 202 and capacitor 204 in series. The emitter is grounded, and the collector is connected through resistor 206 to a +22 v. terminal 208. The output signal is taken from the collector by way of a capacitor 210 and resistor 212 in series, the resistor 212 also being bridged by a capacitor 214 and resistor 216 in series. The output lead, indicated at 218, is connected

in turn to whatever output system the organ has; for instance, the system indicated at 118 in FIG. 1.

The transistor 196 is of 2N2926 type, yellow coded. Other values in the preamplifier circuit are as follows:

5	Resistors:	
	202	22K
	200	220K
	198	18K
10	212	330K
	216	47K
	206	22K
	Capacitors:	
	204	pf-- 100
15	210	μ f-- .01
	214	pf-- 120

It is important to note that the reason filtering the generators in groups is feasible with this system, whereas it cannot readily be done with AC keying, is that with AC keying the outputs from the various generators go to the various bus bars representative of the various harmonics, and the band spread, therefore, on each of the harmonic buses is so wide that the portion of the transients within the band is appreciable, whereas in the system shown, the portion of the transients within the narrower bands of course is much less. With the present system, the frequency bands can be kept as narrow as desired, because the outputs from the various generators go through individual paths, regardless of whether the output is for a fundamental or for any one of the several harmonics.

An extension of this idea is illustrated in FIG. 4. In this figure a group of signal generators is indicated at 230. Each of these passes its signal through its individual keyer at 232. The outputs of these keyers are collected in groups of six to eight (eight are shown) to form common group outputs represented by the group output leads 234. It will be understood that the generators and keyers of each particular group are for adjacent semitones, and therefore each group contains substantially less than an octave of tone signals. Each of the common leads 234 therefore contains a collection of diverse signals, but the signals on any particular lead 234 will have a relationship to each other which is considerably closer than a ratio of 2 to 1.

These individual common leads 234 are connected to the common output lead 236 through individual filters indicated at 238. These filters 238 may be of any suitable tuned type, the requirement being simply that they pass, without substantial distortion, signals within something less than a 2 to 1 range. The effect of this is not only that the filters remove even better the transients which may accompany the tone signals, as compared with the system of FIG. 3 for instance, but that they remove all of the overtone structure in the generator output. Thus, the generator for international A at 440 c.p.s., if not supplying a true sine wave, will be accompanied by a second harmonic at 880 c.p.s. and a third harmonic at 1320 c.p.s., and so on. Since the filter at 238 for this frequency group cuts between 440 c.p.s. and 880 c.p.s., and therefore passes the 440 c.p.s. signal without contamination by the 880 c.p.s. or 1320 c.p.s. signal, the output at 236 will include only the 440 c.p.s. signal as an undistorted sine wave.

The importance of this is that by using such a system it is possible to obtain a sine wave synthesis in the organ output without using any sine wave generators. That is of considerable commercial importance, since it is now possible to design an organ on the basis of supplying generators for one octave at the high frequency end of the spectrum, and then supplying the lower octaves by successive stages of frequency division. Frequency dividers as ordinarily provided for this purpose are of the flip-flop type and usually give a square wave output, which of course would be of little value in a synthesis organ, but with

this system such square waves, or even sawtooth waves, are entirely usable, since these signals will come through to the output as sine waves regardless of the harmonic content of the signal which is input to its filter 238.

In any event, the lead 236 which collects the filter outputs is connected to a preamplifier, such as the one at 194 in FIG. 3 for instance. From the preamplifier the signal passes to the output system and speaker, as at 118 and 120 in FIG. 1 for instance.

From the above description of a specific embodiment of our invention it will be seen that variations can be made without departing from the spirit and scope of the invention, and that, therefore, the scope of the invention is to be measured from the scope of the following claims.

Having described our invention, what we claim as new and useful and desire to secure by Letters Patent of the United States is:

1. A synthesis type organ having a plurality of tone signal generators, a common output system, a plurality of keyers, one for each of said generators, connecting its respective generator to the output system, a plurality of playing key actuated keying contacts for each of said keyers, said keying contacts for each of said keyers being adapted individually to key DC control voltage increments into a common keyer control lead, one for each keyer, means connecting each of said common keyer control leads to its keyer to control signal transmission through its keyer, and each of said keyers being adapted to transmit its tone signal to said output system on an intensity basis which is substantially linear with respect to the sum of the values of said DC control voltage increments.

