

July 23, 1963

J. R. BRAND ET AL

3,098,407

tone filters

Filed June 20, 1960

3 Sheets-Sheet 1

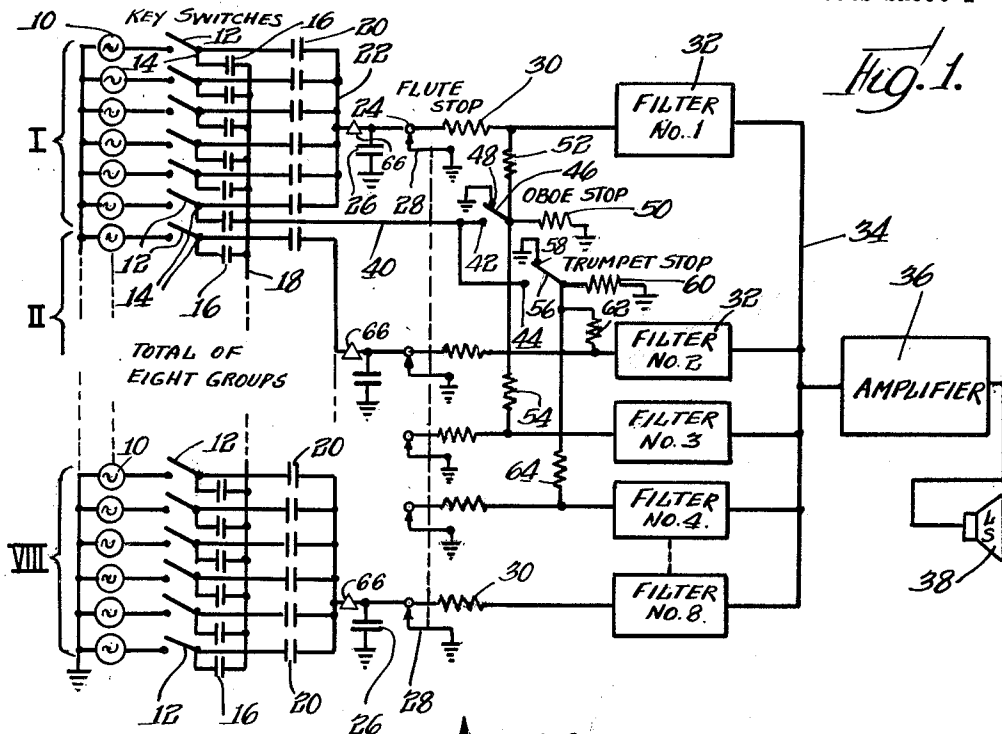


Fig. 5.

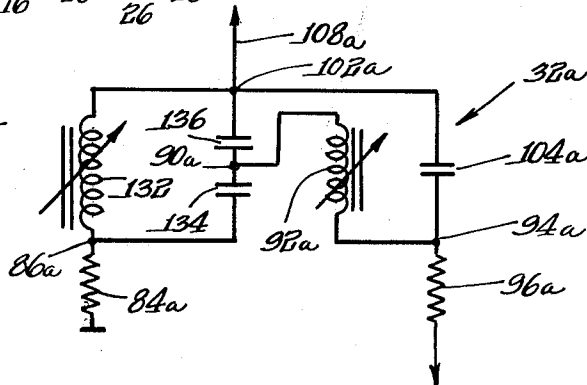
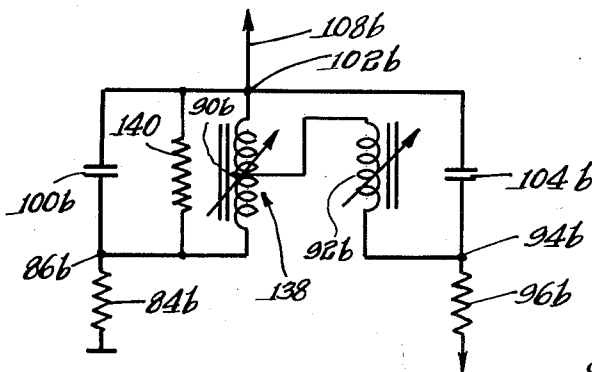


Fig. 6.



