

Jan. 13, 1970

W. R. AYRES

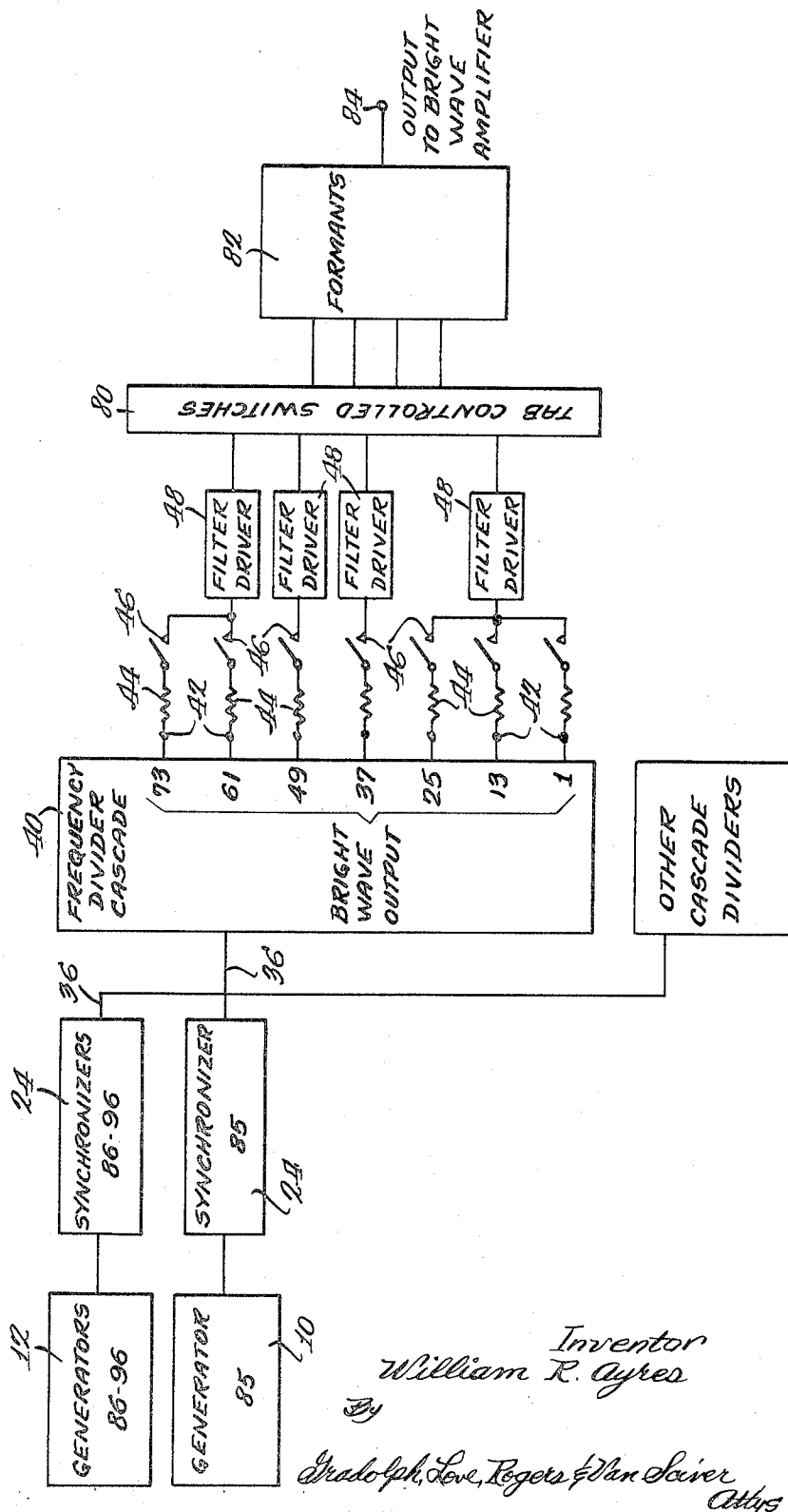
3,489,842

ELECTRICAL MUSICAL INSTRUMENT

Filed June 24, 1966

4 Sheets-Sheet 1

Fig. 1.



