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Schrecongost

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[54] **INTEGRATED CIRCUIT SYNTHESIS AND BRIGHT WAVE ORGAN SYSTEM**

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[73] Assignee: **Hammond Corporation,** Deerfield, Ill.

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[52] **U.S. Cl.** **84/1.22,** 84/23

[51] **Int. Cl.** **G10h 1/06**

[58] **Field of Search**.................. 84/1.01, 1.23, 1.26, 84/1.19, 1.11; 307/213; 331/51, 52, 57; 328/48

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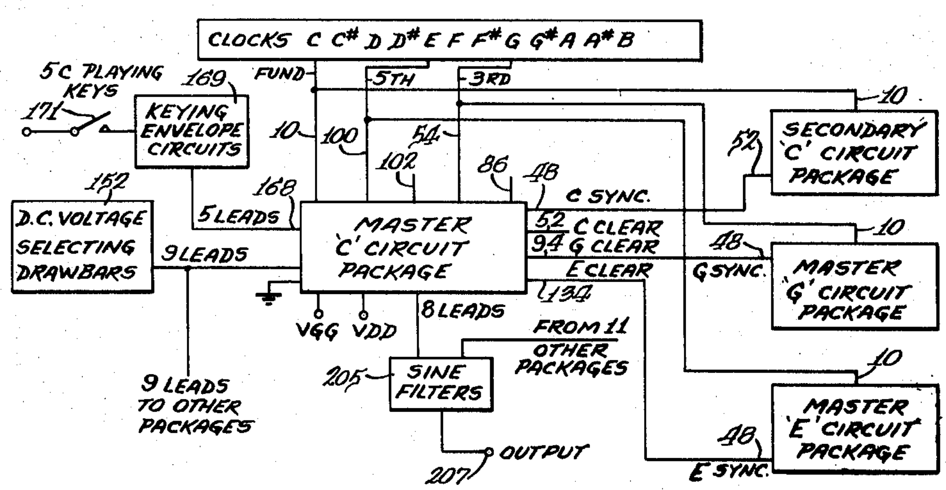
Assistant Examiner—U. Weldon
Attorney—Gradolph & Rogers

[57] **ABSTRACT**

A synthesis organ system with direct current keying, envelope shaping and individual harmonic scaling which makes use of 12 musical signals representative of the notes of the top octave of the instrument and derives other note signals by frequency division and in which MOSFET integrated circuit technology is used in the envelope shaping, the keying, the harmonic scaling and the frequency division. The system provides for optimization of the circuit elements and internal circuits in the integrated circuit packages consistent with the number of package leads and the complexity of the external circuit so as to arrive at a minimum overall cost for the system. Alternatives are described, the choice depending largely upon the overall production quantity required, the relative cost of the packages, and to some extent upon individual preference. Other variations of the basic system are discussed. The system also has provision for all harmonic wave formation by the addition of square waves to provide pedal notes or for enlarging the keyboard resources of the instrument.

26 Claims, 9 Drawing Figures



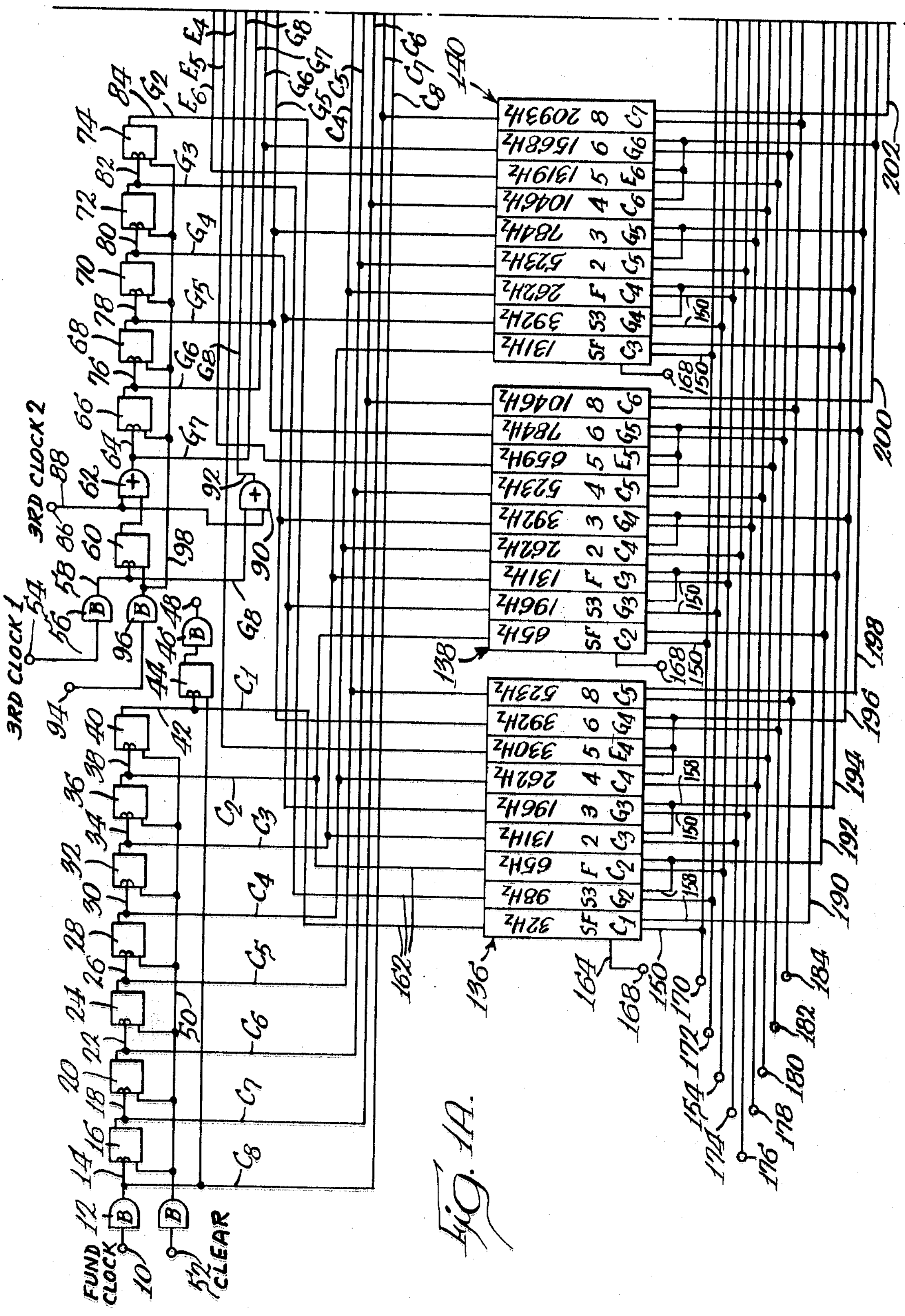


Fig. 1A.

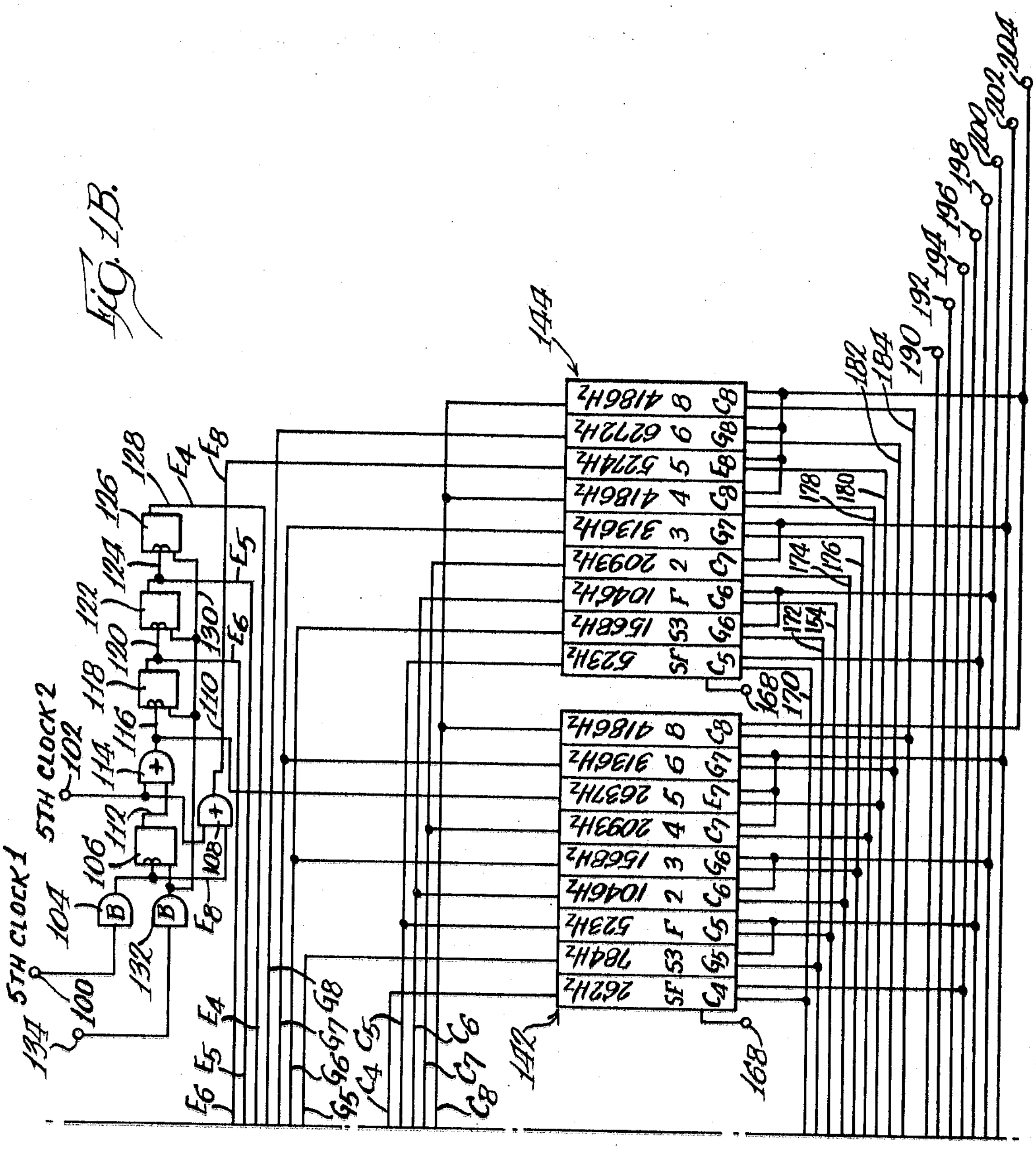


FIG. 1B.