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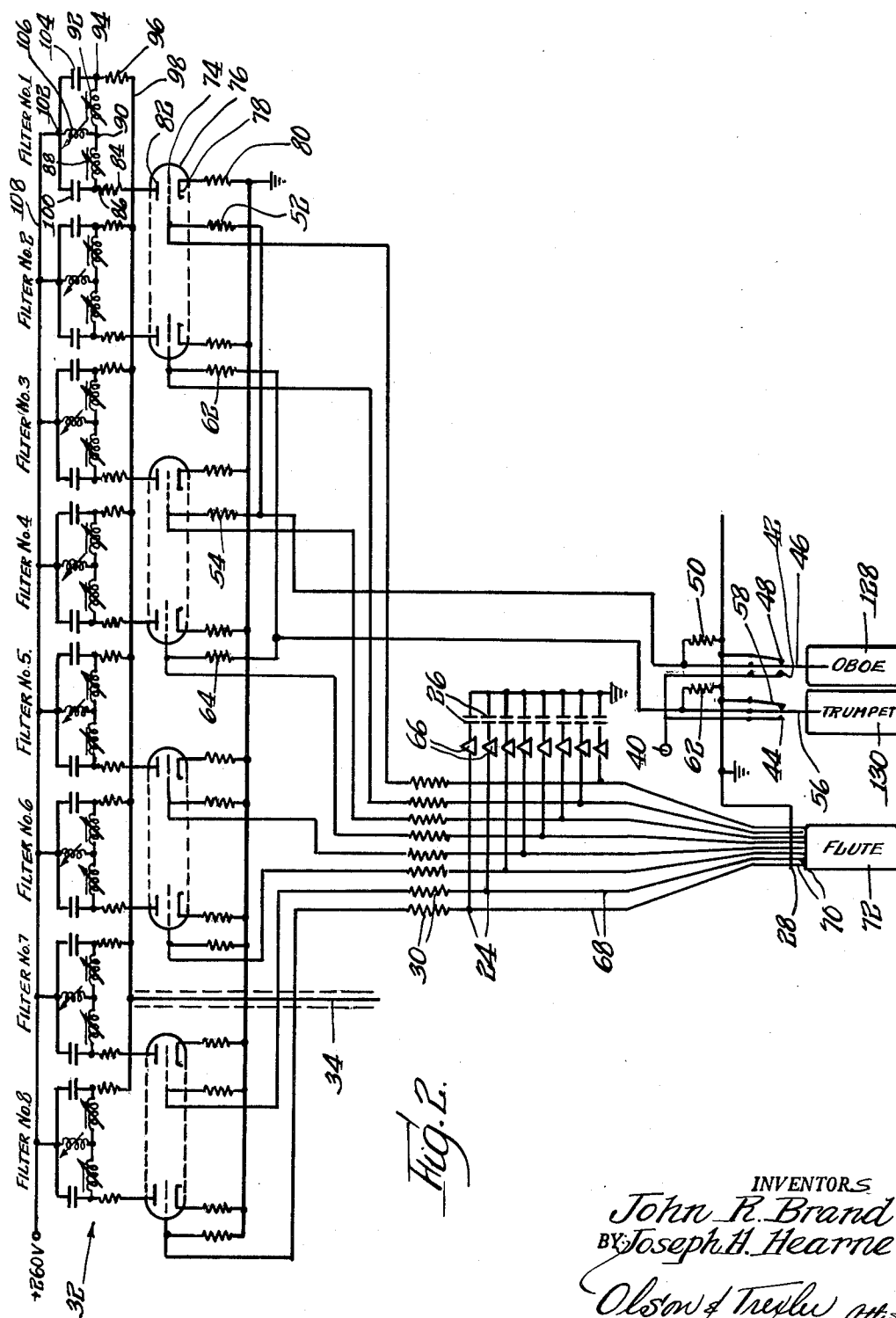
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