Inventor
William R. Ayres
By
Gradolph, Love, Rogers & Van Siver
Attys

Jan. 13, 1970

W. R. AYRES

3,489,842

ELECTRICAL MUSICAL INSTRUMENT

Filed June 24, 1966

4 Sheets-Sheet 2

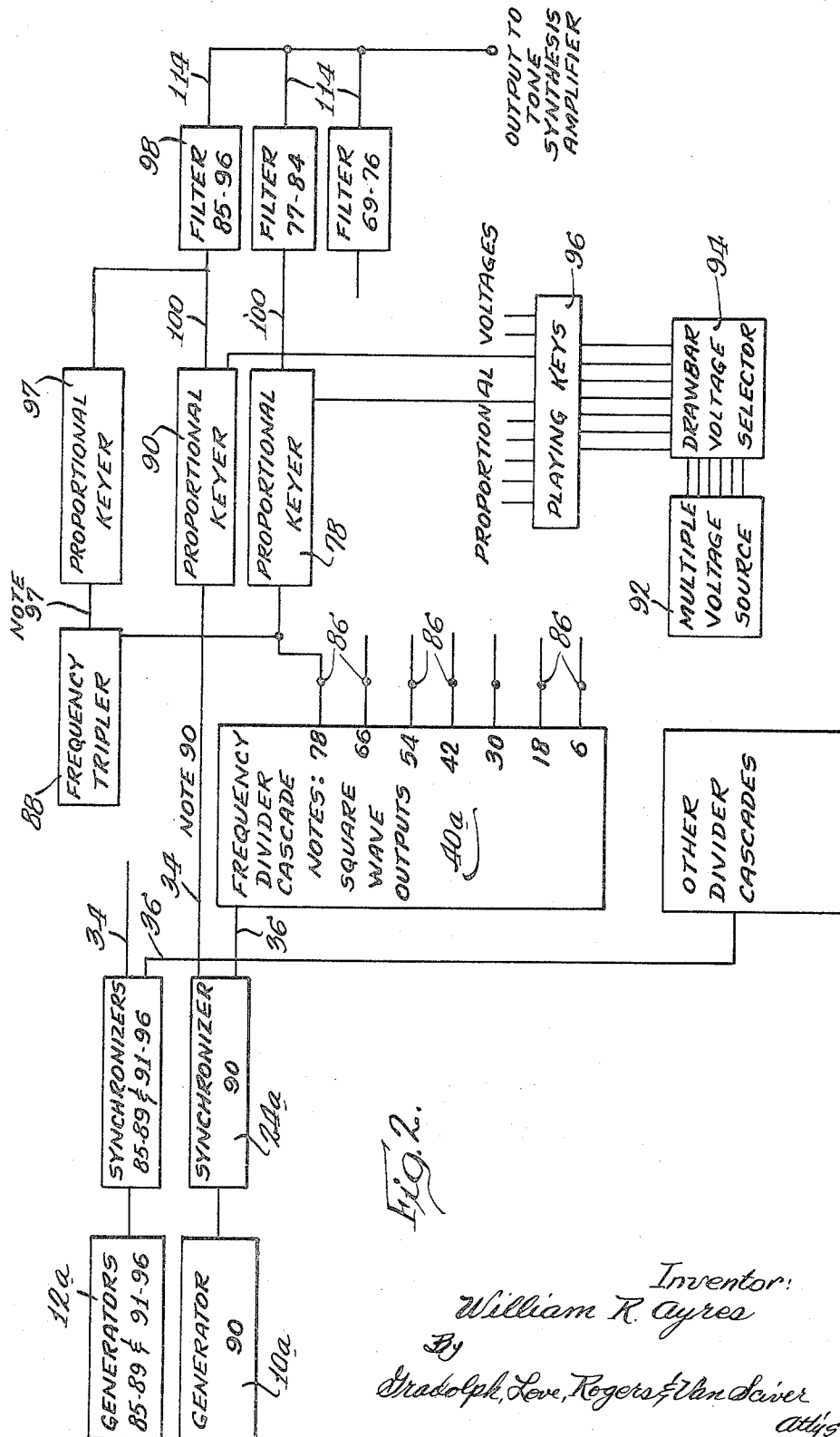


Fig. 2.