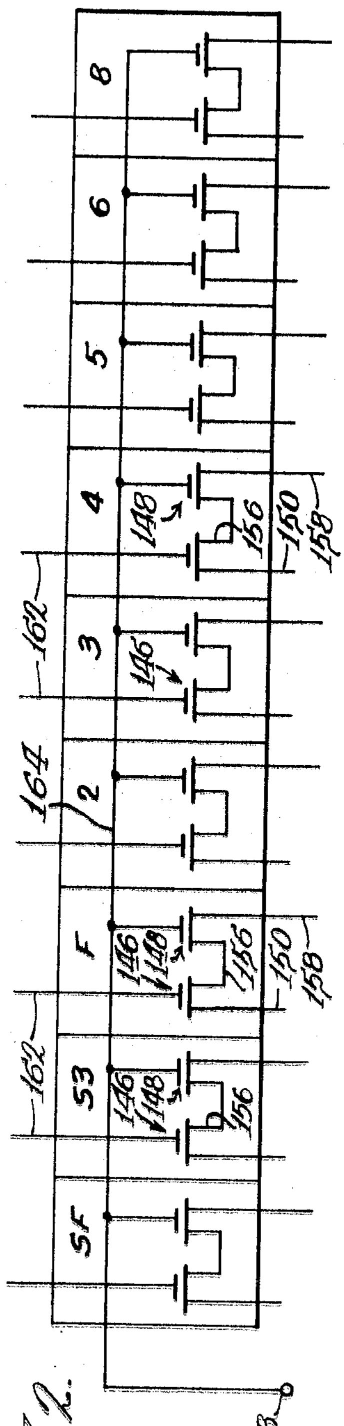

SF
53
F
2
3
4
5
6
8
146
148
156
150
158
162
164
168

Fig. 2.

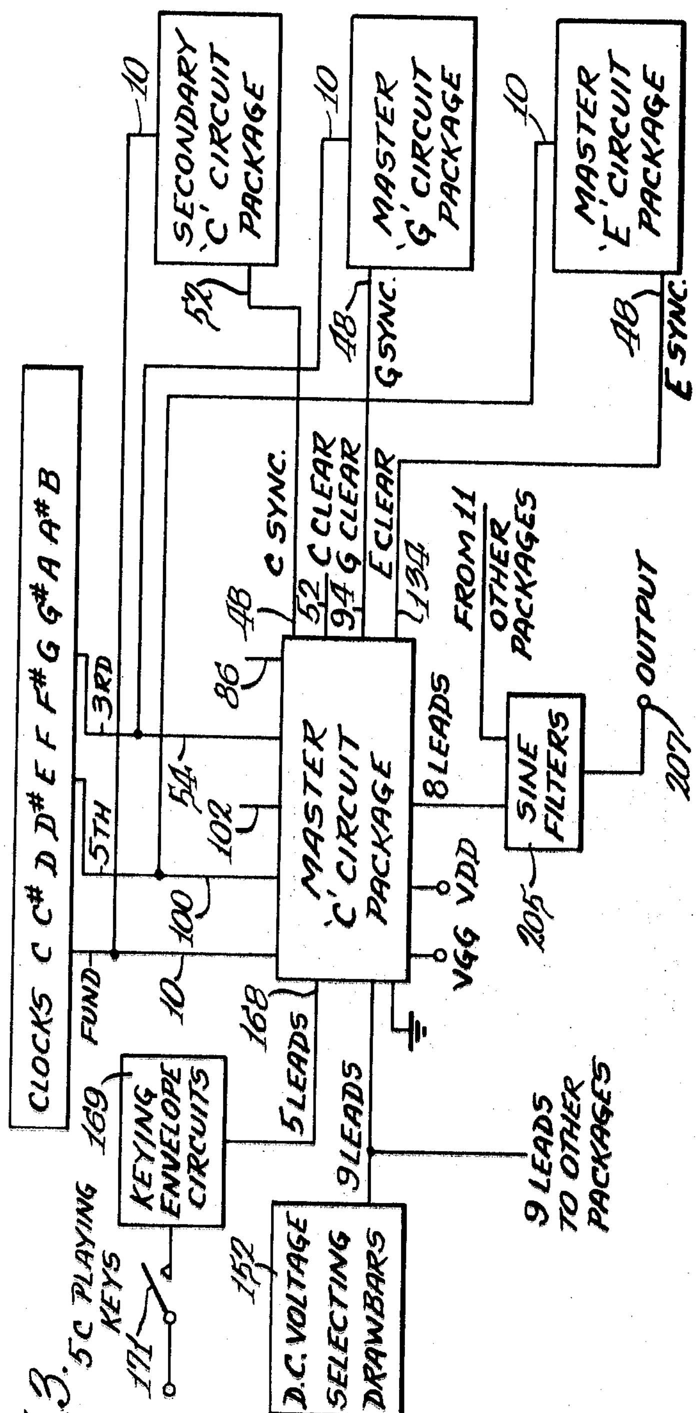

CLOCKS C C# D D# E F F# G G# A A# B
FUND
5TH
3RD
SECONDARY 'C' CIRCUIT PACKAGE
MASTER 'G' CIRCUIT PACKAGE
MASTER 'E' CIRCUIT PACKAGE
MASTER 'C' CIRCUIT PACKAGE
C SYNC.
G SYNC.
E SYNC.
C CLEAR
G CLEAR
E CLEAR
FROM 11 OTHER PACKAGES
8 LEADS
SINE FILTERS
OUTPUT
5 LEADS
9 LEADS
9 LEADS TO OTHER PACKAGES
KEYING ENVELOPE CIRCUITS
D.C. VOLTAGE SELECTING DRAWBARS
5C PLAYING KEYS
VGG
VDD
10
48
52
54
86
94
100
102
134
152
168
169
171
205
207

Fig. 3.

Fig. 4.

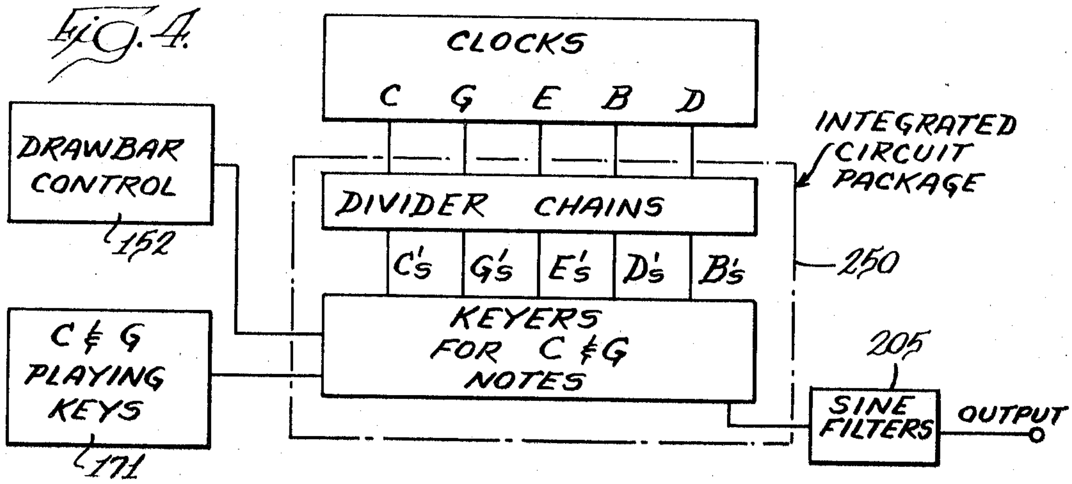


Fig. 5.

