Jan. 7, 1969 D. J. LESLIE 3,420,941

MULTIVOICE ELECTRONIC ORGAN

Filed Dec. 10, 1965 Sheet 1 of 7

FIG. 1.

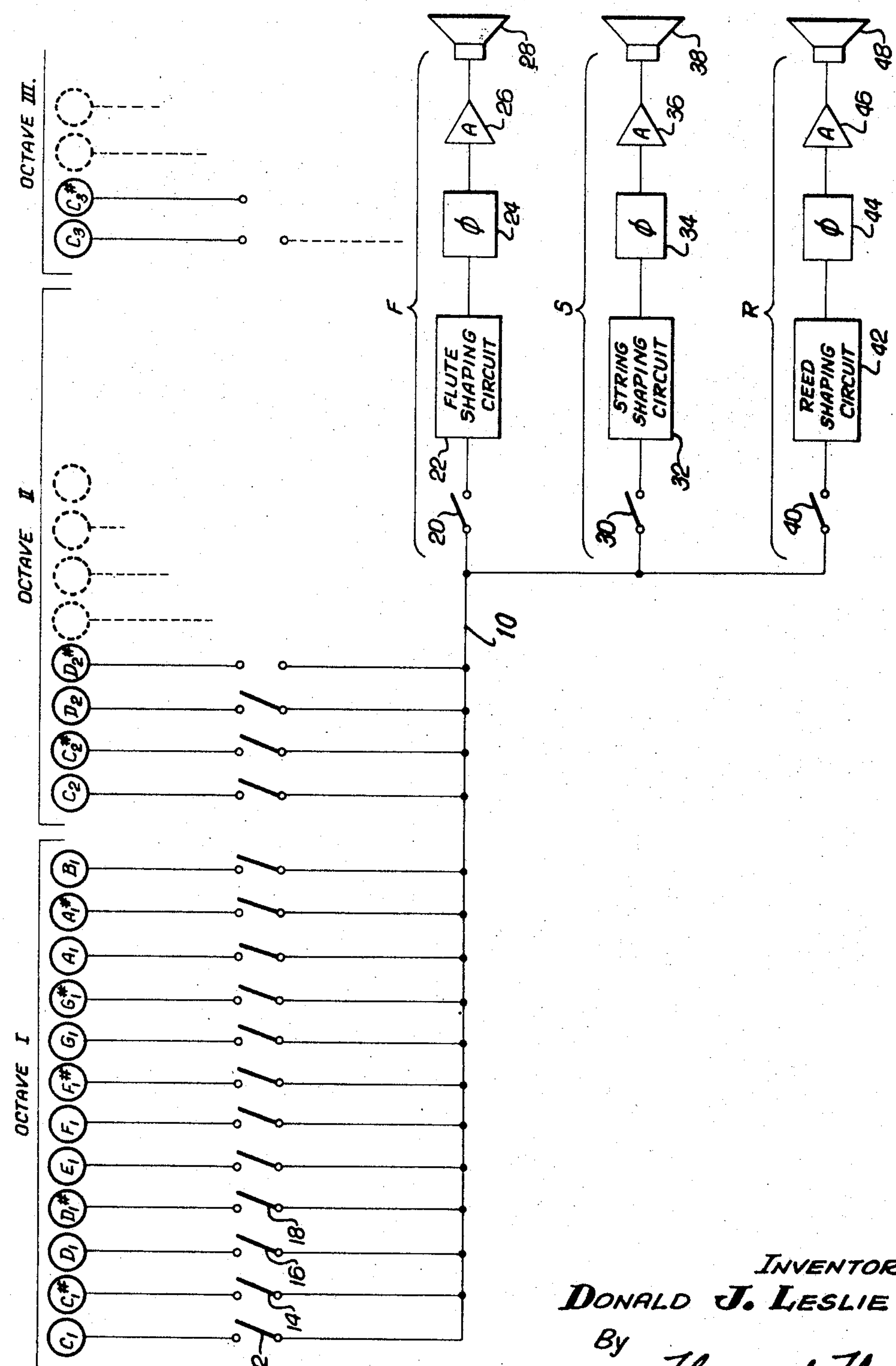

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FIG. 2.