Inventor:
William R. Ayres
By
Gladolph, Love, Rogers & Van Dine
attys

Jan. 13, 1970

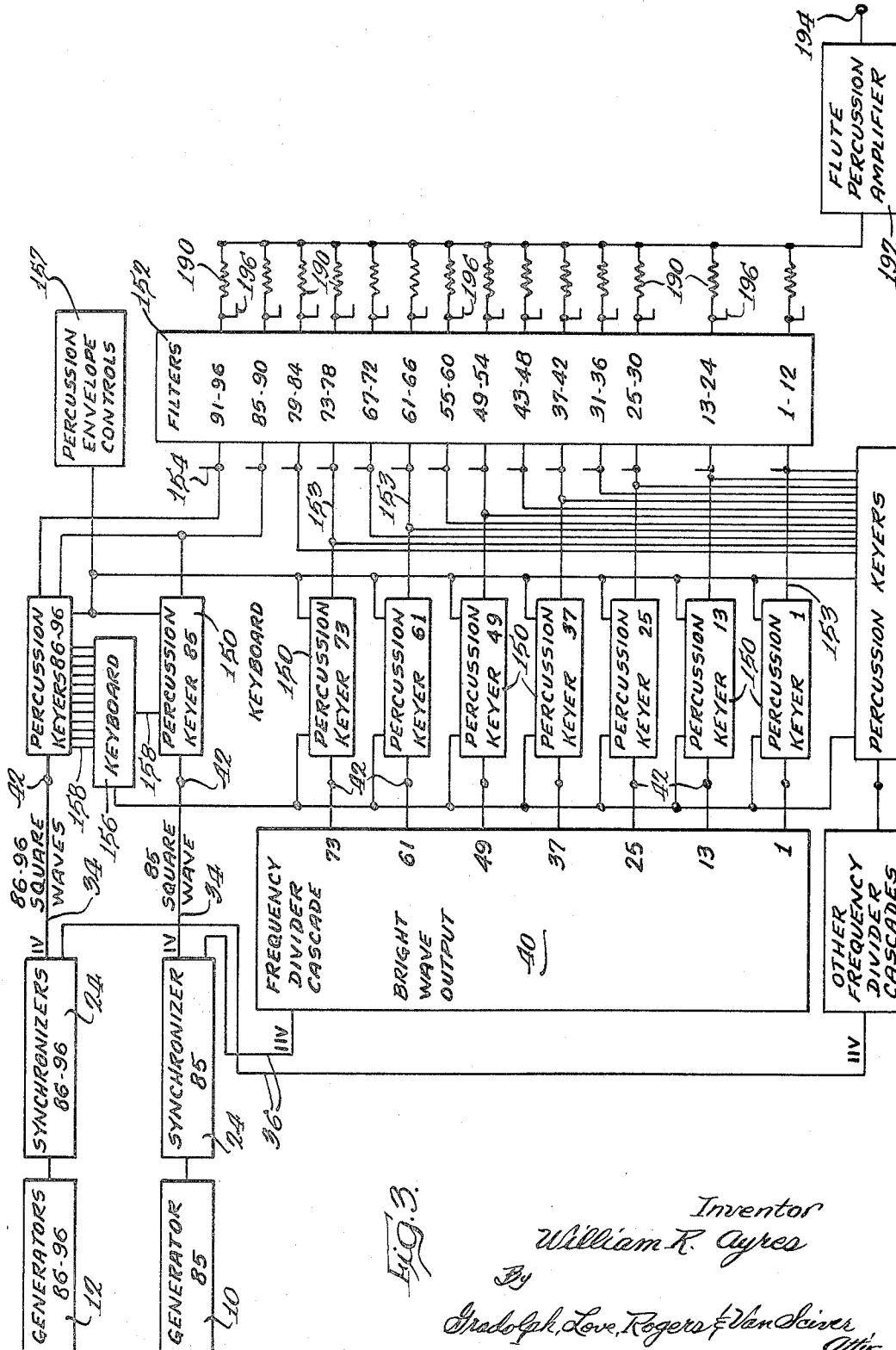
W. R. AYRES

3,489,842

ELECTRICAL MUSICAL INSTRUMENT

Filed June 24, 1966

4 Sheets-Sheet 3



Jan. 13, 1970

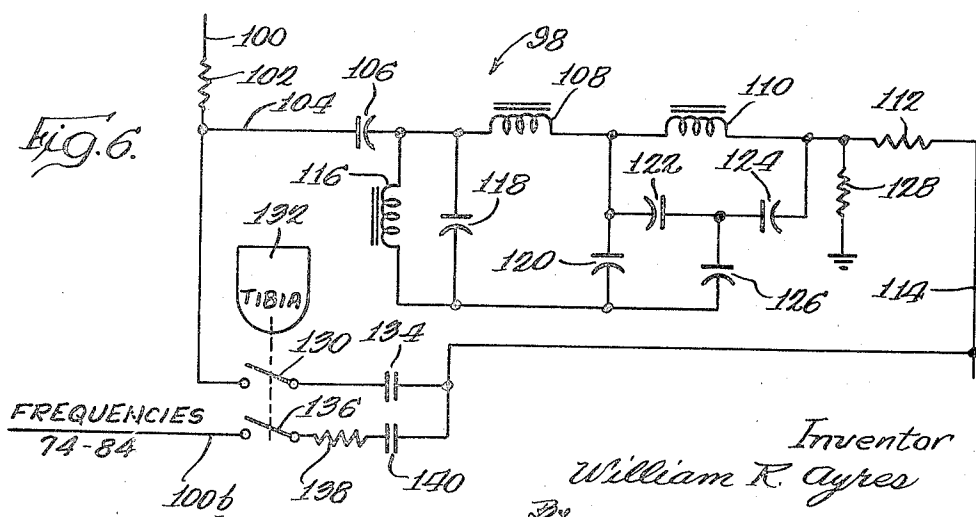
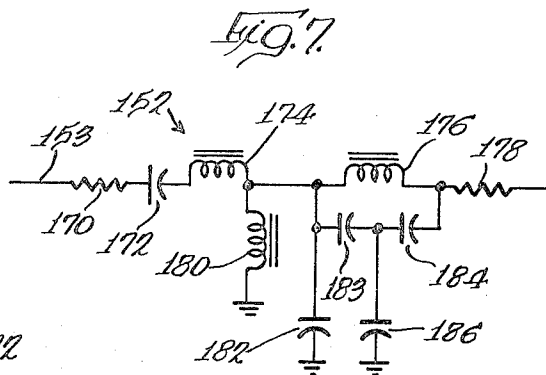
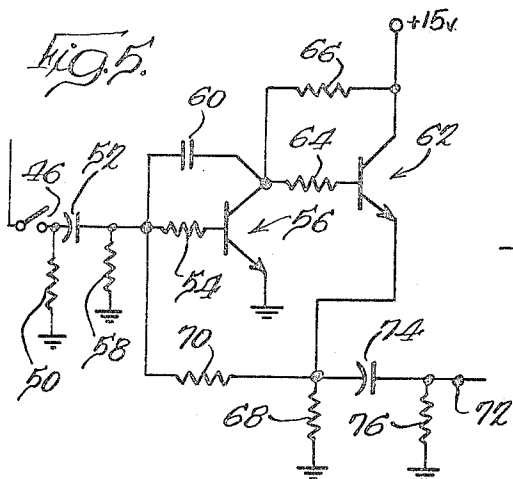
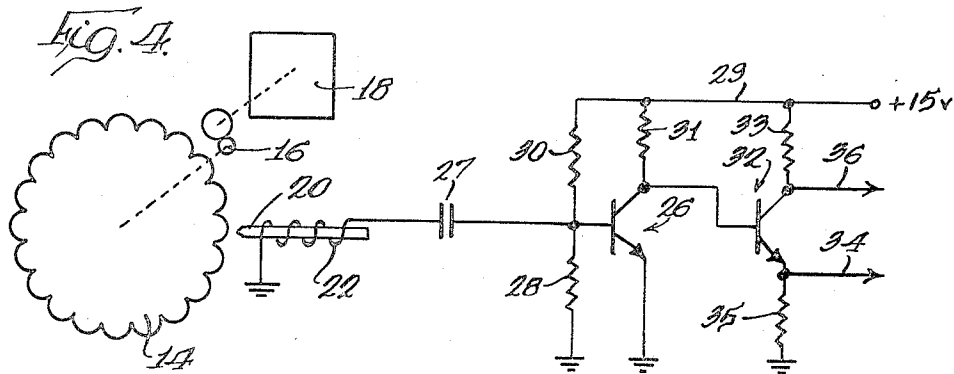
W. R. AYRES