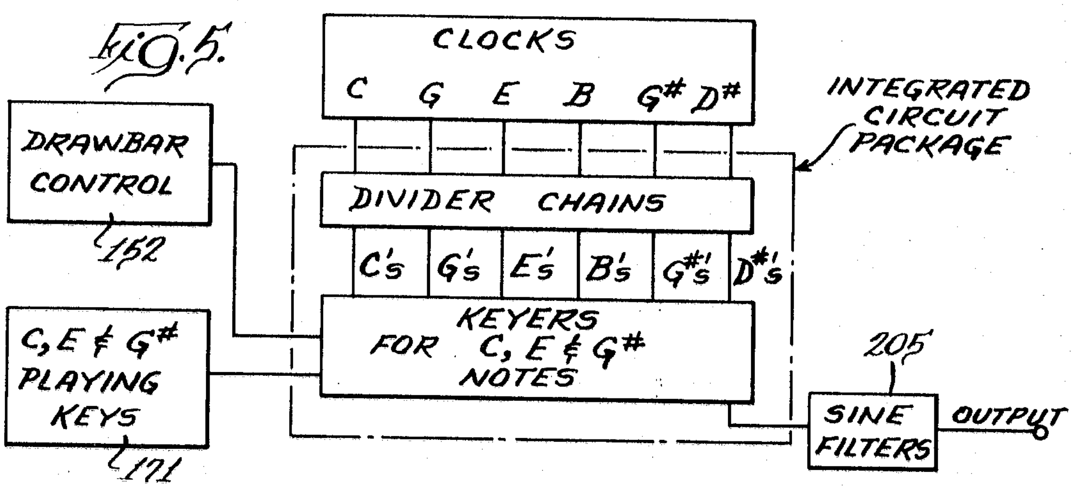
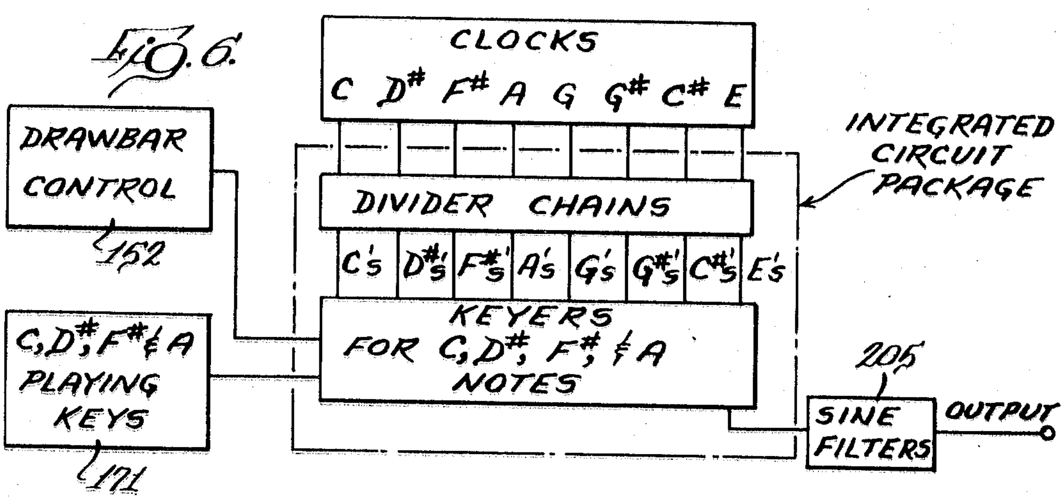


Fig. 6.



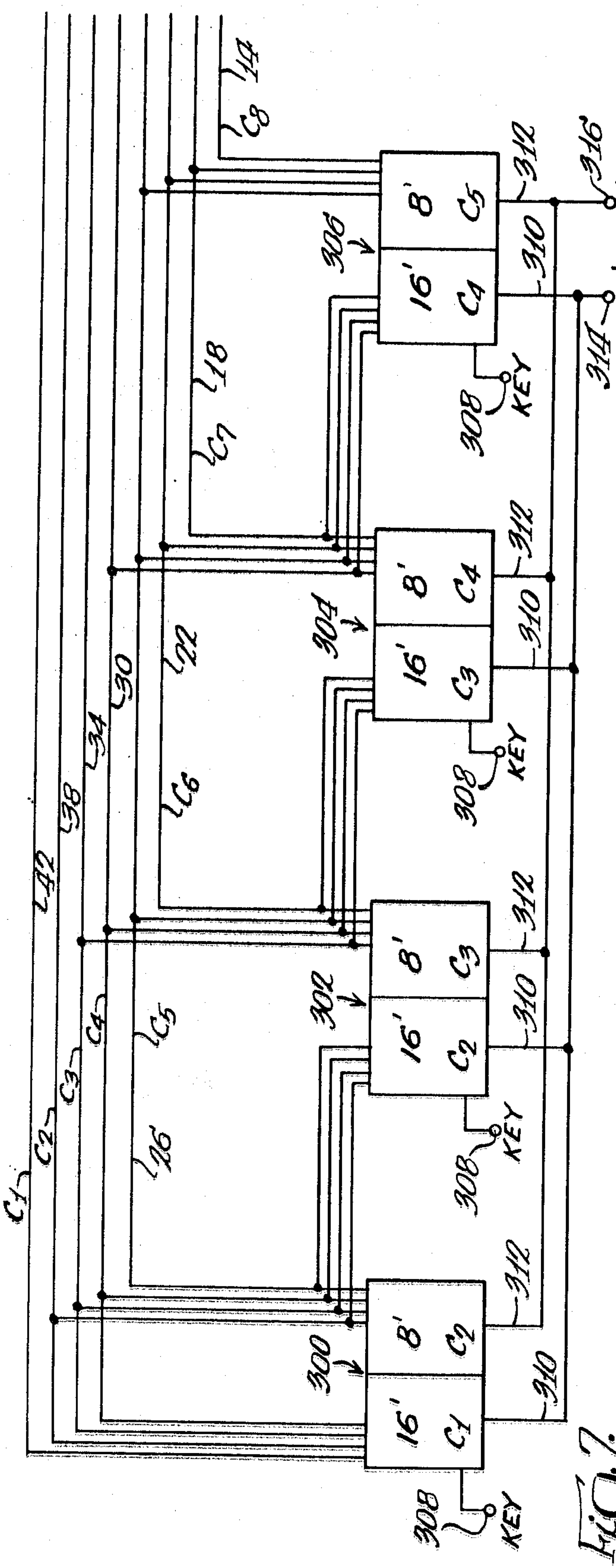

C1
C2
C3
C4
C5
C6
C7
C8
16'
8'
300
302
304
306
308
310
312
314
316
KEY
42
38
34
30
26
22
18
14

Fig. 7.

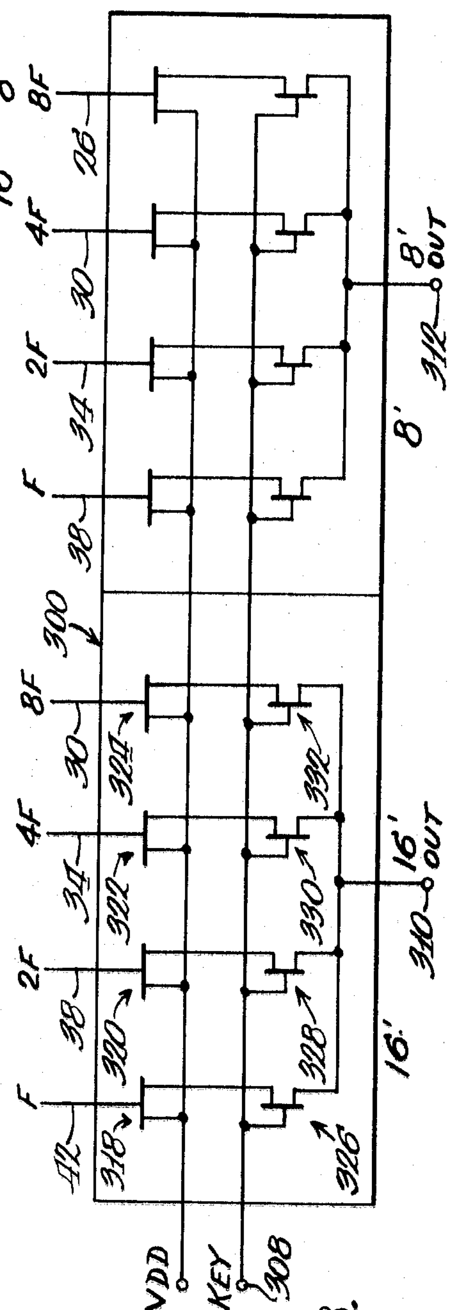

8F
4F
2F
F
8' OUT
16' OUT
VDD
KEY
308
300
310
312
318
320
322
324
326
328
330
332
16'
8'

Fig. 8.

INTEGRATED CIRCUIT SYNTHESIS AND BRIGHT WAVE ORGAN SYSTEM

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The invention is primarily directed to the use of MOSFET integrated circuit techniques in the provision of a synthesis organ system and provides within the integrated circuit packages the principal elements for frequency division, direct current (D.C.) keying, harmonic scaling and envelope shaping. The invention also contemplates external circuits used with the integrated circuit packages and is primarily concerned with minimizing overall cost and complexity for the system as a whole. The system also provides for the formation and keying of bright wave note signals from the same packages.

SUMMARY OF THE INVENTION

Synthesis organs, of which Hammond U.S. Pat. No. 1,956,350 is probably the most representative example, have been basic to the musical instrument industry for many years. This type organ has great advantages, but also has certain undesirable features. This invention solves the traditional problems while retaining the advantages of the synthesis approach and is an extension of the arrangement forming the subject of U.S. Pat. No. 3,636,231 filed in the names of Ray B. Schrecongost and David Millet, Case 13, and entitled "D.C. Keyed Synthesis Organ".

A synthesis organ is based upon the knowledge that sustained complex musical tones can be synthesized by mixing properly scaled sine waves having frequencies representative of the fundamental and the various harmonics of the tone to be synthesized. Customarily this is done by having each organ playing key operate a group of contacts, such that when, for instance, the playing key for A-440 Hz is pressed, it connects a sine wave generator operating at 440 Hz to a fundamental bus, the 880 Hz generator to a secondharmonic bus, the 1320 Hz generator to a third harmonic bus and so on. By connecting the various buses to the output through any of several taps across a resistor or transformer primary, the relative strengths of the various harmonics can be adjusted as desired. Usually nine or so contacts for each of most of the playing keys are necessary in such organs.