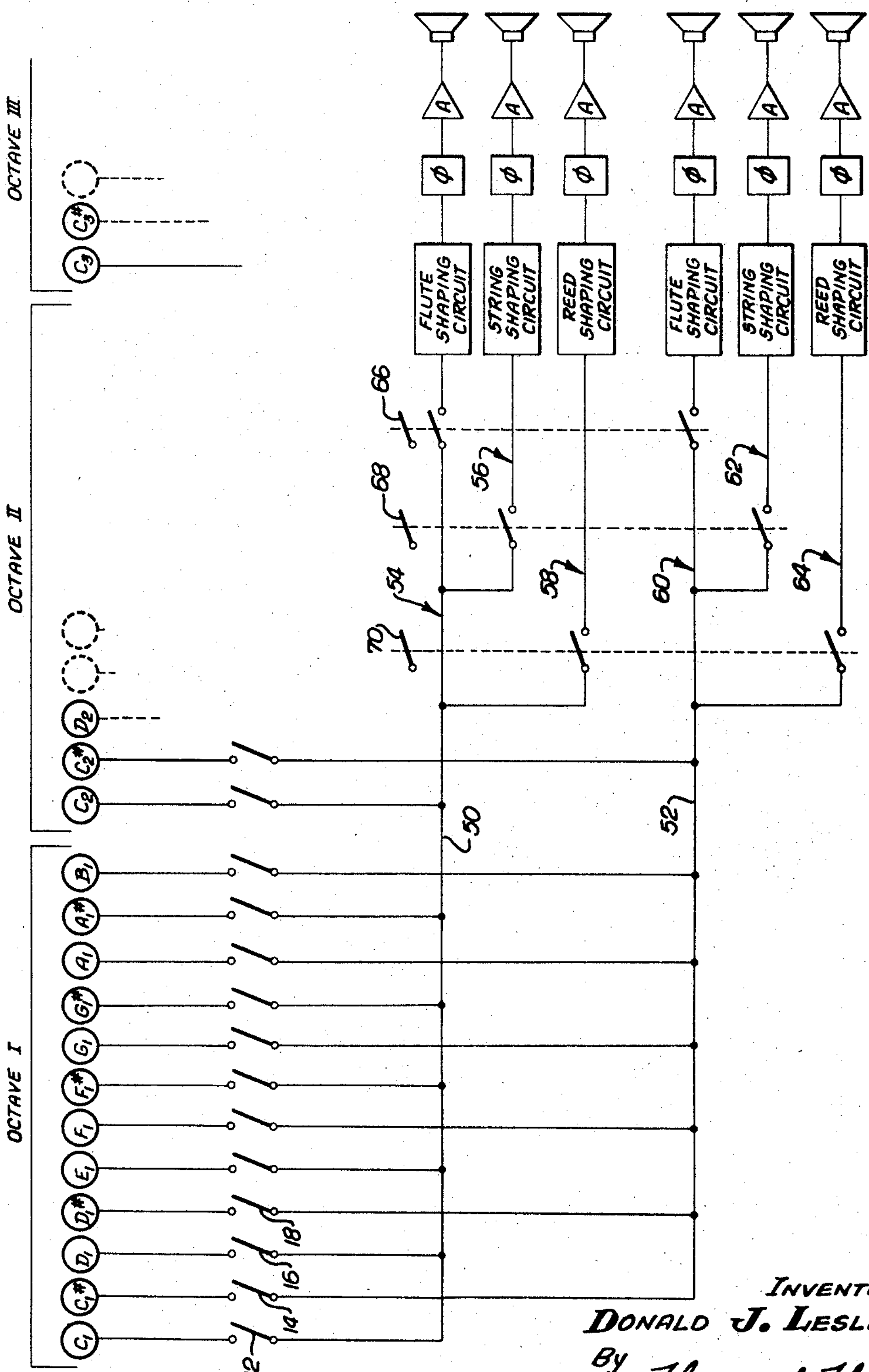

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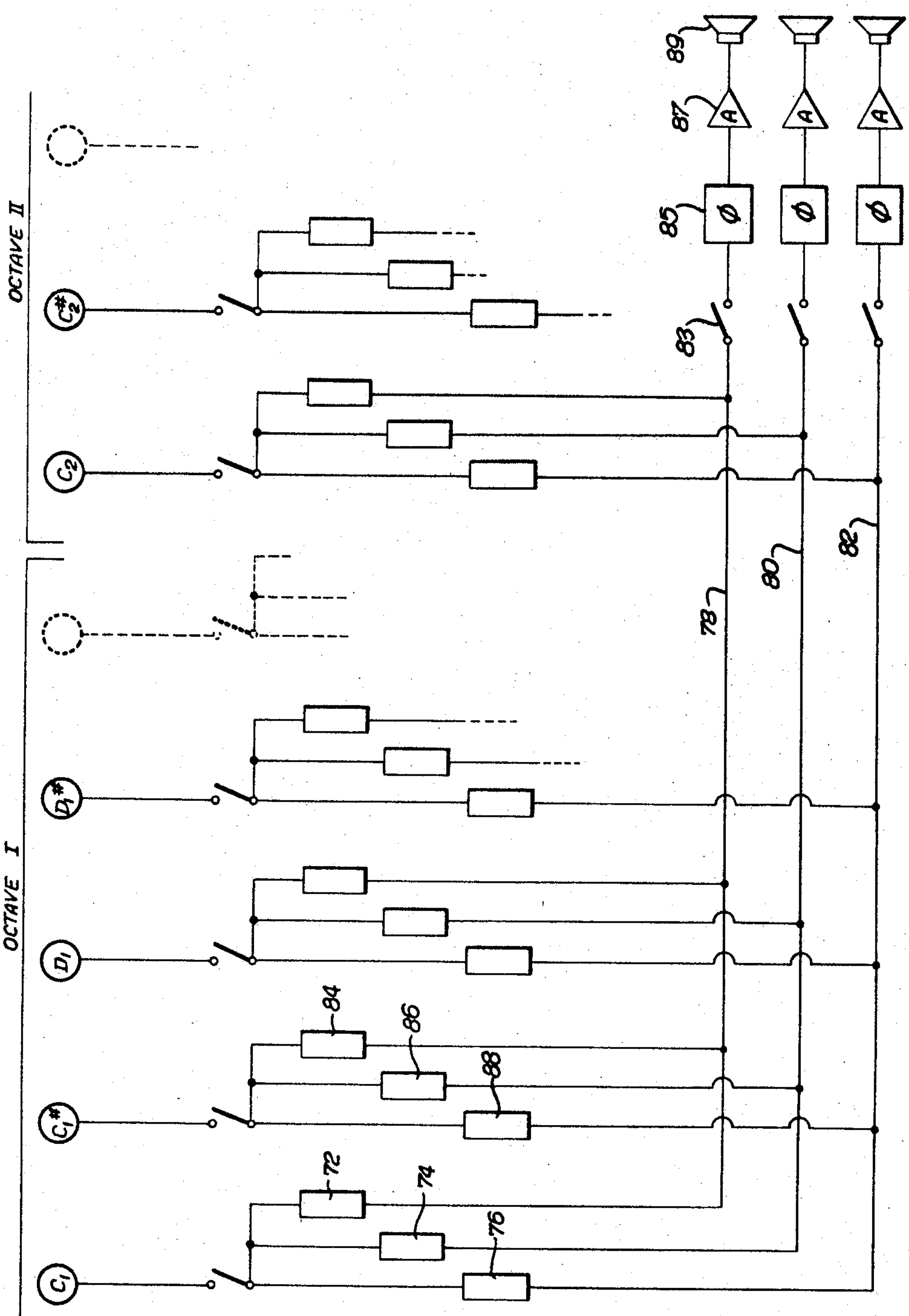
Fig. 3.