3,489,842

ELECTRICAL MUSICAL INSTRUMENT

Filed June 24, 1966

4 Sheets-Sheet 4



Inventor
William R. Ayres
By

Gradolph Love Rogers & Van Orner
Attys

1

3,489,842

ELECTRICAL MUSICAL INSTRUMENT

William R. Ayres, Park Ridge, Ill., assignor to Hammond Corporation, Chicago, Ill., a corporation of Delaware

Filed June 24, 1966, Ser. No. 560,217

Int. Cl. G10h 1/00

U.S. Cl. 84—1.01

7 Claims

ABSTRACT OF THE DISCLOSURE

A musical instrument system in which synchronously driven tone wheel generators supply a master-octave of note signals which are locked together and to the power supply frequency. Frequency dividers in cascade supply successively lower locked in octaves and are actuated by driver circuits which amplify the signals from the master generators. The frequency dividers supply both bright waves and square waves. The bright waves are formanted and the square waves are filtered to supply sine waves used in synthesis. The output from the drivers is also used and the third harmonic of certain frequency dividers obtained by filtration is used for certain high note signals. Controls provide for mixing signals as desired and for percussion.

This invention relates to electrical musical instruments of the keyboard type. More particularly the principal aspect of the invention has to do with the provision of an instrument which combines the advantages of the electric tone synthesis type organ with the advantages present in organs which use the electronic formant approach.

It is the principal object of this invention to provide a novel, completely tone-stable organ which may, nevertheless, have the electronic formant approach to tone production.

An additional object is to provide a novel, tone-synthesis type organ which uses an electronic tone generating system.

Yet another object is to provide an organ of fixed pitch which combines the features of the tone synthesis and the formant approaches to tone signal production.

Still another object is to provide a novel organ system which has the features outlined above along with ancillary features which contribute to the musical effect.

Other objects and advantages will become apparent from the following description of a preferred embodiment of the invention.

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

FIG. 1 is a block diagram illustrating in simplified form one of the organ sections used in the instrument of this invention;

FIG. 2 is a simplified block diagram illustrating another of the organ sections;

FIG. 3 is a simplified block diagram illustrating still another organ section;

FIG. 4 is a schematic diagram illustrating the tone generation synchronizing system; and

FIGS. 5, 6 and 7 are schematic diagrams of circuit details incorporated in the instrument.

There are two general types of electric organs, and almost all currently manufactured instruments fall into one or the other of these categories.

One of these is the tone synthesis organ and is the result of logical development of the arrangement set forth in Hammond Patent No. 1,956,350. This system uses a multiplicity of tone signal generators, one for each of the fundamental note frequencies, plus some extras, each of which generates a sine wave signal. Various combinations are then made of these sine wave signals on an adjustable amplitude basis to simulate various musical instruments

2

and other special effects. The theory upon which this organ approach is based is that any complex musical tone can be analyzed into a combination of the fundamental and certain of its harmonics and subharmonics, which are peculiar to the particular tonal effect. Thus, the tone can be synthesized by a recombination of the appropriate sine wave signals.

The other approach—known generally as the formant system—generates complex tone signals which preferably have a declining series of all harmonics, and then, by the use of various filter or resonant circuits or “formants,” various portions of the harmonic structure are emphasized or reduced to produce the desired ultimate effect.

Each of these systems has advantages, some of which are discussed below, since it is believed that this will promote understanding of the invention.

Generally speaking, the formant approach leads to a more extensive inclusion of the higher harmonic series at lower cost. A sawtooth wave, or any near approximation thereof, which is available from relatively simple generators, theoretically includes all harmonics in a regularly declining series, and, as a practical matter, it is no serious problem to obtain all harmonics within the hearing range. To duplicate this with the synthesis approach requires a great number of generators, and the system, therefore, becomes complex and expensive. Also, the fact that the formant system uses complex wave generators results in a natural series of harmonics, which method can impart a greater fullness of sound when chords are played.

On the other hand, more precise control over the harmonic mixtures is afforded by the tone synthesis approach, particularly for the production of special tonal effects. For example, with the synthesis system one may emphasize particular harmonics to a degree not practically achievable in a conventional formant organ. Further, in the presently described system, one may add selectable degrees of tempered harmonic content to formanted bright voices, and produce pleasing interplays (beats) of natural and tempered harmonics. There are other advantages ascribable to each of the systems, but the above will serve to indicate the value of an instrument which combines the best features of the two systems. This the instrument of the present invention does, as will appear presently.

Referring to FIG. 1, where a portion of the system is shown in block form, a generator for note 85 is shown at 10, whereas similar generators for notes 86 through 96 are indicated at 12. These generators together provide notes for a single octave at the high frequency end of the instrument scale, extending, in the present instance, in round members, from note 85 (which is C at 4185 Hz.) to note 96 (which is B at 7902 Hz.). Those not familiar with this note designation system are referred to the chart in the previously mentioned Hammond Patent No. 1,956,350.

The generators 10–12 for notes 85 to 96 are all of the type shown in FIG. 4. Essentially, each consists of a rotatable tone wheel 14 driven at a constant appropriate rotational speed by a connection through an appropriate speed changing system 16 to a synchronous electric motor 18. The edge of the wheel 14 is serrated, and as it rotates in the proximity of a permanent magnetic pole 20, it generates an alternating current signal of proper frequency in a coil 22 which is magnetically coupled to the pole piece 20. Signal generators of this type, and their positive synchronization relative to each other and to the normal 60 Hz. power supply, are now well understood in this art, but those requiring more specific information are referred to Hammond Patent No. 1,956,350.