A problem contributed by the multiple contacts is that the playing key action tends to be somewhat stiffer than is desirable to some persons. Additionally, this direct contact keying of the tone signals, known as A.C. keying, at a low signal level requires very high quality and hence expensive contact systems. Also keying transients are difficult to control and there are limitations on control of the keying envelope.

The system, however, has distinct advantages in that great control of tone quality is possible since the fundamental and each harmonic has its level independently selected as desired.

Another type of organ, usually referred to as a formant or bright wave organ, uses bright wave signals having a high order of harmonic content as the starting point. Formant circuits which resonate or otherwise discriminate on a frequency basis are then used to alter the harmonic balance of these complex signals. This system does not have the choice of tone coloration available with the synthesis approach, but since it is not

necessary to key a multiplicity of signals representative of the fundamental and various harmonics separately, it is feasible to provide direct current (D.C.) keying to give more elaborate tone envelopes. This, in general, is because only one D.C. keyer is necessary per tone signal source to key the complex signals. For notes toward the lower end of the keyboard or for pedal notes, the bright wave approach has an advantageous feature in that a longer harmonic series is more readily available. The present invention provides for this and the description of the arrangement will in general follow the description of the synthesis system.

The previously referred to patent provides a system for D.C. keying the fundamental and various harmonics individually with full choice of the relative levels of the various harmonics and otherwise provides the advantages of single contact D.C. keying in an organ of the synthesis type. The system also makes use of square wave signals which are less expensive to provide than sine waves.

In this connection, it should be understood that a relatively inexpensive arrangement for providing signals for all of the musical tones necessary in an organ is to provide for the twelve tones of the top octave of the instrument and then to use bistable flip-flop frequency dividers, which divide by two, to provide the signals for the next lower octave and another set of dividers to obtain the next lower octave, and so on. Since the output signals from the most commonly used binary dividers are in the form of square waves, these signals cannot be used directly in a synthesis organ which fundamentally depends upon a selected mixture of sine waves. That invention makes use of such square wave signals without the previously proposed expedient of providing sine wave filters individual to each of the outputs by forming mixtures of the square waves which are subsequently filtered in groups of adjacent semitones, the filters having as broad a band pass for the fundamentals as is reasonable while rejecting the third and higher harmonics. The mixtures resulting are, therefore, essentially sine wave mixtures.

Generally what is required for practicing this invention is an arrangement, as shown in the beforementioned patent, such that when a playing key is pressed, a potential is supplied which actuates simultaneously individual keyers for the fundamental and the various harmonics, in this instance a total of nine keyers. Additionally, each of the keyers needs a D.C. input at any of several voltage levels, in this instance nine, which control the signal level of the particular harmonic to be keyed. Since all of the notes of a particular manual will desirably have the same harmonic content, one control is actuated to select the potential applied to all of the keyers for all of the fundamentals, another control to select the potential for all of the second harmonic keyers and so on. These controls usually take the form of drawbars, one for each harmonic, which are pulled or pushed to any of nine positions to select a particular one of parallel busses, each of which has a different potential. Additionally, there needs to be some output system for collecting adjacent semitones in groups for filtration and for supplying the filtered mixture to an output system. Ordinarily, there will be the provision of twelve master signals for the twelve semitones of the top octave of the instrument, 12 flip-flop frequency dividers to obtain the next lower octave, 12 more for the octave below that and so on until the lowest notes required for the instrument are supplied. There is also the problem introduced by the fact that usually the instrument will have two manuals of keys and at least an octave of pedals.

The principal objective of this invention is to organize all these requirements into circuitry which makes the most appropriate use of integrated circuit capabilities in association with the necessary external circuits, it being appreciated that as an integrated circuit is made to perform more functions it becomes more expensive and as a rule more leads to external circuits are required for each package. Cost is also affected by the fact that a few highly complex integrated circuits can serve the functions of many identical simpler integrated circuits and, hence, the purchase requirements are greater if the approach favors the use of a larger number of the simpler circuits. Thus, to some extent, the most favorable solution will depend upon the total organ production capable of using particular identical integrated circuit packages.

One approach which illustrates the problem would be to put all the frequency dividers, keyers, and output signal level scaling components for a whole manual of keys into a single integrated circuit package. This would result in probably the maximum simplification of the actual organ assembly problem. In a typical organ, however, this would require twelve input leads for connection to the twelve master signal sources, sometimes referred to as triggers or clocks, nine connections to the nine voltage leads from the drawbar control assembly, seven to nine or so output leads to seven to nine or so sine filter inputs, a ground lead, two minus voltage leads, referred to usually as Vgg and Vdd for operation of the frequency dividers, and 61 leads or so from the playing keys of the manual. The total of 90 or more pins per integrated circuit package and the circuit density required is not probably beyond the state of the art, but is hardly practical economically at present. Such systems, however, may be worthy of further study.

On the other hand, the keyer system proposed in the previously referred to patent shows an integrated circuit with connections to nine signal sources, one keying lead, nine connections to the drawbar control system, seven or so output connections to the sine filters for a total of 26 or so pins for each integrated circuit package. This system assumes that the frequency dividers are separate from the keyer integrated circuits. The dividers could, of course, be incorporated in other integrated circuits. For an organ having a manual of 61 keys, 61 of the integrated circuit packages would be required for each manual and there would be considerable circuitry external to the packages including connections to a large number of frequency dividers and master signal sources (nine each for most of the playing keys).

The system of the present invention supplies practical solutions to the problem and provides for the large number of frequency dividers within the integrated circuit packages along with the keyers. It also greatly reduces the number of required integrated circuit packages and simplifies the external circuitry as compared with the system of the previously referred to patent, thereby reducing the overall cost, wiring complexity, and service difficulties.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1, composed of FIGS. 1A and 1B, is a diagrammatic representation of an integrated circuit of this invention for supplying the frequency dividing, harmonic scaling and keying functions for all of the "C" keys, in one manual of an organ, in this instance from C_1 to C_6 inclusive;

FIG. 2 is a diagrammatic representation of one keying block for one playing key, five of which are included in the circuit of FIG. 1, one for each octave;

FIG. 3 is a block diagram of the FIG. 1 system generally showing primarily circuit package interconnections;

FIG. 4 is a block diagram illustrating a modification of the basic system capable of providing all the note signals for a manual of keys with six integrated circuit packages;

FIG. 5 is similar to FIG. 4, but illustrates a system capable of providing a manual of notes with four packages;

FIG. 6 is similar to FIG. 5, but shows a system capable of providing a manual of notes with three packages;

FIG. 7 is a diagram of a bright wave system which may be combined with the system of FIG. 1 so as to be present in the same integrated circuit package; and

FIG. 8 is a diagram of one of the blocks, four of which are shown in FIG. 7.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In this description and in the drawings the terminology and the illustration scheme follow, where it is believed reasonable, that which has become customary in the integrated circuit industry. Furthermore, circuit arrangements on the integrated circuit chips for accomplishing well known purposes are not shown nor described in detail, since this is not necessary to an understanding of the invention and would greatly complicate and enlarge the disclosure. Such commonly used elements as flip-flop, divide by two, frequency dividers, buffers which compensate for signal level variation, clearing circuits in the dividers which reset all the flip-flops connected to a lead to zero or some other starting position, and adder and buffer circuits which pass to an output any signals received at either of two inputs, simply are specified in terms of the function they perform. Interconnections between such elements are shown and described, however.

The system uses a number of "synthesis keying blocks", all of which are identical. One of these for one playing key is shown and described. The input master signals which are at the frequencies, in a high octave, of the fundamental, the third harmonic of the fundamental, the fifth harmonic of the fundamental and so on are referred to respectively as the fundamental clock, the third clock, the fifth clock and so on.

The organization shown in FIGS. 1, 2 and 3 is representative of a synthesis system embodying the invention. FIG. 1 shows an integrated circuit package which provides the frequency dividing, the D.C. keying, the harmonic scaling, and the output mixing for all of the "C" notes of a complete 60 key manual of a synthesis organ. As will appear, an additional package will provide the extra C for a 61 key manual. Another identical integrated circuit is required for the C# keys, another for the B keys and so on. Thus, twelve of these identical packages are used for each manual of keys or 24 for the two manuals of an organ having 60 key manuals. Usually 61 key manuals are provided extending from C_1 to

C_8. A 60 key manual would omit the C_8 key. The arrangement for obtaining this extra C key, C_8, will be described later, but for the present, a 60 key manual will be assumed to simplify the description. For a 60 key manual, the 12 frequencies or clocks introduced to the packages from a master source cover the range in half tone intervals from the C clock at 4186 Hz (all frequencies for convenience will be rounded to the closest whole number), sometimes referred to as C_8, to the B_8 clock at 7902 Hz.

It is necessary to understand that the synthesis approach to tone formulation using the present scheme requires a mixture of the fundamental and various harmonics. For middle C, C_4, the fundamental is 262 Hz. The various harmonics mixed therewith are as follows. Second harmonic, 523 Hz, third harmonic, 784 Hz, fourth, 1046 Hz, fifth, 1319 Hz, sixth, 1568 Hz, eighth, 2092 Hz, subfundamental 131 Hz, and subthird 392 Hz. Note that the subfundamental, the fundamental, the second, the fourth, and the eighth can be acquired from successive stages of binary frequency division of the C clock at 4186 Hz. Similarly, the subthird, the third, and the sixth can be obtained by successive binary division of the G clock at 6272 Hz and the fifth by similar division of the E clock at 5274 Hz. This also holds true for the other octaves of the instrument. That is, C_4, middle C, has its third harmonic at G_5. In the octave above middle C, C_5; C_4 becomes the subfundamental, and G_5 becomes the subthird. In the octave below middle C, C_3; C_4 becomes the second harmonic and G_5 the sixth and so on.