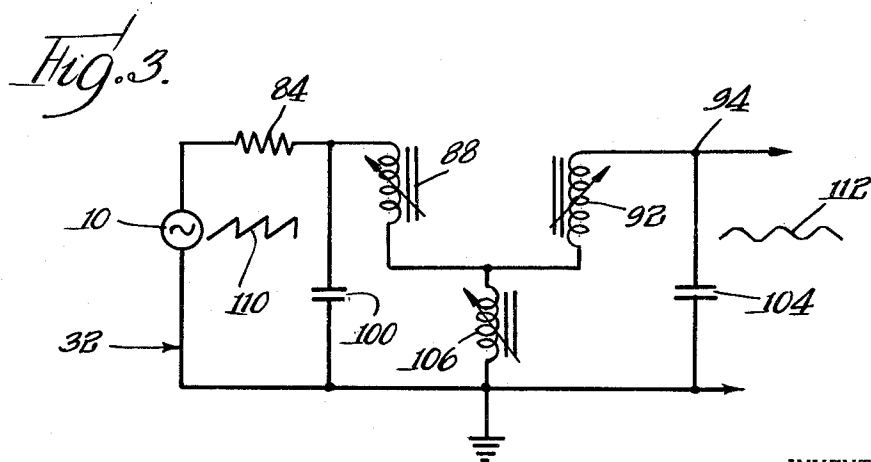
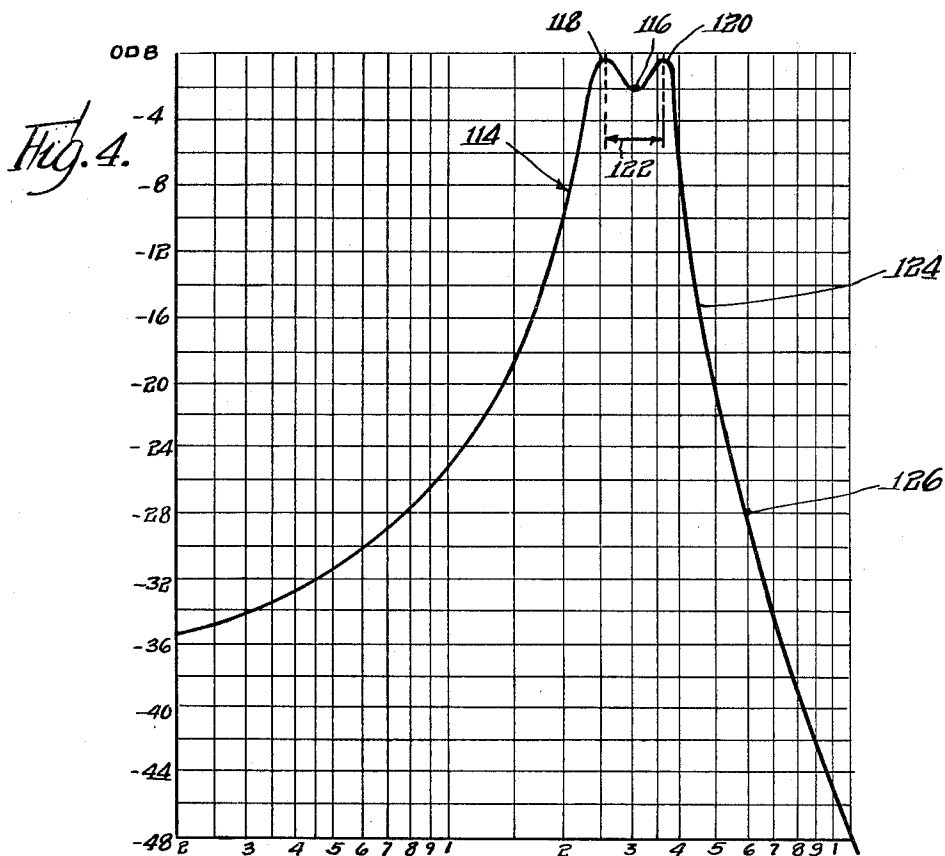
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TONE FILTERS