2. A synthesis type organ having a plurality of tone signal generators, a common output system, a plurality of keyers, one for each of said generators, connecting its respective generator to the output system, a plurality of playing key actuated keying contacts for each of said keyers, said keying contacts for each of said keyers being adapted individually to key DC control voltage increments into a common keyer control lead, one for each keyer, switching means adapted for selecting one of several values for each of said voltage increments for application to each of the contacts for a single keyer control lead, means connecting each of said common keyer control leads to its keyer to control signal transmission through its keyer, and each of said keyers being adapted to transmit its tone signal to said output system on an intensity basis which is substantially linear with respect to the sum of the values of said DC control voltage increments.

3. A synthesis type organ having a plurality of tone signal generators, a common output system, a plurality of keyers, one for each of said generators, connecting its respective generator to the output system, a plurality of playing key actuated keying contacts for each of said keyers, a plurality of bus bars for said keying contacts equivalent in number to the number of keying contacts for one of said keyers, means for applying a selected one of several control DC voltages individually to each of said bus bars, means connecting the keying contacts for each one of said keyers to a common keyer lead so that said keying contacts for each of said keyers key DC control voltage increments into each of said common keyer control leads, means connecting each of said common keyer control leads to its keyer to control signal transmission through its keyer, and each of said keyers being adapted to transmit its tone signal to said output system on an intensity basis which is substantially linear with respect to the sum of the values of said DC control voltage increments.

4. A synthesis type organ having a plurality of tone signal generators, a common output system, a plurality of keyers, one for each of said generators, means including said keyers for connecting said generators in a plurality of frequency band groups to the output system, a filter system for each of said frequency band connections to the output system, each said filter system rejecting fre-

quencies substantially above or below the fundamental frequencies of the generators in its respective band, a plurality of playing key actuated keying contacts for each of said keyers, said keying contacts for each of said keyers being adapted individually to key DC control voltage increments into a common keyer control lead, one for each keyer, means connecting each of said common keyer control leads to its keyer to control signal transmission through its keyer, and each of said keyers being adapted to transmit its tone signal to said output system on an intensity basis which is substantially linear with respect to the sum of the values of said DC control voltage increments.

5. The combination called for in claim 4 in which said frequency band groups each include not substantially more than the fundamental frequencies for eight adjacent musical semitones and the filters for said band groups reject substantially completely frequencies which are at least one octave above or one octave below any of the fundamental frequencies in their band group.

6. A synthesis type organ having a plurality of tone signal generators, a common output system, a plurality of keyers, one for each of said generators, connecting its respective generator to the output system, a plurality of playing key actuated keying contacts for each of said keyers, said keying contacts for each of said keyers being adapted individually to key negative control voltage increments into a common keyer control lead, one for each keyer, each of said keyers being adapted to transmit its tone signal to said output system on an intensity basis which is substantially linear with respect to the sum of the values of said negative control voltage increments, each of said keyers comprising a transistor, means connecting its generator to the base thereof, means providing a connection from the collector thereof to said output system and to the positive side of a source of potential, circuit means including a diode connected between the emitter and the other side of said potential source, said diode being oriented to conduct when said emitter is negative relative to said other side of said potential source, and means including a load resistance connecting said common keyer control lead to said emitter.

7. The combination called for in claim 6 in which said diode varies in impedance with the current therethrough in the manner of a silicon diode.

8. The combination called for in claim 6 in which said diode has substantially the impedance variation with current of type 1N461A and said transistor has substantially the electrical characteristics of type 2N2926.

9. An organ having a plurality of tone signal source mechanisms, each of said mechanisms having a control terminal the DC potential of which establishes the signal intensity output of the respective mechanism, the output of each said mechanism being substantially linear with the DC voltage applied to its said terminal, an output system connected to receive the signal outputs from said source mechanisms, a plurality of playing key actuated keying contacts for each of said mechanisms, a plurality of harmonically related bus bars for said keying contacts equivalent in number to the number of keying contacts for one of said mechanisms, means for applying a selected one of several different control DC voltages individually to each of said bus bars, means connecting the keying contacts for each of said mechanisms to a respective common lead so that the keying contacts for each of said mechanisms key DC control voltage increments into a common control lead for each respective mechanism, means connecting each of said common control leads to the control terminal for its respective mechanism to control the output of its mechanism, whereby each of said signal source mechanisms will supply its tone signal to said output system on an intensity basis which is substantially linear with respect to the sum of the values of

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the keyed DC control voltage increments supplied to its
said control terminal.

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