This system also follows for all of the notes of the instrument, that is, the 12 clocks will provide signals which when each is subjected to division by chains of flip-flop dividers will provide all of the frequencies needed for all of the fundamentals and borrowed harmonics of a 60 key manual. By borrowed harmonics is meant harmonics based upon the even tempered scale. This is customary practice in synthesis organs. If the use of natural harmonics is desired, this can be accomplished as will appear later by using three times the number of clocks. This is usually considered an unnecessary refinement, however. The relationship is illustrated in the following table.

Note Fundamental and Octave Harmonics	Borrowed or Natural Third, Sixth and Subthird Harmonics	Borrowed or Natural Fifth Harmonic
C	G	E
C #	G #	F
D	A	F #
D #	A #	G
E	B	G #
F	C	A
F #	C #	A #
G	D	B
G #	D #	C
A	E	C #
A #	F	D
B	F #	D #

Referring to FIG. 1 of the drawing which shows specifically the integrated circuit package for the C's of the manual, the C_8 clock signal at 4186 Hz is introduced at terminal **10** connected to buffer **12**, connected in turn by lead **14** to flip-flop binary divider **16**. To avoid confusion, the ground lead, which is obvious, and two voltage leads, known usually as Vgg and Vdd are not shown since the voltage connections are necessary merely for operation of the circuit elements which are not detailed, the frequency dividers, for instance. The buffer **12** is for the purpose of adjusting as necessary the level of the input signal so as to match it to that of the frequency divider **16**. Other buffers in the circuit serve a similar purpose and insure that the signal levels whether from a clock or from a frequency divider are substantially identical. The buffers also insure that the input level of the clock signal to a frequency divider meets the requirements of the divider circuit.

Operation of divider **16** supplies a half frequency signal at C_7 to lead **18** connected to divider **20**. Divider **20** supplies a C_6 signal to lead **22** connected to divider **24**. Additional dividers in the chain are indicated at **28, 32, 36, 40,** and **44**. The interconnecting leads and the respective frequency designations are **26**, C_5; **30**, C_4; **34**, C_3; **38**, C_2; and **42**, C_1. The additional divider stage **44** supplies a short spike at 16 Hz which passes through buffer **46** to a synchronizing output terminal **48**.

All of the C flip-flops, **16, 20, 24, 28, 32, 36** and **40** have connections to a lead **50**, connected in turn to a terminal **52** labeled "clear". A short pulse applied to terminal **52** resets all the dividers in the chain to a uniform starting or zero condition.

By connecting a lead from terminal **48**, the C synchronizing output of one of the C integrated circuits, such as the circuit of FIG. 1, to the clear terminal **52** of any other C integrated circuit in the instrument, the pulses from the first circuit will reset if necessary all of the other C circuits to operate in the same phase as the first circuit. This is necessary to prevent cancellation if more than one source of C signals are connected together electrically. The same synchronizing arrangement is used to interconnect the packages for the C #'s, the B's and so on. There are also other interconnections between the individual packages which make use of the synchronizing output **48** which will be discussed presently.

Near the top center of FIG. 1 there is a terminal **54** labeled 3rd. clock 1. The external connection to this terminal is the G_8 clock signal at 6272 Hz when as in this instance, the integrated circuit is for the C notes. Terminal **54** is connected through buffer **56** to lead **58** and to frequency divider **60**. The half frequency signal from divider **60** is connected through a summing and buffering circuit **62** to lead **64**. This lead is connected through additional frequency dividing stages in series indicated in order at **66, 68, 70, 72** and **74**. The interstage connections after divider **66** are in order, **76, 78, 80, 82**, and a final output **84** from divider **74**. Lead **58**, therefore, provides G_8; lead **64**, G_7; **76**, G_6; **78**, G_5; **80**, G_4; **82**, G_3; and **84**, G_2.

There is a second third harmonic clock input terminal **86** labeled 3rd clock 2. The reason for the provision of this connection will be discussed subsequently. It is connected as follows. A lead **88** connects terminal **86** to previously mentioned summing and buffering circuit **62**. Thus, the signal in lead **64** can be either that at terminal **86** or that from terminal **54** which has been divided by two at flip-flop **60**, depending upon whether there is an external connection to terminal **86** or to terminal **54**. Lead **88** is also connected through a second summing and buffering circuit **90** to lead **92**. Lead **58** is also connected through the same summing circuit to lead **92**, so that the lead **92** will have either the signal from terminal **86** or from terminal **54**, depending upon which terminal is externally connected. For the present, assume that terminal **54** is connected to the G_8

clock at 6272 Hz, and that terminal **86** is unconnected to any external circuit. The exceptions to this arrangement will be discussed subsequently.

With the G_8 clock connected to terminal **54** the signal on lead **92** will be at G_8. Note that if G_7 at half the frequency of G_8 had been connected to terminal **86** and if terminal **54** had been left unconnected, the signal on lead **92** would be at G_7 rather than G_8, but that the frequencies on the other signal leads **64, 76, 78, 80, 82** and **84** would be unchanged. As will appear more fully presently, clock **2** is thus used where a frequency higher than available is indicated for connection to the clock **1** terminal. As a substitute, the frequency an octave lower is connected to clock **2** terminal.

A clearing terminal for the G dividers is indicated at **94** and is connected through a buffer **96** to a lead **98** connected in turn to all of the G dividers **60, 66, 68, 70, 72** and **74.** As with the clearing lead **50** for the C dividers, a pulse on terminal **94** resets all the dividers to which it is connected to zero position. This synchronizes the G dividers in FIG. **1** with a master G circuit somewhere else in the organ, the master G circuit having a synchronizing output terminal which is the equivalent of the C synchronizing output terminal **48** of FIG. **1.** This master G synchronizing output terminal is connected to the G clear terminal **94** of FIG. **1.** Thus, all G's in the collected output will be in phase regardless of whether they are present as fundamentals or even harmonics of G notes or third, sixth or subthird harmonics of C notes or fifth harmonics of D # notes. This arrangement is also provided for phase synchronizing all sources for the C # signals, the D signals and so on.

To the right of the dividers for the G system there is a terminal **100** labeled "5th clock 1", and to the right of that a "5th clock 2, terminal 102". These are the E equivalent of the G terminals at **54** and **86** respectively and are similarly connected. The input signal to terminal **100** is the E_8 clock at 5274 Hz. This terminal is connected through buffer **104** to flip-flop **106** and through buffer, adder **108** to lead **110.** The output **112** of frequency divider **106** is connected through buffering and summing circuit **114** to lead **116** connected to the second stage frequency divider **118.** The **5**th clock **2** terminal **102** is connected to inputs to the buffering and summing circuits **114** and **108.** The output **120** of divider **118** is connected to divider **122** having an output **124** connected to the last stage of frequency division at **126** having its output at **128.**

Thus, with the E_8 clock at **5274** Hz connected to terminal **100,** the tone signals at the several leads are: **100,** E_8; **112,** E_7; **116,** E_7; **120,** E_6; **124,** E_5; **128,** E_4. If instead, the E_7 clock is connected to terminal **102,** then all the signals will be the same excepting that E_7 will appear on lead **110** rather than E_8 as explained above.

As with the G divider system, the E dividers **106, 118, 122** and **126** are connected to a clearing lead **130** connected through buffer **132** to clear terminal **134.** Thus, a pulse at terminal **134** from some remote master E circuit will reset the E dividers of FIG. **1** and synchronize them into identical phase relation with the E master circuit.

As with the G circuits of FIG. **1,** in the present instance, it should be assumed that the circuit operates with the E_8 clock connected to terminal **100** and that there are no external connections to terminal **102.**

In FIG. **1,** below the frequency dividers just described are a row of five keying blocks indicated from the left in order by the numerals **136, 138, 140, 142** and **144.** Each of these contains nine subblocks labeled from the left in each instance, SF, subfundamental; S3, subthird; F, fundamental; **2,** second harmonic; **3,** third harmonic; **4,** fourth harmonic; **5,** fifth harmonic; **6,** sixth harmonic; and **8,** eighth harmonic. All of the keying blocks **136, 138, 140, 142** and **144** are identical and one of these is shown in detail in FIG. **2.** In each of the subblocks the circuit is the same and so only one, the one labeled F will be described.

In the subblock F there are two field effect transistors **146** and **148** in series. The input or drain **150** of the first FET is supplied with a connection to a terminal **154.** A D.C. current at any of several voltage levels can be supplied to this terminal by adjustment of a drawbar control as is explained in detail in the previously mentioned patent. The output or source **156** of transistor **146** is connected to the drain of transistor **148** and the source of the latter to an output lead **158.** An input tone signal lead **162** is connected to the gate of transistor **146** and the gate of transistor **148** is connected to a keying lead **164.**

Assuming that the signal lead **162** is connected to a source of square waves at a desired frequency, the transistor **146** will chop the input D.C. on lead **150** at that frequency so that the input to transistor **148** will be a square wave at the frequency of lead **162** and at a level determined by the potential of the D.C. on lead **150.** Transistor **148** will normally be cut off, but will conduct when an appropriate potential is applied to keying lead **164.** This keying lead is connected to terminal **168** which in turn is connected to a keying envelope shaper **169** actuated by the appropriate playing key **171** for the note of which the particular F subblock is the fundamental. As an example, since the subblock under discussion is the F subblock in block **136,** and as will be pointed out presently the signal to lead **162** is a square wave at 65 Hz, actuating the connected playing key will sound the C fundamental two octaves below middle C.