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3 Sheets-Sheet 3



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3,098,407

1 TONE FILTERS

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7 Claims. (Cl. 84—1.11)

This invention relates generally to the synthetic production of musical tones, and more particularly to the control of tone oscillations in an electronic organ by means of wave shaping filters.

It is known that musical tones can be produced synthetically by generating "messy" oscillations, i.e., oscillations which are rich in harmonics. Each note then can be individually filtered to provide the desired harmonic content, whereby to simulate desired musical tones. Unfortunately, this requires a rather large number of filters. Furthermore, if each note is to be capable of producing or simulating tones corresponding to different instruments, as, for example, the various voices of an organ, the number of filters required is multiplied. Suitable filters are expensive, and obviously require a certain amount of space. As a result, electronic organs in the past have generally been large and expensive, or restricted in quality, or in the number of voices that can be produced. Accordingly, it is an object of this invention to provide an electronic musical instrument having a relatively small number of tone filters, each of which is effective for a group of notes, thereby reducing the requisite number of filters.

More specifically, it is an object of this invention to provide an electronic musical instrument having filters therein each of which produces the fundamentals with substantially equal intensity of a substantial number of notes, and which substantially eliminates the harmonics of all of such notes.

It is yet another object of this invention to provide an electronic musical instrument having a plurality of filters for substantially eliminating the harmonics of respective groups of notes to provide flute tones, wherein all of the notes of the instrument are selectively applied to certain only of the filters to produce additional organ voices with shifting harmonic structure.

It is a still further object of this invention to provide an electronic musical instrument having filters therein each of which has a predetermined, rather broad response range with a relatively sharp cut off at the upper end of the range and a relatively less sharp cut off at the bottom of the response range.

Other and further objects and advantages of the present invention will be apparent from the following description when taken in connection with the accompanying drawings wherein:

FIG. 1 is a block wiring diagram illustrating a musical instrument constructed in accordance with the principles of this invention;

FIG. 2 is a fragmentary wiring diagram of a portion of the instrument;

FIG. 3 is a schematic wiring diagram of one of the filters showing the input and output thereof;

FIG. 4 is a response curve of one of the filters;

FIG. 5 is a schematic wiring diagram showing a modification of the filters; and

FIG. 6 is another schematic wiring diagram showing a further modification.

Referring now in greater particularity to the drawings, and first to FIG. 1, there will be seen a plurality of tone generators schematically indicated at 10. The generators may be of any suitable type producing a wave rich in harmonics. In the illustrative embodiment, there are forty-

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eight tone generators. These tone generators are divided into eight groups of six notes each, the groups being indicated by I-VIII. As will be obvious, six-note groups each comprise a half octave of semi-tones.

Each of the tone generators 10 is connected through a corresponding switch 12 to a junction 14. The key switches are normally open. All of the junctions 14 are connected through similar capacitors 16 to a common collector or bus 18, of which more will be said hereinafter. The junctions 14 are also connected in the aforementioned six-note groups through respective capacitors 20 to eight collectors or busses 22 which are respectively connected to contacts 24. The collectors 22 and contacts 24 are respectively shunted to ground by capacitors 26. All of the contacts 24 normally are engaged by a common movable switch arm 28 which is shown schematically in FIG. 1 as a plurality of ganged arms. (The nature of the figure does not permit showing the arm as common.) The arm 28 is grounded. Accordingly, as long as a switch 28 is closed, any oscillation appearing at 24 is shunted to ground. All of the switches 28 are ganged, as indicated, and comprise a flute stop.

The fixed switch contacts 24 are respectively connected through resistors 30 to filters 32. There are eight such filters respectively labeled as 1-8. All of the filters are connected on the output side to a common collector or bus 34. This bus is, in turn, connected to an amplifier 36, and the amplifier is connected to a loud speaker 38. All of the foregoing parts are preferably mounted in an organ console, as will be apparent. The filters 32 are respectively rather sharply tuned, dropping off quite rapidly on the high side of the tuned range, whereby substantially to eliminate the harmonics, and thus to produce a flute tone.

Filters 1-4 are subjected to a double use. Thus, the common collector or bus 18 is connected by means of a wire 40 to a fixed switch contact 42 of an oboe stop, and to a fixed switch contact 44 of a trumpet stop. The oboe stop switch further includes a movable switch arm 46, which in its rest position engages a grounded fixed switch contact 48. The switch arm 46 further is shunted to the ground by a resistor 50. The switch arm 46 is connected through a resistor 52 to filter 1 of the filters 32, and is further connected through a resistor 54 through filter 3.

The trumpet stop switch further includes a movable switch arm 56 which normally engages a grounded fixed contact 58, and which is shunted to ground by a resistor 60. The movable switch arm 56 is connected through a resistor 62 to filter 2 of the filters 32, and further is connected through a resistor 64 to filter 4.