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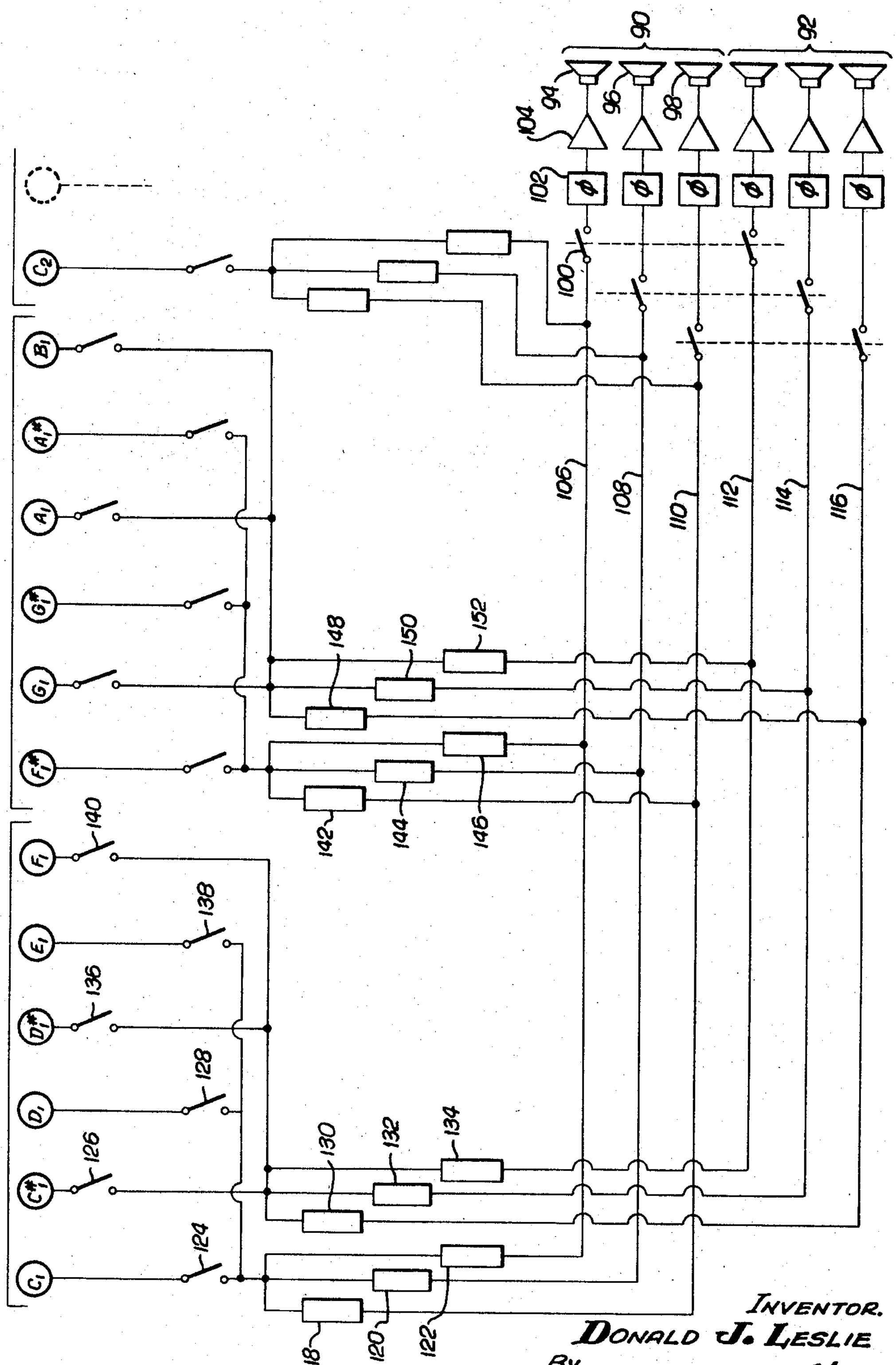

FIG. 4.