Any well known external keying circuit may be used at **168,** such that when a playing key is pressed, the D.C. potential applied to terminal **168** can rise and fall in a desirable manner to give the potential on lead **164** and hence the output to lead **158** an appropriate keying envelope.

In the keying block of FIG. **2** the keying terminal **168** and lead **164** are shown as connected to the gates of all of the keying transistors—those in the position of transistor **148** in subblock F— and thus, whatever keying potential or envelope is applied to transistor **148** will be applied to all of the similarly located transistors in the other subblocks, from SF (subfundamental) at one end to **8** (eighth harmonic) at the other, whenever playing key contacts **171** are closed. Whatever square wave signals are applied to the several leads **162** will, therefore, appear in the several output leads **158** at the individual voltage levels determined by the potentials on the several leads **150.**

For convenience, and to avoid the confusion of excessive individual numbering, all of the musical signal leads entering the tops of the keyers are given the numeral **162.** Where necessary, a specific lead is designated for example as lead **162,** keyer F, block **136.** Similarly, the keying lead for all subblocks has the number **164.** The variable D.C. lead to each keyer for scaling the individual harmonics enters the keyer to the left at the bottom and in each instance has the indicia **150.** All keyer output leads are at the bottom right of the sub-blocks and are indicated by the numeral **158.**

All D.C. drawbar input leads for the same harmonic in the several blocks are connected to a single bus and these nine busses lead to terminals as follows. All SF (subfundamental) D.C. leads **150** connect to terminal **170**, so that whatever potential is applied to terminal **170** is applied at the input to transistor **146** of all of the SF keyers in the blocks **136, 138, 140, 142** and **144.** Similarly, terminal **172** is connected to all of the keyer leads **150** of all of the S3 keyers. Previously mentioned terminal **154** is connected to all the F keyer **150** leads. In like manner, the **150** leads from the **2** (second harmonic) keyers connect to terminal **174**, the **3** keyer **150** leads to terminal **176**, the **4** keyer leads to terminal **178**, the **5** keyers to terminal **180**, the **6** keyers to terminal **182**, and the **8** keyers to terminal **184.**

As mentioned, one suitable specific arrangement for applying selected D.C. voltages to the individual terminals **170, 172, 154, 174, 176, 178, 180, 182** and **184** is shown and described in the previously referred to patent and need not be repeated here.

At the lower right of FIG. **1** a group of eight terminals are indicated by the numerals **190, 192, 194, 196, 198, 200, 202, 204.** Each of these terminals is connected to one of a group of external band pass filters capable of passing thirteen or so adjacent semitones. Internally, terminal **190** is connected to keyer output lead **158** for the SF keyer of block **136.** As will appear presently, the frequency of the fundamental of the square wave at this lead is C at 32 Hz.

Terminal **192** is connected to the **158** leads of keyers F and S3 of block **136** and keyer SF of block **138.** The frequencies of the fundamentals of the square waves at terminal **192** are, therefore, 65 and 98 Hz.

Other connections are as follows. Terminal **194** to leads **158** of keyers **2** and **3** of block **136**, S3 and F of block **138** and SF of block **140.**

Terminal **196** to keyers **4, 5** and **6** of block **136, 2** and **3** of block **138,** S3 and F of block **140**, and SF of block **142.**

Terminal **198** to keyers **8** of block **136, 4, 5** and **6** of block **138, 2** and **3** of block **140,** S3 and F of block **142** and SF of block **144.**

Terminal **200** to keyers **8** of block **138, 4, 5** and **6** of block **140, 2** and **3** of block **142,** and S3 and F of block **144.**

Terminal **202** to **8** of block **140, 4, 5** and **6** of block **142,** and **2** and **3** of block **144.**

Terminal **204** to **8** of block **142,** and **4, 5, 6** and **8** of block **144.** The reason for including keyer **8** of block **144** in the last group will appear presently.

The input square wave signal leads **162** to the keyers are as follows, starting with the fundamentals and even harmonics, that is, the C note tone signals.

C_8 lead **14** is connected to leads **162** of keyer **8** of block **142** and keyers **4** and **8** of block **144.** The frequency of this signal as previously explained is that of the C clock at 4186 Hz.

C_7 lead **18** is connected to keyer **8** of block **140,** keyer **4** of block **142,** and keyer **2** of block **144.**

C_6 lead **22** connects to keyers **8** of block **138, 4** of block **140, 2** of block **142,** and F of block **144.**

C_5 lead **26** is connected to keyers **8** of block **136, 4** of block **138, 2** of block **140,** F of block **142,** and SF of block **144.**

C_4 lead **30** is connected to keyers **4** of block **136, 2** of block **138,** F of block **140** and SF of block **142.**

C_3 lead **34** is connected to keyers **2** of block **136,** F of block **138,** and SF of block **140.**

C_2 lead **38** is connected to keyers F of block **136** and SF of block **138.**

C_1 lead **42** is connected to keyer SF of block **136.**

The G square wave signal system is connected as follows.

Lead **92** is connected to keyer **6** of block **144.** Since as was stated previously, terminal **54**, the 3rd clock **1**, is connected to the external G_8 clock at 6272 Hz and terminal **86** is not connected, lead **92** will be at the G_8 frequency.

G_7 lead **64** is connected to keyers **6** of block **142** and **3** of block **144.**

G_6 lead **76** is connected to keyers **6** of block **140, 3** of block **142** and S3 of block **144.**

G_5 lead **78** is connected to keyers **6** of block **138, 3** of block **140,** and S3 of block **142.**

G_4 lead **80** is connected to keyers **6** of block **136, 3** of block **138** and S3 of block **140.**

G_3 lead **82** is connected to keyers **3** of block **136** and S3 of block **138.**

G_2 lead **84** is connected to keyer S3 of block **136.**

The E square wave system is connected as follows.

Lead **110** is connected to keyer **5** of block **144.** This signal is, therefore, at E_8 or 5274 Hz providing, as stated, the E_8 external clock is connected to terminal **100** and terminal **102** is not externally connected.

The other E connections are E_7 lead **116** to keyer **5** of block **142,** E_6 lead to keyer **5** of block **140,** E_5 lead **124** to keyer **5** of block **138** and E_4 lead **128** to keyer **5** of block **136.**

The frequencies of the various square waves supplied to the leads **162** of block **136** for instance, are as follows.

SF	32 Hz
S3	98 Hz
F	65 Hz
2	131 Hz
3	196 Hz
4	262 Hz
5	330 Hz
6	392 Hz
8	523 Hz

For block **138** these frequencies are doubled and they are doubled again and again for blocks **140** and **142.**

For block **144** they are as follows.

SF	523 Hz
S3	1568 Hz
F	1046 Hz
2	2093 Hz
3	3136 Hz
4	4186 Hz
5	5274 Hz
6	6272 Hz
8	4186 Hz

Note that here the eighth harmonic keyer does not have available the ideal frequency 8372 Hz, but uses the fourth, 4186 Hz instead. This doubling back of the eighth harmonic of the highest octave is of little consequence musically and at these high frequencies strengthening the fourth harmonic rather than supplying the eighth is satisfactory and justified by practical layout limitations. However, the frequency 8273 Hz may be supplied by making the C clock frequency 8273 Hz and adding an additional integrated circuit package to provide another stage of frequency division in the C chain.

This system described above is provided on the assumption that only one set of twelve clock frequencies are to be available. In this instance they are from C_8 4186 Hz to B_8 7902 Hz. Thus, when the integrated circuit is for one of the notes requiring a clock toward the high frequency end, clocks for the ideal third and fifth may not be available. For instance, in the C example given, C_8 provides the fundamentals and octave harmonics, G_8 the third and sixth harmonics and E_8 the fifth harmonics. If, however, the integrated circuit which is identical were to be used for the B notes, the B_8 clock would be connected to terminal **10**, but to be identical to the C circuit would require that F # $_9$ be connected to terminal **54** and D # $_9$ to terminal **100**. Since only F # $_8$ and D # $_8$ are available as clocks, these clocks are connected to terminals **86** and **102** respectively and terminals **54** and **100** are grounded.

The result of this is to put F # $_8$ on both leads **92** and **64** and D # $_8$ on both leads **110** and **116**. This change results in F # $_8$ being applied to keyers **6** and **3** of block **144** and keyer **6** of block **142**. Similarly, D # $_8$ is applied to keyers **5** of blocks **142** and **144**. In this instance the fifth, sixth and eighth harmonics of the B top octave are an octave below the true frequency, but at these high frequencies the deleterious effect is too minor to justify supplying the ideal frequencies.

Reference to the previously set forth table will show that if all the clocks are in the range from C_8 to B_8, terminal **54** will be used for notes C, C # , D, D # and E and that terminal **100** will be used for all notes other than C # , A, A # and B.

Taking the integrated circuit of FIG. **1** which supplies all of the C notes together with their harmonics, the following terminals are required for the package.

Three terminals for ground and two voltages, Vgg and Vdd;

Five terminals for connection to the clocks;

Three clear terminals to receive synchronizing pulses from the master circuits;

One synchronizing output terminal;

Nine D.C. voltage input terminals for scaling of the various harmonics;

Five playing key terminals; and

Eight output terminals to the filter circuits.

The number of terminals for each package is, therefore, **34**, which at the present state of the art is reasonable, and only twelve packages are required per organ manual.