Certain simplifications were made in connection with FIG. 1 for facility of illustration, as will be apparent with reference to the fragmentary detailed wiring diagram of FIG. 2. Thus, in FIG. 2, the input connections from the tone generators to the filters and associated structure are in groups of six, indicated at the triangles 66. These, of course, are shunted to ground by the capacitors 26. The fixed contacts 24 are not actually directly contacted by the grounding switch arm 28 as in FIG. 1, but are connected by wires 68 to movable contacts 70 fixed to a flute stop tablet 72. All of these contacts 70 are normally in engagement with a single fixed grounded contact 28, and are movable therefrom as the flute stop tablet 72 is manually manipulated.

The junctions or fixed switch contacts 24 are connected through the resistors 30 respectively to the control grids 74 of triode vacuum tubes 76. There are eight such triode vacuum tube sections, conveniently comprising the halves of dual triodes, such as a 12AX7. These tubes have been omitted from FIG. 1 for simplicity of illustration. The cathode 78 of each triode tube section is grounded through resistor 80, and the plate 82 is connected to the input of the respective filter 32.

All of the filters 32 are of the same configuration, although the values thereof are different. The input to each filter from the corresponding tube 76 is through a resistor 84 which is connected to a connecting point 86. The point 86 is connected through a variable inductance 88 to a point 90, and this point is connected to a variable inductance 92 to a filter output point 94. The point 94 is connected through a resistor 96 to a common bus or output line 98 which is connected to the cable 34, comprising a shielded lead.

Each point 86 further is connected through a capacitor 100 to a point 102. The point 102 is connected through another capacitor 104 to the point 94. In addition, the point 102 is connected through a variable inductance 106 to the point 90. The point 106 in each instance is also connected to a B+ bus line 108 supplied with potential at a +260 volts, whereby to provide plate potential for the tubes 76.

The resistors 84 comprise a part of the tube circuit, which is provided for amplification and isolation, and the resistors 96 are for purposes of isolation. Each filter actually comprises the inductances 88, 94 and 106, and the capacitors 100 and 104. The inductances 88 and 92 are not inductively coupled to one another, and inductive coupling in the filter is through the inductance 106.

The equivalent circuit of the filter 32 is seen in FIG. 3, wherein it will be observed that the output wave of the generator 10 is a saw-tooth wave 110. The filter converts this to essentially a pure sine wave 112, as perhaps will be best understood with reference to the filter response curve shown in FIG. 4.

The filter response curve, designated generally by the numeral 114, is a double humped curve, somewhat similar to an overcoupled tuned transformer. As will be observed, there is less than a 2 db difference between the amplitude of the center frequency 116, and the amplitude of the lower peak or hump 18 and the upper peak or hump 120. Thus, the frequency range indicated at 122 between the two peaks represents the frequency range of the fundamentals of the six notes fed into any filter. Response to the fundamentals of these six notes therefore is substantially uniform. The response curve drops off quite rapidly at 124, and it will be observed that at a point 126 which is twice the frequency of the median frequency 116, the curve is down 28 db from the reference point, and this is 26 db less than the median frequency. Thus, the second harmonic is for all practical purposes eliminated, as are all higher frequencies. Even considering the frequency at the first peak 118, the second harmonic is at least 20 db down, and the situation is even more favorable relative to the frequency at the second peak 120. Hence, a very realistic flute tone is produced.

It will be recalled that the trumpet and oboe stops are also connected to certain of the filters. Thus, in FIG. 2, the circle 40 represents the connecting wire 40 previously discussed in connection with FIG. 1. The switch arm 46 is moved by an oboe stop tablet 128, while the switch arm 56 is moved by a trumpet stop tablet 130. The resistors 52 and 54 leading from the oboe stop switch are respectively connected to the grids of the triode tubes 76 associated with the first and third filters. Similarly, the resistors 62 and 64 leading from the trumpet stop switch are connected to the grids 74 of the triode tubes 76 respectively associated with the second and fourth filters. Accordingly, when one or both of the oboe and trumpet stops are played, any or all of the notes generated are applied to two combinations of two filters each. Obviously, much of the range of all of the notes played falls outside the nominal response region 122 of any given filter. It might be expected that notes falling below the first peak of one of the filters to which the notes are applied would be attenuated sharply. This is not true, however. The fundamental is cut down, and perhaps also some of the harmonics, but some of the harmonics pass through in the peaked region. As a result, the apparent intensity is about

the same, but with greatly changed harmonic structure. As will be apparent, the harmonic structure will change from one note to another for any given filter or combination thereof. However, this phenomenon of changing harmonic structure is common in musical instruments.