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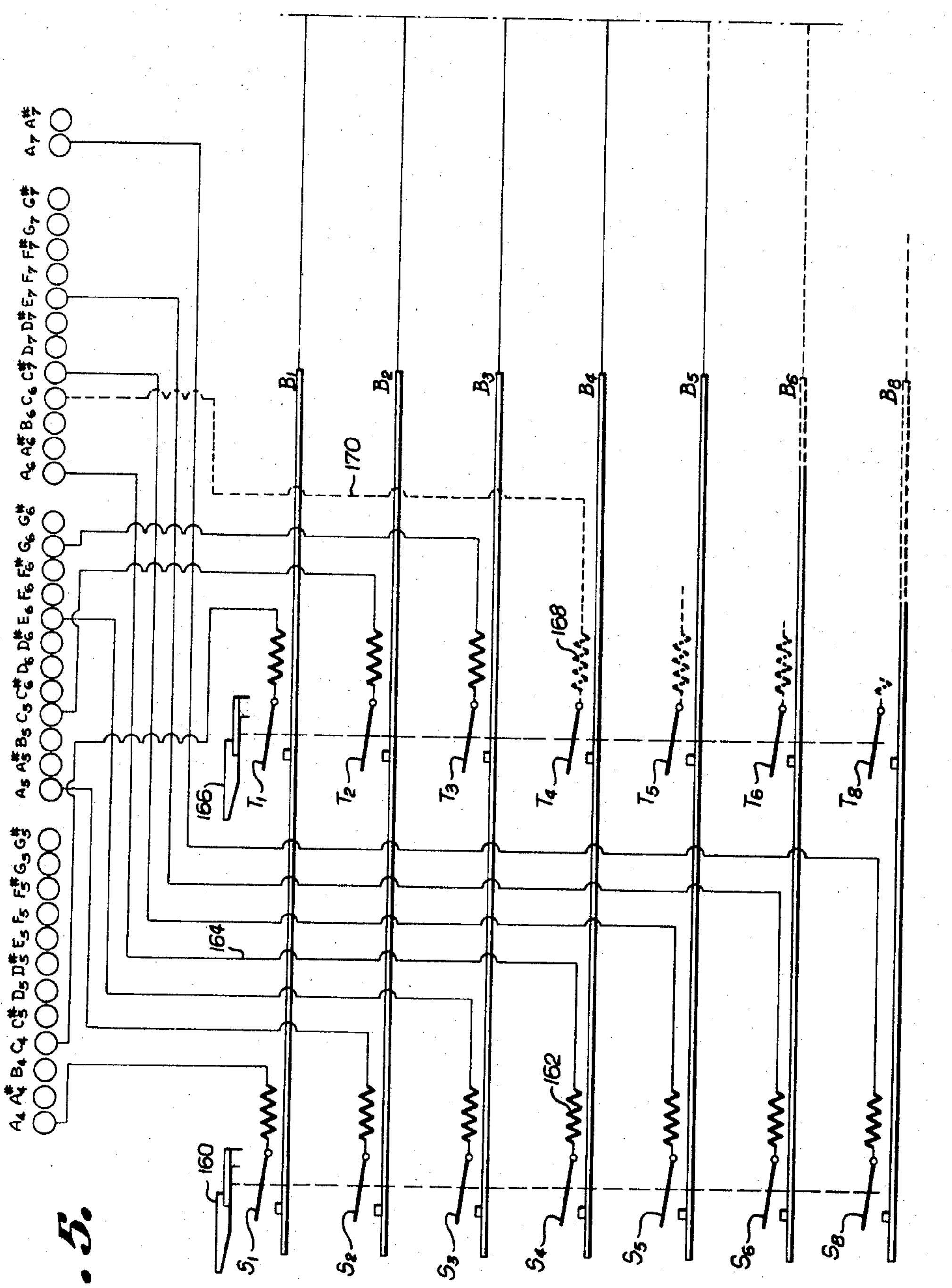

FIG. 5.

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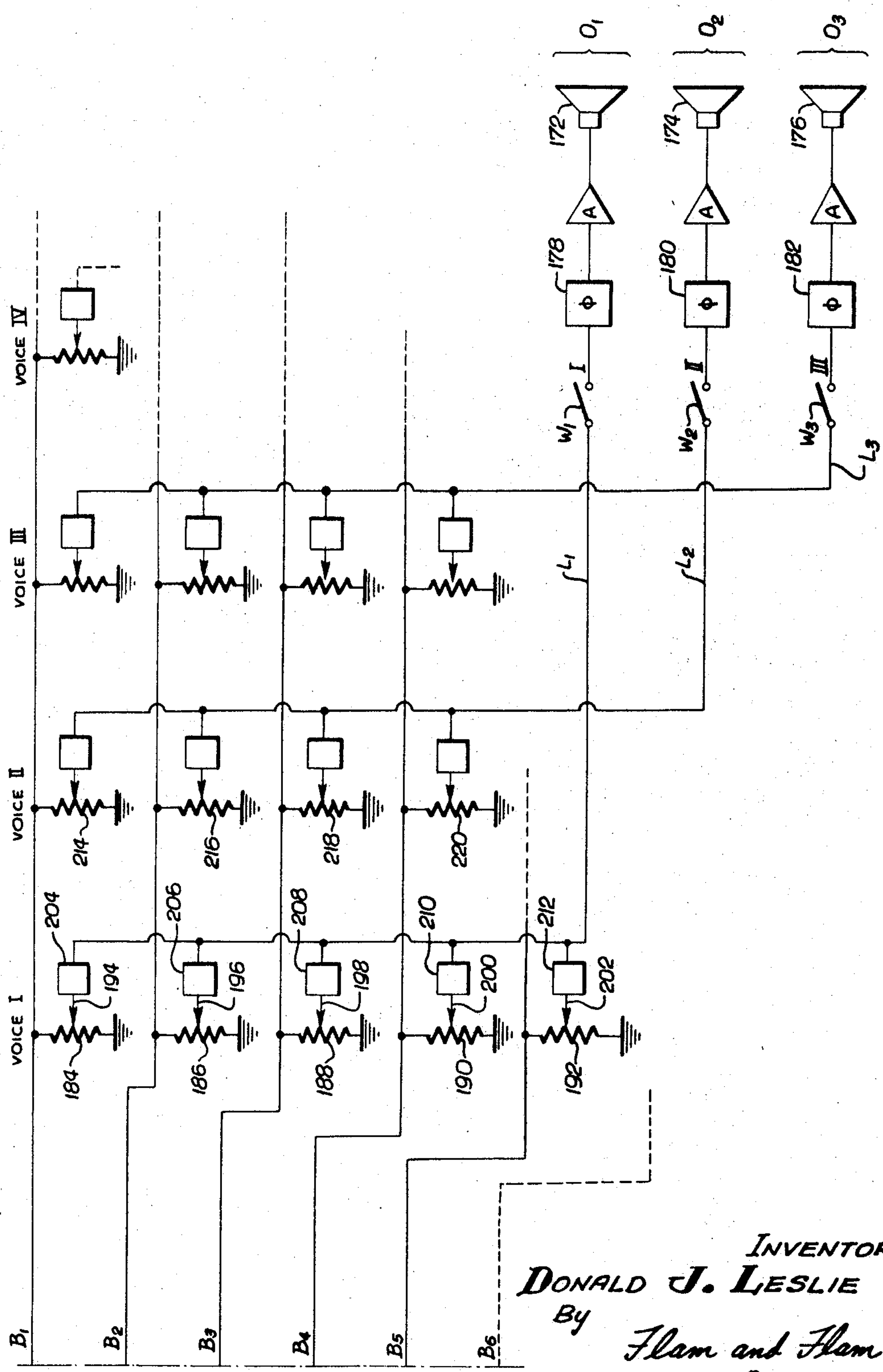

Fig. 5a.