In operation, pressing a C playing key closes the single set of contacts **171** for that particular C. This applies a D.C. keying voltage, either steady or with a desired keying envelope, depending upon the nature of the keying envelope shaping circuit **169**, many of which are available. The most common types simply make use of a resistor-capacitor timing circuit. This operates all of the transistors **148**, FIG. **2**, of the appropriate keying block. The signals fed to the transistors **148** are square waves at the appropriate frequencies and selected voltage level obtained by chopping the appropriate level D.C. applied to terminals **170, 172, 154, 174, 176, 178, 180, 182** and **184** at the frequencies of the square waves applied to leads **162**. Square waves at the appropriate frequencies for all desired harmonics, at the individual appropriate selected voltage levels, and with a selected keying envelope, are thus supplied to a group of sine filters, **205**, connected to terminals **190, 192, 194, 196, 198, 200, 202** and **204**. The filters pass the fundamentals and discriminate against the third and higher odd harmonics. The outputs from the filters are, therefore, sine waves, since square waves have present only odd harmonics of the fundamental. These sine waves or mixtures of sine waves are then collected and applied to output terminal **207** which is connected to the output system, not shown, of the organ. The output system forms no part of this invention, but normally contains amplification, swell control, vibrato, reverberation and selected other features and one or more speakers.

An important feature of this invention is that one integrated circuit package has the keying circuitry for all of the C's or other notes. All 12 packages are identical. This keying circuitry has provision for keying the fundamental and eight harmonics simultaneously and for scaling the harmonic structure as desired. Additionally, only three connected clock leads are necessary for providing all of the fundamentals and the necessary harmonic structure for the five C's, or other notes, of the entire manual. Furthermore, since identical note frequencies will originate from three sources per manual, one for fundamentals and even harmonics, one for third, subthird, and sixth harmonics, and one for fifth harmonics, the packages provide synchronizing pulses from a master package, one for C's, one for C # and so on, to which other packages having circuits for the same notes respond so as to insure complete phase synchronization. Normally such synchronization will be necessary only when the instrument is turned on and will take only about a sixteenth of a second. Once synchronized, all tone signal sources should remain in phase until the instrument is next turned off.

A feature which should be noted is that although the signal outputs from the individual keyers total **45**, the keyer output leads are collected in groups within each package so that only eight pins are necessary for connection of these outputs to the external circuits. As an example, output lead **200** is connected to G_6 and C_6 of block **144**, C_6 and G_6 of block **142**, C_6, E_6 and G_6 of block **140**, and C_6 of block **138**. The signals on this lead, therefore, span the range of from **1046** Hz to **1568** Hz.

If for any reason it is desired to use natural harmonics for the synthesis rather than borrowed harmonics, the appropriate natural harmonic frequencies can be connected to the third clock terminals **54** or **86** and to the fifth clock terminals **100** or **102**. To provide these natural harmonic frequencies it is necessary to have three sets of clocks, one set for the fundamentals and octave frequencies, another set for the third, sixth and subthird harmonics and a set for the fifth harmonics. The thing to be appreciated is that regardless of whether natural or borrowed harmonics are used, no change is required in the integrating circuit packages. One advantage in using three sets of clocks is that the clock sets can be modulated differently to produce special vibrato effects with the octave frequencies, the third harmonic series and the fifths at different vibrato rates for instance.

Although the system described is for a 60 key manual, it is normal for a keyboard to have 61 keys with C_6 for the highest key. Thus, although all the other notes span a range of five octaves, the highest and lowest C's in a 61 key manual are six octaves apart. The frequencies of the twelve clocks mentioned above and the number of frequency divider stages have been chosen to supply a 60 key manual and the extra C at C_8 is most easily provided by a 13th package which is supplied at terminal **10** by an additional C clock at 8372 Hz. Also, in the manner previously mentioned, the G clock is connected to terminal **86** and the E clock to terminal **102.** This has the effect of providing outputs from block **144** as follows. SF, C_6; S3, G_8; F, C_7; **2**, C_8; **3**, G_8; **4**, C_9; **5**, E_8; **6**, G_8; **8**, C_9. This is a satisfactory composition for a note this high in the scale.

This use of a 13th package and extra C clock for the top C is less expensive than it would be to have the twelve clocks at double the frequencies set forth earlier and to provide each of the 12 packages with three extra frequency dividers and an extra keying block and to make the circuit changes necessary, including adding the extra pin terminals, to obtain six octaves of notes from each package, since this would have little utility for any of the notes excepting the C's. Such a system incould, of course, be provided if desired.

The embodiment of the invention just described is under most circumstances to be preferred at the present state of the art and has been set forth in considerable detail since it makes use of principles it is believed are not widely appreciated. These principles can also be embodied in somewhat more complicated integrated circuit systems which require fewer identical integrated circuit packages per manual. For example, there is a system which requires six packages per manual with about 35 terminals or pins per package for the synthesis, another that needs about 43 pins per package and four packages per manual, and another with about 55 pins per package which needs only three packages per manual and so on.

The six package per manual scheme is shown in FIG. **4.** The integrated circuit package **250** serves all the C's and G's for a single manual. It thus serves for two sets of octavely related notes and by using six identical packages, all notes are provided. Inputs are the clocks for C, G, E, D and B.

For the C notes, the C clock provides the fundamentals and even harmonics, the G clock provides the third harmonic system and the E clock the fifth harmonic as in the previous C example. For the G notes, the G clock provides the fundamentals and even harmonics, the D clock the third harmonic system and the B clock the fifth harmonics. Note that the G clock is used in common. It provides the fundamentals for the G notes and the third harmonic system for the C notes.

Similarly, with the integrated circuit connected to the C #, G #, F, D # and C clocks, all C # and G # notes are provided for with G # supplying the third harmonic system and F the fifth harmonic for all C # notes and the D # supplying the third harmonic system and C the fifth for all G # notes. This and other clock combinations to obtain similar results for other notes at the rate of two octavely related note systems per package will be evident from the previously set forth table.

The system of FIG. **5** has an additional clock input over the arrangement of FIG. **4** and one package provides for three note systems, in this example notes C, E and G #. Four packages, therefore, serve for a complete manual. As shown, the clock inputs are C, G, E, B, G # and D #. Here G and E supply the third and fifth harmonics for C; B and G # provide the third and fifth harmonics for E; and D # and C provide the third and fifth for G #. This system makes dual use of the clocks for C, E and G #.

A four note per package system is shown in FIG. **6,** such that only three packages per manual are required. As specifically shown, the package provides all C, D#, F# and A notes. The clock inputs are for the notes C, C#, D#, E, F#, G, G# and A. This system is based upon the diminished chord. Here G and E supply the third and fifth harmonics for C; A# and G provide the third and fifth harmonics for D#. C# and A# supply the third and fifths for F#; and E and C # supply the third and fifth harmonics for A. Although this arrangement is reasonably economical of package pins, the necessary circuit density as quite high, but not beyond the range of possibility. At present one of the less complicated packages is probably to be preferred as a practical matter, however.

One reason for preferring the system of FIG. **1** at present is that the circuit density and the number of package pins necessary is low enough to permit the incorporation in the same package of several octaves of all harmonic or bright wave note signals. This, of course, is a convenience and represents a cost saving if bright waves are to be provided.

FIGS. **7** and **8** illustrate circuitry in the packages illustrated in FIGS. **1, 2** and **3** for the synthesis of bright wave musical note signals from the octavely related square wave signals already present. The bright waves thus produced can be used to enlarge the keyboard resources of the instrument over the lower portion of the scale or to provide bright wave pedal notes. The arrangement shown in FIGS. **7** and **8** provides four octaves of both **8'** and **16'** C notes, using pedal nomenclature, which, of course, is more than is required for a pedal system. If these bright waves are used to augment the keyboard resources, the same notes would be considered **16'** and **32'** notes.

In FIG. **7**, leads **14, 18, 22, 26, 30, 34, 38** and **42** are shown. These are the same leads shown in FIG. **1** and may be considered to be the FIG. **1** leads having these numbers extended to the left. They, therefore, carry square wave signals with the fundamentals respectively at C_8, C_7, C_6, C_5, C_4, C_3, C_2 and C_1, assuming as in the earlier description that the package under description is for the C notes.

For each bright wave C note these square waves are combined by an arrangement commonly referred to as stairstepping to produce a stepped wave which is a close approximation to a sawtooth, the theoretical bright wave. What is required is to take the square wave having its fundamental frequency at the desired musical note frequency at a certain voltage level. To this is added the square wave an octave higher at half the voltage level plus the square wave two octaves higher at one fourth the voltage level of the fundamental, plus the square wave three octaves higher at one eighth the voltage level. This process can be continued to produce a smoother and smoother sawtooth, but the addition of four octaves of square waves is sufficient for practical purposes, and is the basis of the present approach.

In FIG. **7** four blocks are shown, indicated from the left by the numerals **300,302, 304** and **306.** Each of these has a keying lead **308** which is the equivalent of the keying leads **164** previously mentioned. The outputs from each block consist of a **16'** lead **310** and an **8'** lead **312.** All the **16'** leads **310** are connected together and to a 16′ output terminal 314. Similarly, the 8′ leads are all connected to 8′ terminal 316.

The 16′ section in block 300 with its fundamental at C_1 is connected to square wave leads 42, 38, 34, and 30. The 8′ section in this same block has its fundamental at C_2 and is connected to square wave leads 38, 34, 30 and 26. In the next block 302, the 16′ section has the same square wave input connections as the 8′ section of block 300. The 8′ section of block 302 is connected to square wave leads 34, 30, 26 and 22. This same pattern is followed for blocks 304 and 306 as is shown in FIG. 7.

Note that the number of additional terminals or pins required to be added to the package of FIG. 1, for instance, to accommodate this bright wave system is only the two output terminals 314 and 316 plus the keying leads 308, four of which are shown in this example. All other connections are made within the package.