Ordinarily, in a synthesis type organ, the sine wave signals generated by the tone wheels are appropriately mixed to give the desired proportions of fundamental and

harmonic constituents. Here, however, they are used together with synchronizer or intercoupling circuits at 24 principally to drive a group of frequency divider cascades as will appear. There is a synchronizer for each tone wheel generator system, and each comprises a two-stage over-driven amplifier as shown in FIG. 4.

Each of these synchronizers comprises an NPN transistor 26 having its base connected through a capacitor 27 to the output of coil 22. The base is also connected to ground through resistor 28 and to a $+15$ v. lead 29 through resistor 30. The emitter is grounded, and the collector is connected to lead 29 through resistor 31 and to the base of a second transistor 32. The collector of transistor 32 is connected to lead 29 through resistor 33 and to an output lead 36. The emitter is connected to a second output lead 34 and to ground through resistor 35.

Approximate values for this circuit may be as follows: Transistors 26 and 32 are type 2N-3397. Resistors are as follows: 28, 4.7K; 30, 68K; 31, 22K; 33, 15K; and 35, 22 ohms. The capacitor at 27 has a value of .047 μ f.

The output of coil 22 is essentially a sine wave at about 0.2 v. RMS, but the amplifier outputs at 36 and 34 are essentially square waves at the same frequency, but at a much higher level, with the level at lead 34 being considerably lower than at 36.

Referring back to FIG. 1, the higher voltage output lead 36 from each of the synchronizers 24 is connected to drive a cascade of frequency dividers which supply lower frequency octavely related tone signals for the instrument. To simplify the drawing, the synchronizer for frequency 85 is shown connected to drive divider cascade 40, whereas the other synchronizers, for frequencies 86 to 96 are shown as grouped and connected to the box labeled "Other divider cascades." It will be understood, however, that each of the synchronizers for signals 86 to 96 is connected to a separate cascade which is the counterpart of cascade 40.

In the divider cascade, which preferably is of the type forming the subject matter of Schrecongost patent application Ser. No. 455,820, or Schrecongost Ser. No. 542,625, signal frequency 85, which is C at about 4186 Hz., is divided by two, so as to give frequency 73, which is C at about 2093, and this signal is again divided to give frequency 61, which is C at about 1046, and so on. Thus, from this synchronizer and its divider cascade signals for the following notes are available: 85, 73, 61, 49, 37, 25, 13, and 1, note 1 being C at about 32.7 Hz. The other synchronizers and their cascades together similarly supply the other note signals within the range of the instrument.

The advantage in using the divider systems of the previously mentioned Schrecongost applications is that each stage thereof provides a square wave output for driving the next stage in the cascade, and also an all-harmonic (sawtooth) output having the advantages previously mentioned in the discussion of formant type organs. In FIG. 1 the sawtooth output connections are shown, but use of the square wave signals as note signal sources is also made in this instrument as will appear presently in connection with the discussion of FIG. 2.

In FIG. 1 each of the divider 40 bright wave output terminals 42 is connected through individual isolation resistors 44 of about 10K ohms to individual playing key contacts 46, which in turn are connected to a group of filter drivers at 48. One of the filter drivers is shown in FIG. 5, where it will be seen that a representative playing key switch 46 is connected to ground through resistor 50 and by way of capacitor 52 and resistor 54 in series to the base of NPN transistor 56. Common point between resistor 54 and capacitor 52 is also connected to ground through resistor 58 and to the collector by way of capacitor 60. The emitter is grounded and the collector is connected to the base of a second NPN transistor 62 by way of resistor 64 and to transistor 62 collector and a $+25$ v. supply by way of resistor 66. The emitter of transistor 62 is

connected to ground through resistor 68 and back through resistor 70 to the common point between resistors 58 and 54. The emitter of transistor 62 is also connected to the output terminal 72 by way of capacitor 74, the terminal 72 also being connected to ground through resistor 76.

It is not necessary to use a separate filter driver for each frequency, since the purpose of these circuits is to provide amplification prior to filtration and filtration is accomplished in groups of adjacent frequencies. Thus, about five or six adjacent semitones—about half an octave—pass through a single filter driver. For those not familiar with the harmonic content of various wave forms it should be noted that saw tooth or bright waves contain all harmonics whereas square waves, sometimes referred to as dull waves contain only the fundamental and odd harmonics, the even harmonics being essentially missing. In fact, at the upper and lower ends of the musical scale more than half an octave can share one filter, because of the ear's poor frequency discrimination in these areas. Specifically, in the present system, frequencies 73 to 61 feed into one filter, bright wave frequencies above 73 not being needed in this portion of the instrument. Other filters are supplied for the following frequency groups: 55 to 60, 49 to 54, 43 to 48, 37 to 42, 31 to 36, and 1 to 30. The filter drivers raise the amplitude of the signals from about 0.3 v. P to P to about 15 v. P to P.

Valves in this circuit may be: Transistors, type 2N-3395. Resistors, 50, 10K; 58, 15K; 54, 100 ohms; 64, 1K; 66, 18K; 68, 4.7K; 70, 120K; 76, 100K. Capacitor 60, .1 mf.

The values of capacitors 52 and 74 are the same and change with the frequency group, and are as follows in μ f.: group 73-61, 1.0; 55-60, .47; 49-54, .33; 43-48, .22; 37-42, .15; 31-36, .1; 1-30, .075.