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FIG. 7.

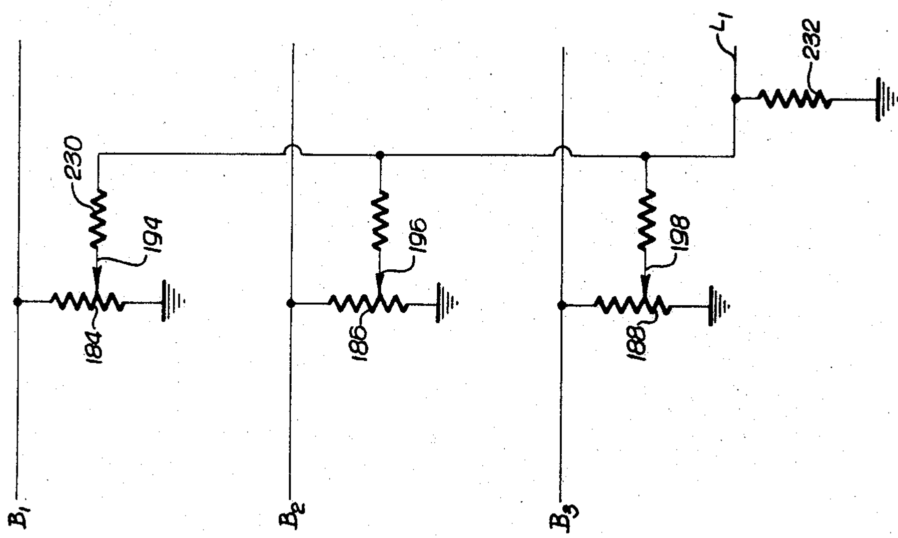
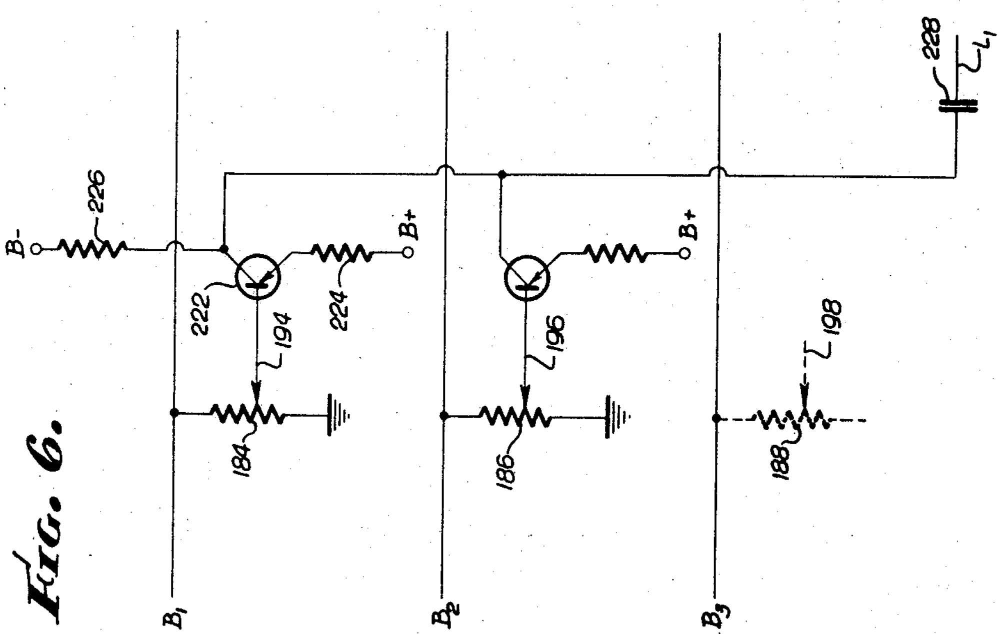


FIG. 6.



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3,420,941
MULTIVOICE ELECTRONIC ORGAN

Donald J. Leslie, Altadena, Calif., assignor, by mesne assignments, to Columbia Broadcasting System, Inc.
Continuation-in-part of application Ser. No. 463,828, June 14, 1965. This application Dec. 10, 1965, Ser. No. 523,814
U.S. Cl. 84—1.24 14 Claims
Int. Cl. G10h *1/02*

This is a continuation-in-part of application Ser. No. 463,828, filed June 14, 1965, now abandoned.

This invention relates to electronic organs.

In many electronic organs a plurality of voices are derived from a common set of generators. For example, to derive a flute tone, a complex generator is connected to the output via a "flute" filter or shaping circuit when the playing key operates a switch. This particular filter or shaping circuit is placed in circuit by operation of a typical stop or tab labelled appropriately. To derive a string tone, the very same complex generator is connected to the output, but through a different filter or shaping circuit operated by another stop or tab labelled, for example "violin."

If the shaping circuits for flute and violin are operated separately, then well-defined characteristic flute and violin tones are perceived. However, when they are operated simultaneously, flute and string tones are not separately perceived, but instead a new single tone results. This is far from the effect that might be achieved by operating two stops of a pipe organ since, in such circumstances, two different ranks of pipes would be operated. Such two ranks would be heard in chorus for a number of reasons, including the fact that corresponding pipes for C_1 in the respective ranks cannot be in perfect tune.