In FIG. 8 the organization of a typical block is shown. In the interest of definiteness the connections are those of block 300, but the blocks are otherwise identical.

In the 16′ section of block 300 there are four MOSFET elements 318, 320, 322, and 324. The drains of these elements are connected together and to the Vdd supply present in the package. The gates in order are connected to the square wave leads 42, 38, 34 and 30. The source of each transistor 318, 320, 322, 324 is connected respectively to the drain of a second set of MOSFET elements 326, 328, 330 and 332. All the gates of these transistors 326, 328, 330 and 332 are connected together and to the keying lead 308 and the 16′ output lead 310 is connected to the sources of all four transistors 326, 328, 330 and 332.

This system operates as follows. When the keying lead 308 is energized, all of the elements 326, 328, 330 and 332 become conductive. Current from the Vdd source is chopped by the transistors 318, 320, 322 and 324 at the frequencies applied to the gates by the leads 42, 38, 34 and 30. Since these leads carry square waves, square waves appear at the outputs. The scaling of the levels of the individual signals through the four branches to the common output depends upon the relative effective resistances of the branches. That is, the resistance through transistor 320 plus 328 is twice the effective resistance through transistor 318 plus 326. Similarly the resistance through path 322 plus 330 is four times and that through 324 plus 332 eight times the resistance through 318 plus 326. The relative resistances through these paths when keying lead 308 is energized are established at the time the integrated circuit element is made by a difference in geometry of the individual MOSFET elements.

The 8′ section of the block 300 is identical to the 16′ section just described excepting for the connections to square wave leads 38, 34, 30, and 26 rather than to leads 42, 38, 34 and 30 and the connection of the outputs to 8′ output terminal 312 rather than to 16′ terminal 310. When keying lead 308 is energized, therefore, the 16′ bright wave is present at terminal 310 and an 8′ bright wave at terminal 312. As is customary, formant and other control and output circuits are connected to receive these bright waves.

I claim:

1. An integrated circuit package for supplying and keying octavely related notes for an electrical musical instrument comprising a supporting means having circuits thereon providing three binary divider chains, an input to one of said chains for connection to a fundamental clock, an input to a second of said chains for connection to a third harmonic clock, an input to the third of said chains for connection to a fifth harmonic clock, said chains providing sources for the fundamentals, octave harmonics, third, subthird, sixth, and fifth harmonics for several octavely related notes, a plurality of groups of keyers on said supporting means, one of said groups for each of said octavely related notes, each of said groups having separate keyers for the fundamental and each of the harmonics for one of said octavely related notes, a lead connected to all of the keyers in a group to turn on all the keyers connected thereto when energized, circuit means connecting the various frequency sources in said chains to the appropriate keyers in each of said groups, and an output system for said keyers.

2. An integrated circuit package as called for in claim 1 in which each of said divider chains has means for resetting all of the dividers in its chain to predetermined starting positions when a synchronizing pulse is supplied to said means, and the divider chain for connection to said fundamental clock has means for supplying synchronizing pulses at a frequency which is a binary submultiple of the lowest frequency of the fundamental clock driven chain connected to any of said keyers.

3. An integrated circuit package as called for in claim 1 in which each of the keyers in a group of keyers when all in the group are turned on has an output determined by the level of an input voltage supplied thereof, and means for supplying independently selected voltages to individual keyers in said groups of keyers to relatively proportion the output levels of the fundamental and several harmonics keyed together.

4. An integrated circuit package as called for in claim 1 in which each of said divider chains has means for resetting all of the dividers in its chain to predetermined starting positions when a synchronizing pulse is supplied to said means.

5. An integrated circuit package as called for in claim 3 in which each of said divider chains has means for resetting all of the dividers in its chain to predetermined starting positions when a synchronizing pulse is supplied to said means, and the divider chain for connection to said fundamental clock has means for supplying synchronizing pulses at a frequency which is a binary submultiple of the lowest frequency of the fundamental clock driven chain connected to any of said keyers.

6. An integrated circuit package as called for in claim 1 having a second clock input connected to the third harmonic divider chain and a second clock input connected to the fifth harmonic divider chain, said second inputs to the third and fifth harmonic divider chains being connected to bypass the first divider stage of each of said third and fifth harmonic divider chains respectively.

7. An integrated circuit package as called for in claim 1 in which said output system includes means within the package to collect the outputs from said keyers in frequency bands, each of said bands including adjacent tone frequencies the fundamentals of which will pass together through a sine filter adapted to reject the third and higher order harmonics of the fundamentals.

8. An integrated circuit package as called for in claim 1 including a separate set of keyers on said supporting means connected for keying square wave signals from said fundamental divider chain in groups, each of the

last said groups comprising at least a frequency at a certain level plus twice said frequency at half said certain level plus four times said frequency at one fourth said certain level, a second output system for said separate set of keyers, and circuit means for actuating the keyers in the last said groups.

9. An integrated circuit package for supplying and keying at least one set of octavely related notes for an electrical musical instrument comprising a supporting means having circuits thereon providing at least three binary divider chains, an input to one of said chains for connection to a fundamental clock, inputs to at least two others of said chains for connection respectively to clocks which are octavely related to the third harmonic and fifth harmonic of the fundamental clock, said chains providing sources for at least the fundamentals, octave harmonics, third, subthird, sixth and fifth harmonics for a group of octavely related notes, a plurality of groups of keyers on said supporting means one of said groups for each of said octavely related notes, each of said groups having separate keyers for the fundamental and each of the harmonics for one note, a lead connected to all of the keyers in a group to turn on all the keyers connected thereto when energized, circuit means connecting the several frequency sources in said chains to the appropriate keyers in each of said groups, and an output system for said keyers.

10. An integrated circuit package as called for in claim 9 in which each of the keyers in a group of keyers when all in the group are turned on has an output determined by the level of an input voltage supplied thereto, and means for supplying independently selected voltages to individual keyers in said groups of keyers to relatively proportion the output levels of the fundamental and several harmonics keyed together.

11. An integrated circuit package as called for in claim 9 in which each of said divider chains has means for resetting all of the dividers in its chain to predetermined starting positions when a synchronizing pulse is supplied to said means.

12. An integrated circuit package as called for in claim 9 in which each of said divider chains has means for resetting all of the dividers in its chain to predetermined starting positions when a synchronizing pulse is supplied to said means, and the divider chain for connection to said fundamental clock has means for supplying synchronizing pulses at a frequency which is a binary submultiple of the lowest frequency of the fundamental clock driven chain connected to any of said keyers.

13. An integrated circuit package as called for in claim 10 in which each of said divider chains has means for resetting all of the dividers in its chain to predetermined starting positions when a synchronizing pulse is supplied to said means, and the divider chain for connection to said fundamental clock has means for supplying synchronizing pulses at a frequency which is a binary submultiple of the lowest frequency of the fundamental clock driven chain connected to any of said keyers.

14. An integrated circuit package as called for in claim 9 having a second clock input connected to the third harmonic divider chain and a second clock input connected to the fifth harmonic divider chain, said second inputs to the third and fifth harmonic divider chains being connected to bypass the first divider stage of each of said third and fifth harmonic divider chains respectively.

15. An integrated circuit package as called for in claim 9 in which said output system includes means within the package to collect the outputs from said keyers in frequency bands, each of said bands including adjacent tone frequencies the fundamentals of which will pass together though a sine filter adapted to reject the third and higher order harmonics of the fundamentals.

16. An integrated circuit package as called for in claim 9 including a separate set of keyers on said supporting means connected for keying square wave signals from said fundamental divider chain in groups, each of the last said groups comprising at least a frequency at a certain level plus twice said frequency at half said certain level plus four times said frequency at one fourth said certain level, a second output system for said separate set of keyers, and circuit means for actuating the keyers in the last said groups.

17. An integrated circuit package for supplying and keying a plurality of notes for an electrical musical instrument comprising a supporting means having circuits thereon providing a plurality of binary divider chains, clock inputs individual to said chains to provide with said chains several series of octavely related musical note signals, one series for each of said chains, each of said clocks having a frequency that bears a musical third or fifth relationship to at least one of the others of said clocks, a plurality of keyers in groups, connections from three of said divider chains to each of said groups of keyers to provide each of said groups with a fundamental, an octave harmonic series, a third harmonic series, and a fifth harmonic, keying circuits connected to operate the keyers in each of said groups together and independently of other groups, and an output system connected to said keyers.

18. An integrated circuit package as called for in claim 17 in which there are three clock inputs and the groups of keyers supply a series of octavely related notes.

19. An integrated circuit package as called for in claim 17 in which there are five clock inputs and the groups of keyers supply two series of octavely related notes.

20. An integrated circuit package as called for in claim 17 in which there are six clock inputs and the groups of keyers supply three series of octavely related notes.

21. An integrated circuit package as called for in claim 17 in which there are eight clock inputs and the groups of keyers supply four series of octavely related notes.

22. An integrated circuit package as called for in claim 17, including means for adjustably scaling the outputs of the keyers in said groups to vary the harmonic balance of the outputs of said groups.

23. An integrated circuit package as called for in claim 18, including means for adjustably scaling the outputs of the keyers in said groups to vary the harmonic balance of the outputs of said groups.

24. An integrated circuit package as called for in claim 19, including means for adjustably scaling the outputs of the keyers in said groups to vary the harmonic balance of the outputs of said groups.

25. An integrated circuit package as called for in claim 20, including means for adjustably scaling the outputs of the keyers in said groups to vary the harmonic balance of the outputs of said groups.

26. An integrated circuit package as called for in claim 21, including means for adjustably scaling the outputs of the keyers in said groups to vary the harmonic balance of the outputs of said groups.

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