Each of the filter drivers feeds its signal into an appropriate tab controlled switching system at 80 which, at the will of the organist, feeds the signals selectively into any appropriate collection of formants at 82 which need no special discussion, since their use and circuitry are well understood. From the formants 82 the signals pass to the bright wave output terminal 84, which is connected to any suitable output amplifier, swell control system, power amplifier and speaker, all of which may be conventional.

This segment of the system supplies the basic bright wave portion of the instrument, and although it is based upon bright wave signal producing oscillators of the electronic type, the entire system is locked in tune by the synchronous motor driven tone wheel generators 10 and 12 and synchronizers 24.

FIG. 2 illustrates the basic synthesis portion of the instrument. Here the same generators 10 and 12 are used, except that, for the purpose of showing a special feature, the F generator frequency 90 at about 5588 Hz., is illustrated separately at 10a rather than the C generator 10 of FIG. 1. The other generators in the group are indicated at 12a. Similarly, the F synchronizer is shown at 24a and the F frequency divider cascade at 40a. For a reason to appear presently, it is preferred to use the square wave signal outputs from the divider cascade rather than the bright wave signals. These signal outputs are shown at 86 and are labeled with their frequency numbers 78, 66, 54, 42, 30, 18, and 6. Since in this system it is desired to synthesize the higher harmonics of the fundamentals played, use is made of the lower voltage output terminals 34 of the synchronizers to supply frequencies 85 to 96, which are an octave above the highest frequencies available from the divider cascades. Since the highest note thus available is B 96, it is desirable to go one note higher. This is because it is traditional to have any foldback point or other top frequency point occur after a C.

In the present system this top C note at frequency 97, which is at about 8372 Hz., is obtained by taking F at note 78 and tripling its frequency. The result of this

activity gives C 97 within about two cents of its true value, and at this high frequency the difference is not perceptible. The frequency tripler 88 can be quite simple and needs no special description when it is appreciated that the starting point is a square wave at frequency 78, and that a square wave does not contain appreciable even harmonics. Thus, the first harmonic which occurs is at triple the fundamental frequency, and simple filtration will remove the fundamental and pass the third harmonic. Whether the odd harmonics above the third are removed is of minor consequence, since they will be above audibility in any event. Thus the full range of the generator system is from C 1 at about 32.7 Hz. to C 97 at about 8372 Hz., which is adequate to cover all requirements.

Each of the square wave tone signals from the generator system is connected to its individual proportional keyer, shown at 90. These keyers have the ability to pass a signal at a level which is proportional to the value of a D.C. keying voltage applied thereto. A proportional keyer which accomplishes this purpose and a tone synthesis system based thereon forms the subject of Schrecongost and Ring patent application Ser. No. 491,974, and those interested are referred thereto for a detailed explanation. Briefly, multiple voltage sources 92 feed through drawbar or equivalent controls 94 to the playing keys 96. When any playing key is pressed, contacts are made which supply the proper voltages, as selected by the drawbars, to the proper proportional keyers 90 which are to supply the fundamental and the appropriate collection of harmonics. Each proportional keyer so selected thus passes its particular signal frequency at the desired level to the output system.

The signals passing the keyers are, however, square wave signals and are passed in groups to filters 98 which remove the harmonics and pass the fundamental in essentially sine wave form. The filters 98 are of the band pass type, and one filter can handle several adjacent frequencies, since the band can easily be made wide enough to accommodate them without passing any of the harmonics, the closest of which will be three times the fundamental. As a practical matter, separate filters are provided for the following groups of tone signals: 85 to 97, 77 to 84, 69 to 76, 61 to 68, 53 to 60, 45 to 52, 37 to 44, 29 to 36, 21 to 28, 13 to 20, and 1 to 12.

One of these filters is illustrated in FIG. 6, and the specific values for the components used are for the frequency range covering signals 85 to 97. The square wave signal at frequency 85 to 97 reaches the circuit through lead 100. It passes through resistor 102 to lead 104, which in turn is connected in series through capacitor 106, choke 108, choke 110, and resistor 112, to the output 114. A choke 116 and capacitor 118 are connected in parallel from ground to the junction between capacitor 106 and choke 108. The junction between chokes 108 and 110 is connected to ground through capacitor 120 and through capacitors 122 and 124 in series to the junction between choke 110 and resistor 112. The junction between capacitors 122 and 124 is connected to ground through capacitor 126, and a resistor 128 is connected between ground and the junction between choke 110 and resistor 112. Specific values for this sine wave filter for the particular frequency range specified are:

Resistors, 102 and 128, 3.9K; 112, 15K.

Capacitor values in μ f. are: 106 and 126, .022; 118, 120, 122, and 124, .01.

The chokes have a value of .073 hy. each.

The outputs of the filters are connected together and to the output system which may be substantially identical to that recited in connection with FIG. 1.

This system can also easily be arranged to give a very good tibia effect by mixing a small amount of the high natural harmonic portion of the square wave signal with the sine wave output of the filter. For this purpose, input lead 104 is connected through tibia gang switch 130, controlled by tab 132 and a series 220 PF capacitor 134 to

the output lead 114. Also a lead 100b, the same as lead 100 but carrying frequencies 74 to 84, is connected through switch 136, ganged with switch 130, and 47K resistor 138 and series 2200 PF capacitor 140 to the output 114. The values mentioned are of course subject to variation when voicing the instrument, the point being that the sine wave output of the filters can be tempered for specific purposes by shunting a selected portion—usually a high frequency portion—of the raw square wave signal around the filter system.

The segment of the organ illustrated principally in FIG. 2, therefore, provides for full tone synthesis, and it is locked in tune throughout its range and in tune with the bright wave formant section (FIG. 1) of the organ by the same synchronizers 24.