The obvious remedy for such situation is to provide a number of sets of generators in the electronic organ. This has been done. In some instances, four sets are used for the four basic classes of tones—flute, string, reed and diapason, with each generator set in turn, through appropriate shaping circuits, providing a number of different tones. For example, the string generator can provide the "violin," "cello" and other related sounds. The difficulty with such an arrangement is that four sets of generators must be periodically tuned rather than one. Four sets of generators represent a multiplied initial cost and space requirement. And the various voices derived from the same generator still are not distinct.

In another type of organ, sine wave generators are used, and complex tones corresponding to different voices are built up by borrowing. Thus, for example, the second, third, fourth, fifth, and other harmonics for A_4 are derived from the sine wave generators for A_5, E_6, A_6, $C\sharp_7$, etc. Usually, one bus bar is provided for corresponding harmonics of all of the notes. Thus a suitable scaling device operatively connected to the bus bar can proportion the strength of each harmonic relative to the fundamental whereby each note has the same voice characteristic. Since the same generators are used for all the voices, again it is impossible to perceive separate voices.

The object of this invention is to provide an electronic organ system in which various voices may, in a simple manner, be made distinct without requiring additional generator sets. For this purpose, use is made of dynamic phase shift devices in each voice channel. Such dynamic phase shift devices produce variable phase shifts. If the variation in phase is uniform, a new constant pitch will be produced. If the variation in phase is non-uniform, the resulting pitch will be indeterminate. Due to the changing phase shift produced, a different pitch is created,

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whether determinate or indeterminate, and consequently the voices are separately perceived. Such dynamic phase shift devices are shown in my copending application, Ser. No. 350,717, filed Mar. 10, 1964, entitled, "Electronic Organ System," now U.S. Patent No. 3,372,225.

The dynamic phase shifters introduce the possibility of unmusical and annoying beat effects being created. To avoid this, each dynamic phase shifter feeds a separate output channel, which may comprise either separate speakers or other transducers, such as recording heads.

Another object of this invention is to provide a system of this character in which a single generator system can be used to provide a plurality of distinct voices for the organ. Thus where a set of generators is derived from twelve master oscillators, only twelve oscillators need be tuned.

This invention possesses many other advantages, and has other objects which may be made more clearly apparent from a consideration of several embodiments of the invention. For this purpose, there are shown a few forms in the drawings accompanying and forming part of the present specification. These forms will now be described in detail, illustrating the general principles of the invention; but it is to be understood that this detailed description is not to be taken in a limiting sense, since the scope of the invention is best defined by the appended claims.

Referring to the drawings:

FIGURE 1 is a single wire diagram of an electronic organ system incorporating the present invention;

FIGS. 2, 3 and 4 are diagrams similar to FIG. 1, each showing modified forms of the present invention;

FIGS. 5 and *5a* together constitute a diagram showing still another modified form of the present invention; and

FIGS. 6 and 7 are diagrams illustrating alternate isolation circuits for use in the system shown in FIG. 5.

In FIG. 1, tone generators labelled C_1, $C\sharp_1$, D_1, $D\sharp_1$, etc. are shown, representing all generators of a single set. These generators produce impulses corresponding to notes spanning a musical range of six or eight octaves. The generators in this embodiment produce impulses rich in harmonic content. The generators all connect to a common feeder circuit or bus connection through individually operable key switches **12**, **14**, **16**, **18**, etc. Three separate output circuits F, S, and R are driven by the connection **10**. These output circuits respectively produce flute, string and reed type tones.

The output circuit F includes, in series, a stop or tab switch **20**; a filter or shaping circuit **22** that develops the characteristic flute tone in a well-understood manner; a dynamic phase shift network **24**; a power amplifier **26**; and an output transducer in the form of a speaker **28**. The other output circuits S and R include similar components. Thus the string output circuit includes a stop or tab switch **30**, a shaping circuit **32**, a dynamic phase shift network **34**, an amplifier **36**, and a speaker **38**. The reed output circuit includes a stop or tab switch **40**, a shaping circuit **42**, a dynamic phase shift network **44**, an amplifier **46**, and a speaker **48**. Of course, the three output circuits F, S, and R simply represent a plurality of such circuits; as many may be provided as desired.

The dynamic phase shift networks **24**, **34** and **44** preferably are of the random type shown in FIGS. 6, 7 and 8 in my said copending application Ser. No. 350,717. Such dynamic phase shift networks produce frequency deviations that vary periodically, the deviations being in the range of one or two cycles per second flat or sharp. The sounds issuing from the respective speakers, assuming all the stop switches are closed, will have a definite identity due to the slight tuning variance. The voice characteristics added by the shaping circuits are retained, and the listener clearly perceives the individual voices. Since separate speakers are provided for each voice channel, no beat effects are created by virtue of the phase shift networks.

In the form of the invention illustrated in FIG. 2, two bus connection or feeder circuits **50** and **52** are provided for one set of generators. Generators corresponding to notes C, D, E, F♯, G♯, and A♯ are connected to the feeder circuit **50**, whereas generators corresponding to notes C♯, D♯, F, G, A, and B are connected to the feeder circuit **52**. One group of three voice circuits is driven by the feeder circuit **50** and another group of three identical voice circuits is driven by the feeder circuit **52**. Each voice circuit includes elements corresponding to those described in connection with the voice circuits of FIG. 1, namely, a stop or tab switch, a shaping circuit, a dynamic phase shifting network, an amplifier and a speaker. The six voice circuits are identifiable by reference characters **54**, **56**, and **58** for circuit **50**, and **60**, **62** and **64** for circuit **52**. The voice circuits **54** and **60** include like shaping circuits; the voice circuits **56** and **62** include like shaping circuits; and the voice circuits **58** and **64** include like shaping circuits. These pairs of circuits are operated by the same stops or tabs **66**, **68** and **70**. Upon operation of the stop or tab **68**, for instance, string tones are produced upon operation of the key switches.