The filters used in connection with the oboe and trumpet stops are those at the top of the range. Specifically, filter 1 of the filters 32 is tuned to the highest frequency of any of the filters. Thus, for the most part, the fundamentals, and sometimes certain of the lower harmonics will fall on the relatively shallow curve on the low frequency side of the peaked region, and will not be attenuated to nearly the extent that the harmonics are attenuated with the flute tones. Of course, in the upper frequency range, the harmonics may be more sharply attenuated with concomittent emphasis of the fundamentals, and perhaps one or two of the lowest harmonics. This also is not unusual in musical instruments, since in the higher ranges most musical instruments have a greatly diminished harmonic structure. In fact, it is often quite difficult to tell many instruments apart when they are played at the upper extremity of their ranges.

Certain electrical values are set forth hereinafter as exemplary, and it will be understood that where parts are duplicated the values are the same, unless otherwise specified.

Capacitor 16	-----microfarad--	.0047
Capacitor 20	-----do-----	.001
Capacitor 26	-----do-----	.047
Resistor 30	-----ohms--	470,000
Resistor 50	-----do-----	100,000
Resistor 52	-----do-----	100,000
Resistor 54	-----do-----	100,000
Resistor 60	-----do-----	100,000
Resistor 62	-----do-----	100,000
Resistor 64	-----do-----	100,000
Resistor 80	-----do-----	22,000
Resistor 84	-----do-----	100,000
Resistor 96	-----megohm--	one

As will be understood, the values of the circuit elements or components in the filters vary from one filter to another. The values for illustrative components of filter 1 and of filter 8 are set forth hereinafter, and it is believed that selection of proper values for the intermediate filters is within the scope of the skill of an expert in this art.

	Filter No. 1	Filter No. 8
Inductance 88	1.5	12
Inductance 92	.9	12
Inductance 106	.6	4.5
Capacitor 100	.015	.15
Capacitor 104	.015	.15

As is exemplified by the foregoing summary table, the capacitors 100 and 104 are always equal or balanced. However, the inductances are not. The values given for the inductances are nominal, and they vary somewhat one way or another, since the inductances are variable. Indeed, the double peak to the response curve is produced by proper adjustment of the inductance 106. As the inductance value of this inductance is increased, the initial single peak or hump becomes the double peak desired.

Modifications in structure but not in function, of the filters 32 are shown in FIGS. 5 and 6. Thus, in FIG. 5, wherein similar numerals are used to identify similar parts, with the addition of the suffix *a*, it will be seen that a variable inductor 132 connects the points 86a and 102a. The point 86a is connected to the point 90a by a capacitor 134 and the point 90a is connected to the point 102a by the capacitor 136. The point 90a remains connected to the point 94a by a variable inductor 92a, and the point 102a remains connected to the point 94a through a capacitor 104a. For filter 1, inductor 132 is .3 henry, inductor 92a

is .3 henry, capacitor 136 is .015 mf., as is capacitor 104a, and capacitor 134 is .056 mf. The values increase going to successive filters. The modification of FIG. 5 works in a manner somewhat similar to that previously described, and is somewhat less expensive in production, due to the elimination of one inductance. As is known, capacitors are generally cheaper than inductances. As a result, there is a net gain although one capacitor has been added in the modified circuit.

Another modification of the invention is shown in FIG. 6. In this modification, a single variable inductor 138 is provided, and is tapped at 25% from the bottom thereof, the tap representing the point 90b. The bottom end of the conductor is connected to the point 86b, and the upper end to the point 102b. A resistor 140 may be connected in parallel with the conductor, but it is not in every instance necessary. The resistance 140 is used to adjust the Q of the inductance 138 to the desired value. The value of the resistor 140 may vary for this purpose, but is generally on the order of 150,000 ohms. A capacitor 100b is connected in parallel with the resistor 140, the lower end thereof being connected to the aforesaid point 86b, and the upper end thereof being connected to the aforesaid point 102b. The load resistor 84b is connected to the point 86b, and to the accompanying plate, as in previous embodiments. A variable inductor 92b is connected to the tap 90b and to the point 94b. A capacitor 104b is connected from the point 102b to the point 94b, and the point 94b is connected to the resistor 96b leading to the output. The results produced by the circuit of FIG. 6 are similar to those previously described, and the cost is still less, since only two inductors and two capacitors are used. Even in instances where the resistor 140 is found necessary, there is a net savings, since resistors are, by and large, the cheapest circuit elements.