FIG. 3 illustrates the percussion section of the instrument. Here both the synthesis and formant approaches are used, depending upon the particular percussion instrument it is desired to simulate. Piano and banjo, as examples, are obtained by passing bright wave signals through formants. On the other hand, such percussion instruments as glockenspiel, chime, harp, marimba, and xylophone are best synthesized from sine waves.

In FIG. 3 the generators and synchronizers are at 10–12–24, and they, through leads 36, feed bright wave frequency divider cascades 40 and high frequency square wave signals directly through leads 34, all as is characteristic of FIG. 1. The signal output terminals 42, however, are connected through percussion keyers 150 individual to each frequency, and the outputs of the keyers are collected in groups for filtration or formanting. The filters are indicated at 152 and the leads to the formants at 154.

The percussion keyers may be of any suitable type, such as the keyer which forms the subject of Milho patent No. 3,247,306 or the one of Schrecongost patent application Ser. No. 458,257, or the one of Kohls patent application Ser. No. 554,066. In general, playing a key at the keyboard 156 selects an appropriate D.C. voltage which is supplied to the proper keyer 150. The keyer, by means of a variable gain or variable resistance device operating under the control of the voltage and an RC circuit, regulated by the percussion envelope control 157, passes the tone signal initially at high amplitude, the amplitude automatically decreasing and finally terminating thereafter over a selected time interval. In the interest of avoiding crowding the drawing, individual leads 158 are shown at the top of FIG. 3 between the keyboard and the keyers 85 to 97, but only a single lead 158 is shown to keyers for frequencies 73, 61, 49, 37, 25, 13, and 1. It will be understood, however, that the latter keyers are individually connected to the keyboard also.

The various formant circuits need no special description, since the formanting of bright waves to obtain various effects is well understood, and the particular circuits used are to a considerable extent a matter of choice.

The filters at 152 are similar to those previously indicated in FIG. 6, and have filter drivers (not shown, but see FIG. 5) at their inputs. The filters are designed to cut more narrowly, however, than those used in FIG. 2, since in the present instance it is desired to obtain sine waves from signals which have a strong second harmonic, whereas the square waves used in FIG. 2 have substantially no second harmonics. In FIG. 3 a separate filter is supplied for each group of about six semitones. Specifically, these filters are centered about the following frequencies: 6800 Hz., 4800, 3400, 2400, 1700, 1200, 850, 600, 425, 300, 212, 150, and below 150 Hz. A specific filter for 6800 Hz. for instance, can be considered as similar to that of FIG. 6, and such a filter is shown in FIG. 7. Here the input from the filter driver (not shown, but like FIG. 5) is indicated at 153. From the lead 153 the signal passes in order through a series connection of resistor 170, capacitor 172, choke 174, choke 176, and resistor 178 to the output. The junction between the chokes 174 and 176 is connected to ground through

choke 180 and parallel capacitor 182. Also, a pair of capacitors 183 and 184, in series, bridge choke 176, and the junction between these capacitors is connected to ground through capacitor 186. Values for the particular frequencies involved are: Resistors 170, 8.2K, and 178, 15K; capacitors in $\mu\text{f.}$ are 182, .015; 172, 183, and 184, .0039; 186, .008; chokes 174 and 176 have the value .15 hy.; and choke 180, .04 hy.

From the filters 152 the signals emerge substantially as sine waves. They pass through isolation resistors 190 and are collected and amplified in a flute percussion amplifier 192 and passed to the output terminal 194.

If desired, the individual frequencies in groups, from the filters 152, can be taken off at the points 196 and passed to some sort of cross bar relay switching system or its equivalent of the type common in pipe organs, such that, as selected by appropriate control tabs, each of the notes played can have the fundamental flute tone, plus a selected collection of harmonics according to whatever best satisfies the particular voice. Such a system is not a portion of this invention and is mentioned here simply as an alternative. In this specification, therefore, no particular description is necessary beyond pointing out that the flute signals for such an arrangement can be obtained from the taps at 196.

The above described system provides the full equivalent of a synthesis type organ, plus the full equivalent of an organ based upon the formant system, plus a combined percussion system which provides for some percussion effects being obtained by formanting bright waves while others are based upon flute type tones. The result of this is that there can be a collection of stops which, in each case, can provide a response from the particular signal source which best fits what is called for, and of course, the organ can be actuated so as to combine several of the stops to produce a particular desired effect. Furthermore, all sections, and the notes throughout each section, are locked in tune, since all are synchronized from the A.C. power circuit, which provides a well controlled frequency standard.

A complete practical organ may, of course, contain circuitry and devices for special effects, such as vibrato, celeste, and the like, but such arrangements may have the usual conformation, and form no part of the present invention.

From the above description of a preferred embodiment of the invention, it will be appreciated that changes may 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 my invention, what I claim as new and useful and desire to secure by Letters Patent of the United States is:

1. In an electrical musical instrument adapted for connection to a constant frequency alternating current power circuit, means providing twelve cascades of frequency dividers to provide tone signal sources corresponding in frequency to the notes of the musical scale over a several octave range, a driver circuit for each of said cascades connected to drive the frequency divider for the highest frequency in its cascade, means connected to said constant frequency power circuit and adapted to operate synchronously therewith for establishing the frequencies of all of said drivers at appropriate fixed multiples of the frequency of the constant frequency power circuit, whereby the frequencies available from all of said drivers and all twelve cascades of said frequency dividers are locked relative to each other and relative to the frequency of the constant frequency power circuit.

2. The combination called for in claim 1 in which each of said frequency dividers divides by two and provides a signal output of substantially square waveform lacking in even harmonics, and in which a band pass filter adapted to remove frequencies below a point be-

tween the fundamental and third harmonic and frequencies above a point between the third and fifth harmonic is interposed in the output of at least one of said frequency dividers to provide a signal higher in frequency than the signal fed into the particular frequency divider.