Tones corresponding to C, D, E, F♯, G♯, and A♯ are translated in one group of three output channels, whereas tones corresponding to other noted C♯, D♯, F, G, A and B are translated in the other group of three output channels. Thus, in accordance with my prior Patent No. 2,596,258, beat effects due to simultaneously sounding notes in either fourth or fifth interval musical relationship are avoided, as are beat effects due to mixing of out-of-tune voices. The output channels **54** and **60**, since they are coupled, may be regarded as parts of a single flute output channel. Similarly, channels **56** and **62** may be considered parts of a single string output channel, and channels **58** and **64** may be considered parts of a single reed output channel.

The form of the invention illustrated in FIG. 3 is the same as in FIG. 1, except that each generator has its own shaping circuits. Thus the generator C_1 has flute, string and reed shaping circuits **72**, **74** and **76** respectively that connect to three feeder circuits **78**, **80** and **82**. The generator C♯$_1$ likewise has flute, string and reed shaping circuits **84**, **86**, and **88** cooperable with the feeder circuits **78**, **80** and **82**, etc.

Each output circuit includes a stop or tab switch as at **83**, a dynamic phase shift network **85**, an amplifier **87** and a transducer or speaker **89**. In this particular example, each shaping circuit is carefully designed with respect to a particular fundamental frequency. A quite satisfactory arrangement is illustrated in FIG. 4. Also in FIG. 4, impulses corresponding to notes in alternate half tone relationship are translated in different channel groups. Thus the arragement in FIG. 4 bears similarity to the forms of both FIGS. 2 and 3. In this form, there are two groups of output channels **90** and **92** for alternate notes respectively. In this instance, simply by way of example, there are three individual channels for flute, string and reed. Thus, in one group **90**, there are three speakers **94**, **96**, and **98**. In circuit with the speaker **94**, for example, are a stop or tab switch **100**, a dynamic phase shift network **102**, and an amplifier **104**. Corresponding elements are present in the other output channels.

The output channels are fed by six feeder leads **106**, **108**, **110**, **112**, **114**, and **116**. Flute, string and reed shaping circuit **118**, **120**, and **122** connect with three generators C_1, D_1, and E_1 through key switches **124**, **126**, and **128**. These shaping circuits respectively connect to the feeder leads **106**, **108**, and **110** for one group of output channels. Flute, string and reed shaping circuits **130**, **132**, and **134** connect with three alternate generators C♯$_1$, D♯$_1$, and F_1 through key switches **136**, **138**, and **140**. These shaping circuits connect to the feeder leads **112**, **114**, and **116** for the second group of output channels.

In a similar manner, shaping circuits **142**, **144**, and **146** connect generators F♯$_1$, G♯$_1$, and A♯$_1$ to the feeder circuits **106**, **108**, and **110**. Shaping circuits **148**, **150**, and **152** connect alternate generators G_1, A_1, and B_1 to the feeder circuits **112 114** and **116**. For each octave set of twelve generators, there are four groups of shaping circuits, one group for C, D, and E; another group for F♯, G♯, and A♯; another for C♯, D♯, and F; and another for G, A, and B. In this manner, each shaping circuit can be specifically designed for a narrow band of fundamental frequencies, and, at the same time, beat effects due to fourth and fifth interval notes are avoided.

The systems as thus far described may be embodied in a wide variety of organ systems. For example, there may be three sets of generators, with one or more of the sets provided with a plurality of output channels in which dynamic phase shift networks are incorporated. The shaping circuits may be designed for individual notes, or for any group of adjacent notes. There may be as many individual shaping circuits in a set as desired.

In the form of the invention illustrated in FIGS. 5 and *5a*, the generators A_4, A♯$_4$, B_4, etc. all produce substantially sinusoidal signals, that is, impulses free of harmonics. The generators may be of any known type. One generator is provided for each note, the signal produced corresponding to the fundamental of the note. Thus, the signal produced by the generator A_4 has a frequency of 440 cycles per second.

In order to derive a complex wave form corresponding to a desire voice, a borrowing system is provided. For this purpose, each key has associated therewith, a series of switches. Thus, the key **160** for A_4 has switch arms S_1, S_2, S_3, S_4, S_5, S_6, and S_8 that respectively are engageable with output bus bars B_1, B_2, B_3, B_4, B_5, B_6 and B_8. These bus bars are designed respectively to transmit to the output system, impulses corresponding to the fundamental, the second, third, fourth, fifth, sixth and eighth harmonics. Thus the bus bar B_4 conducts the fourth harmonic of A_4 when the key corresponding to A_4 is depressed. The switch S_4 connects, via an isolation resistor **162** and a lead **164** to the generator A_6. The generator A_6 produces a signal of 1720 cycles per second. This corresponds not only to the fundamental of A_6 but also to the fourth harmonic of A_4. Hence, the signal of A_6 is "borrowed" and used as the fourth harmonic of A_4, all in a well known manner.

The bus bar B_4 also transmits the fourth harmonic of C_4. Thus, the key **166** for C_4 operates a series of switch arms T_1, T_2, T_3, T_4, T_5, T_6, and T_8 that also respectively engage the bus bars B_1, B_2, etc. The switch arm T_4 connects, via isolation resistor **168** and lead **170** to the generator G_6 which produces a signal that corresponds to the fourth harmonic of C_4.

Only a few of the connections for the entire organ are shown for two keys, but from the foregoing description the nature of the entire instrument will be understood. Whenever any key is depressed, the fundamental and all harmonics exist in full strength respectively at the bus bars B_1, B_2, B_3, etc.

A number of different voices may be derived from the bus bars B_1, B_2, B_3, etc., for application to separate output channels O_1, O_2, O_3, etc. (FIG. *5a*). Each output channel includes a stop switch W_1, W_2, W_3, etc. interposed in the corresponding electrical output leads L_1, L_2, L_3, etc. The leads L_1, L_2, L_3, etc. respectively drive transducers or speakers **172**, **174**, **176**, etc. through dynamic phase shift networks **178**, **180**, **182**, etc. As in the previous forms, these phase shift networks are preferably of the random type, and produce frequency deviations averaging about one or two cycles per second. By virtue of the phase shift networks, the voices issuing from the speakers of the channels may be separately perceived.

In order to provide a selected harmonic content for impulses applied to the electrical output lead L_1, a first set of potentiometer resistors **184**, **186**, **188**, **190**, **192**, etc. is provided that connect between ground and the respective bus bars B_1, B_2, B_3, B_4, etc.

Cooperable with the potentiometer resistors are sliders **194**, **196**, **198**, **200**, **202**, etc. that tap off a selected portion of the signals corresponding to fundamental, second, third and other harmonics. These sliders all connect to the electrical output lead L_1 through isolation networks **204**, **206**, **208**, **210**, **212**, etc. These isolation networks prevent the signal across any one of the potentiometer resistors from being drained off through the other potentiometer resistors.

The sliders **194**, **196**, **198**, **200**, **202**, etc. can be adjusted for desired strength of harmonics thus to synthesize any desired voice. A second set of potentiometer resistors **214**, **216**, **218**, **220** etc. is provided that cooperate with the electrical output L_2 and the channel O_2 for synthesizing a different voice. As many additional sets of potentiometer resistors and related circuit components may be provided as there are output channels. In this instance, only three output channels have been shown, but as many may be provided as desired. The sliders for the potentiometer resistors may be externally accessible for adjustment by the organist, or they may be preset with only the stop switches W_1, W_2, W_3, etc. accessible; optionally, some may be accessible and others not. In any case, by virtue of the isolation networks, a number of voices may be simultaneously operative without danger of short circuits or excessive robbing of signals.

Typical isolation networks are illustrated in FIGS. 6 and 7. In FIG. 6, a transistor amplifier **222** is illustrated with its base connected to the tap **194**. The transistor has its own bias resistor **224**. The electrical output lead L_1 connects to the collector of the transistor. Similarly, transistor amplifiers are provided for the other potentiometers. A common load resistor connects the collectors to a suitable source. A common D.C. blocking condenser **228** is interposed in the lead L_1. The transistors provide the requisite high input impedance for isolation purposes while the output impedance is sufficiently low for coupling purposes.

In FIG. 7, a simple resistive network is provided. A relatively high resistance as at **230** is interposed between each slider as at **194**, and the output lead L_1. A common low impedance terminating resistance **232** is provided for all of the signals from the set.

In practice, one of the phase shift networks or devices **24** in FIG. 1 can be deleted without sacrifice in function since the other networks produce the requiste relative shift. Similarly one of the networks **178**, **180** or **182** in FIG. 5*a* may be deleted. In FIGS. 2 and 4, one device in each group can be deleted without change in function. To ensure appropriate separate identities, the phase shift devices are, of course, asynchronous with respect to each other.

The inventor claims:

1. In an electronic organ: a set of tone generators; a plurality of shaping circuits in circuit with said tone generators for producing a variety of voices; a plurality of separate output channels for the respective voices, each including its own transducer means, substantially all of said output channels including dynamic phase shift means whereby the said voices acquire separate identities as they are translated by said transducer.

2. The combination as set forth in claim **1** in which each output channel includes a stop or tab switch for optionally conditioning the output channel for operation.

3. The combination as set forth in claim **1** in which said dynamic phase shift means produce an indeterminate frequency characteristic within a limited range.

4. The combination as set forth in claim **1** in which

each output channel includes companion parts for impulses corresponding to notes in alternate half tone relationship.

5. The combination as set forth in claim **1** in which groups of tone generators are provided with their individual shaping circuits.

6. The combination as set forth in claim **1** in which each output channel includes companion parts for impulses corresponding to notes in alternate half tone relationship; and in which groups of tone generators are provided with their individual shaping circuits.

7. The combination as set forth in claim **1** in which the voice shaping means consists of circuits that mix a plurality of sine waves in harmonic relation in various strengths.

8. In an electronic organ: two groups of output circuits, at least each output circuit except one in each group including a dynamic phase shift device; each output circuit including a transducer and a stop switch; a set of generators for notes in a musical range; key switches for the generators; a plurality of circuit means connecting each generator in alternate half tone relationship to output circuits of one group; circuit means connecting each generator in the other alternate half tone relationship to the output circuits of the other group; and shaping circuits in each of said circuit means.

9. The combination as set forth in claim **8** in which said circuit means branch to provide separate circuits for limited groups of generators, each branch having its said shaping circuits common to the generators of the group.

10. In an electronic organ: a set of tone generators; a plurality of separate output channels each including a transducer; circuit means deriving from the generators, a plurality of distinct voices, and connected to said output channels; substantially all of said output channels including dynamic phase shift means whereby said voices acquire separate identities as they are translated by said transducers.

11. The combination as set forth in claim **10** in which each of said output channels includes its own shaping circuit for imparting the characteristic voice to the corresponding channel.

12. The combination as set forth in claim **10** together with: a set of playing keys corresponding to notes in a musical range; the generators of said set producing substantially sinusoidal impulses corresponding to said notes; a set of bus bars for translating harmonic components; a set of key switches for each of said keys and cooperable with said bus bars respectively; connections between the key switches and the generators for applying to said bus bars signals corresponding to the harmonic components of the key; a set of potentiometer resistors for each of said output channels, and connected respectively to the bus bars for deriving signals therefrom; sliders for each of the potentiometer resistors; and individual isolation networks connecting each slider to the corresponding output channel.

13. The combination as set forth in claim **12** in which said isolation networks comprise transistor amplifiers having a high input impedance and a low output impedance.

14. The combination as set forth in claim **12** in which said isolation networks comprise high impedance elements.

No references cited.

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U.S. Cl. X.R.

84—1.11, 1.19, 1.22