It will now be apparent that there has herein been disclosed novel filtering of complex generated oscillations to produce various desired tones in a synthetic musical instrument. In particular, elimination of substantially all but the harmonics is accomplished to produce flute tones, with the number of requisite filters being only a small fraction of the total number of notes. Further voices of an organ are produced in a most economical fashion by dual use of the flute filters to produce also trumpet and oboe tones.

The specific examples of the invention as herein shown and described are for illustrative purposes only. Various changes in structure will no doubt occur to those skilled in the art, and will be understood as forming a part of the invention insofar as they fall within the spirit and scope of the appended claims.

The invention is claimed as follows:

1. A tone producing system for an electronic musical instrument comprising a plurality of generators corresponding to the notes of such a musical instrument and each producing a complex electrical oscillation, means connecting said generators in groups of sequential tones, a plurality of tone filters each tuned to pass the fundamentals of a corresponding group of generators and to discriminate against the harmonics thereof, means respectively connecting said groups of generators to said filters, amplifier means connected to said filters, electro-acoustic translating means connected to said amplifier means for converting the amplified oscillations into audible musical tones, playing key operated means interconnected with said generators for selectively rendering said generators effective, a common collector, means connecting all of said generators to said common collector, and switch means for connecting said common collector to at least one of said filters.

2. A tone producing system as set forth in claim 1 wherein the switch means connects the common collector to a plurality of filters.

3. A tone producing system as set forth in claim 1 wherein the filter to which the switch means connects the

common collector is tuned to pass the fundamentals of a higher frequency group of generators.

4. A tone producing system for an electronic musical instrument comprising a plurality of generators corresponding to the notes of such a musical instrument and each producing a complex electrical oscillation, means connecting said generators in groups of sequential tones, a plurality of tone filters each tuned to pass the fundamentals of a corresponding group of generators and to discriminate against the harmonics thereof, means respectively connecting said groups of generators to said filters, a common collector, means connecting said common collector to all of said generators, switch means for connecting said common collector to at least one of said filters, said filters each having a predetermined response range at least coextensive with the frequency range of the group of tone generators connected thereto and having a sharp upper cut off and a relatively less sharp lower cut off, amplifier means connected to said filters, electro-acoustic translating means connected to said amplifier means for converting the amplified oscillations into audible musical tones, and playing key operated means interconnected with said generators for selectively rendering said generators effective.

5. A tone producing system as set forth in claim 4 wherein each filter has a double peaked response curve, the peaks of said curve being separated by at least the frequency range of the group of generators connected thereto.

6. A tone producing system for an electronic musical instrument comprising a plurality of generators corresponding to the notes of such a musical instrument and each producing a complex electrical oscillation, means connecting said generators in groups of sequential tones, a plurality of tone filters each tuned to pass the fundamentals of a corresponding group of generators and to discriminate against the harmonics thereof, means respectively connecting said groups of generators to said filters, amplifier means connected to said filters, electro-acoustic translating means connected to said amplifier means for converting the amplified oscillations into audible musical tones, playing key operated means interconnected with said generators for selectively rendering said generators effective, a common collector, means connecting a plurality of said generators to said common collector, and switch means for connecting said common collector to at least one of said filters.

7. A tone producing system for an electronic musical instrument comprising a plurality of audio frequency generators corresponding to the notes of such a musical instrument and each producing a complex electrical oscillation, means connecting said generators in half-octave groups of sequential semi-tones, a plurality of band pass tone filters each comprising interconnected inductance and capacitance elements and tuned to pass the fundamentals of a corresponding half-octave group of generators and to discriminate against the harmonics thereof, each filter having at least two inductances and being over-coupled to have a double peaked response curve with the frequency range between the peaks being substantially equal to the frequency span of the fundamentals of a corresponding half-octave group of generators, each filter responding substantially uniformly over the tonal range of the fundamental frequencies of the half-octave group of generators connected thereto and having a sharp upper cut-off with a relatively less sharp lower cut-off, means respectively connecting said half-octave groups of generators to said filters, amplifier means connected to said filters, electroacoustic translating means connected to said amplifier means for converting the amplified oscillations into musical tones, and playing key operated means interconnected with said generators for selectively rendering said generators effective.

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