3. In an electrical musical instrument adapted for connection to a constant frequency alternating current power circuit, means providing twelve cascades of frequency dividers to provide square wave tone signal outputs corresponding in frequency to the notes of the musical scale over a several octave range, a driver circuit for each of said cascades connected to drive the frequency divider for the highest frequency in its cascade, means connected to said constant frequency power circuit and adapted to operate synchronously therewith for establishing the frequencies of all of said drivers at appropriate fixed multiples of the frequency of the constant frequency power circuit, whereby the frequencies available from all of said drivers and all twelve cascades of said frequency dividers are locked relative to each other and relative to the frequency of the constant frequency power circuit, means providing a filter system interposed in each of said outputs to remove from the square wave signals substantially all of the harmonic content so as to leave substantially only the fundamentals in the signals after filtration, and manually adjustable means for variously mixing said fundamentals as desired.

4. The combination called for in claim 3 including means providing a frequency tripler circuit connected to the output of at least one of the frequency dividers to supply a tone signal higher in frequency than that supplied by any of said driver circuits.

5. In an electrical musical instrument adapted for connection to a constant frequency alternating current power circuit, means providing twelve cascades of frequency dividers to provide tone signal sources corresponding in frequency to the notes of the musical scale over a several octave range, a driver circuit for each of said cascades connected to drive the frequency divider for the highest frequency in its cascade, means connected to said constant frequency power circuit and adapted to operate synchronously therewith for establishing the frequencies of all of said drivers at appropriate fixed multiples of the frequency of the constant frequency power circuit, whereby the frequencies available from all of said drivers and all twelve cascades of said frequency dividers are locked relative to each other and relative to the frequency of the constant frequency power circuit, and means providing output connections to said twelve driver circuits to supply an octave of tone signals higher in frequency than the tone signals supplied by any of the frequency dividers.

6. In an electrical musical instrument, means providing a plurality of cascades of frequency dividers to provide tone signal sources corresponding in frequency to the notes of the musical scale, each of said frequency dividers having a bright wave output, means providing a group of formant circuits connected to receive the bright wave output from said dividers, means for keying said bright wave signals interposed between said frequency dividers and said formant circuits, means providing a filter system connected to receive signals from said dividers in adjacent semitone groups said filter circuits being adapted to remove from the group of adjacent semitones substantially all of the harmonic structure so as to pass only the fundamental sine wave, means providing a group of proportional keyers interposed between said sources and said filter circuits, said proportional keyers being adapted to provide an output signal which varies in amplitude depending upon the voltage applied to a terminal of said keyer, and playing key actuated circuits for supplying variable voltages to said terminals depending upon the amplitude desired for the sine wave signals supplied by the outputs from said filters.

7. In an electrical musical instrument adapted for connection to a constant frequency alternating current power circuit, means providing twelve cascades of frequency dividers to provide tone signal sources corresponding in frequency to the notes of the musical scale over a several octave range, a driver circuit for each of said cascades connected to drive the frequency divider for the highest frequency in its cascade, means connected to said constant frequency power circuit and adapted to operate synchronously therewith for establishing the frequencies of all of said drivers at appropriate fixed multiples of the frequency of the constant frequency power circuit, whereby the frequencies available from all of said drivers and all twelve cascades of said frequency dividers are locked relative to each other and relative to the frequency of the constant frequency power circuit, each of said frequency dividers having two outputs, one of said outputs being of essentially square waveform without even harmonics and the other of said outputs being of all-harmonic waveform and including even harmonics, means providing a filter system connected to receive the square wave output from a group of frequency dividers supplying adjacent frequencies, said filter circuits being adapted to remove from the group of adjacent square wave signals substantially all of the harmonic structure therefrom so as to pass substantially only the sine wave fundamentals, and means providing a group of formant circuits con-

nected to receive the all-harmonic wave outputs from said frequency dividers, means for keying said all-harmonic wave signals interposed between said frequency dividers and said formant circuits, means providing a group of proportional keyers for keying the square wave signals interposed between said frequency dividers and said filter circuits, said proportional keyers being adapted to provide an output signal which varies in amplitude depending upon the voltage applied to a terminal of said keyer, and playing key actuated circuits for supplying variable voltages to said terminals depending upon the amplitude desired for the sine wave signals supplied by the outputs from said filters.

References Cited

UNITED STATES PATENTS

2,941,435	6/1960	Henley	-----	84—1.19	X
3,229,019	1/1966	Peterson	-----	84—1.01	
3,355,539	11/1967	Munch et al.	-----	84—1.01	X
3,410,948	11/1968	Ishibashi et al.	----	84—1.19	X

HERMAN KARL SAALBACH, Primary Examiner

SAXFIELD CHATMON, JR., Assistant Examiner

U.S. Cl. X.R.

84—1.11, 1.19

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,489,842

Dated January 13, 1970

Inventor(s) Ayres, William R.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In Col. 4, beginning in line 11, the passage which reads "For those not familiar with the harmonic content of various wave forms it should be noted that saw tooth or bright waves contain all harmonics whereas square waves, sometimes referred to as dull waves contain only the fundamental and odd harmonics, the even harmonics being essentially missing." should appear in Column 3, following the period in line 56.

Col. 4, line 27, "Valves" should be --Values--.

Col. 7, line 5, "8.2K" should be "2.2K".

SIGNED AND
SEALED

JUL 7 1970

(SEAL)

Attest:

Edward M. Fletcher, Jr.

Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents