# United States Patent [19]

**Moore**

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[54] **MULTIPLEX HARMONY GENERATOR**


[75] Inventor: **Douglas R. Moore**, Niles, Ill.

[73] Assignee: **Chicago Musical Instrument Co.**, Lincolnwood, Ill.



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[21] Appl. No.: **409,009**

[52] **U.S. Cl.** .................. **84/1.17**; 84/1.01; 84/1.03

[51] **Int. Cl.**[2] ..................... **G10H 1/00**; G10H 3/06

[58] **Field of Search** ......... 84/1.01, 1.03, 1.17, 1.24, 84/DIG. 22



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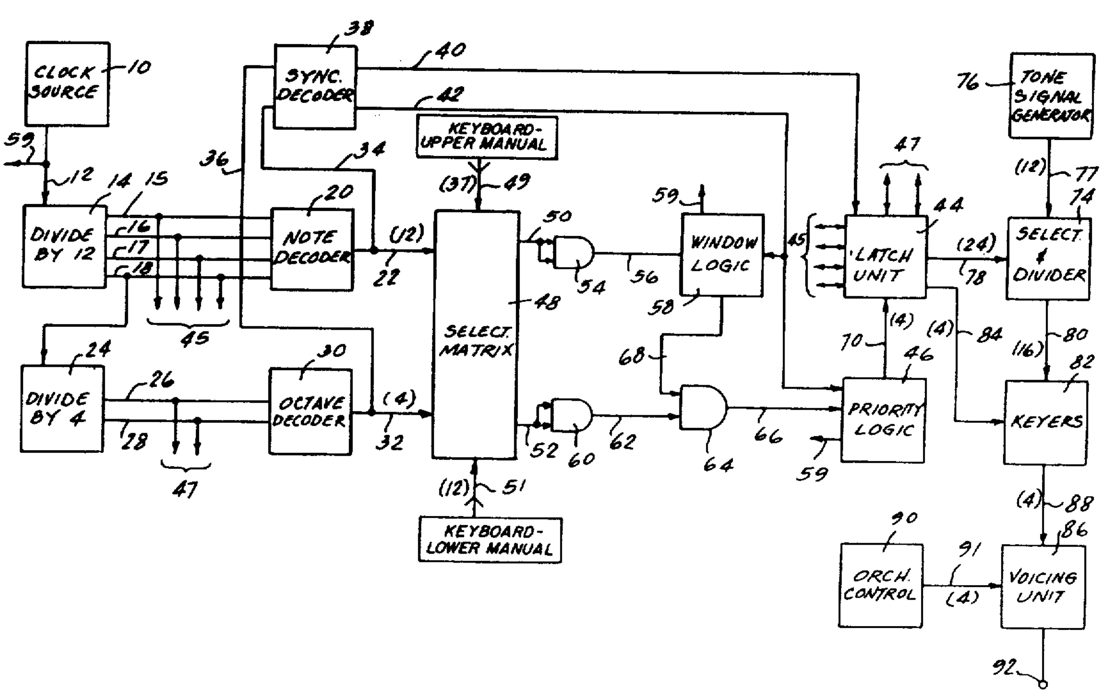
*Primary Examiner*—L. T. Hix
*Assistant Examiner*—U. Weldon
*Attorney, Agent, or Firm*—Hill, Gross, Simpson, Van Santen, Steadman, Chiara & Simpson


[57] **ABSTRACT**


A harmony generator provides signals for causing the output system of an electronic musical instrument to simultaneously sound a plurality of tones forming a chord, such tones corresponding to keys depressed on the left-hand or accompaniment keyboard of the instrument. The tones sounded by operation of the harmony generator are related in pitch to a key depressed by the operator on the righthand or solo keyboard of the instrument, to harmonize therewith. The harmony generator incorporates a matrix which is connected with switches individually actuated by operation of the keys of the two keyboards, and with decoders for identifying particular notes and octaves thereof, whereby the matrix produces a train of pulses representative of a plurality of individual keys, which is received by a logic unit and employed to store, in a plurality of latch units, representations of certain operated ones of the keys of the accompaniment keyboard, and certain data relating to the operated key of the solo keyboard which corresponds to the highest pitch. The latches develop output signals which are effective to select certain ones of a plurality of output signals of a tone signal generator and to selectively reduce them in frequency by an amount corresponding to the data stored in the latches, and then to cause each signal there produced to be connected through an individual voicing circuit prior to being connected with the output system of the instrument. The individual voicing of the tones sounded by the output system simulate an orchestration in which the various parts of a multi-part harmony are played by several separate instruments.


**20 Claims, 9 Drawing Figures**



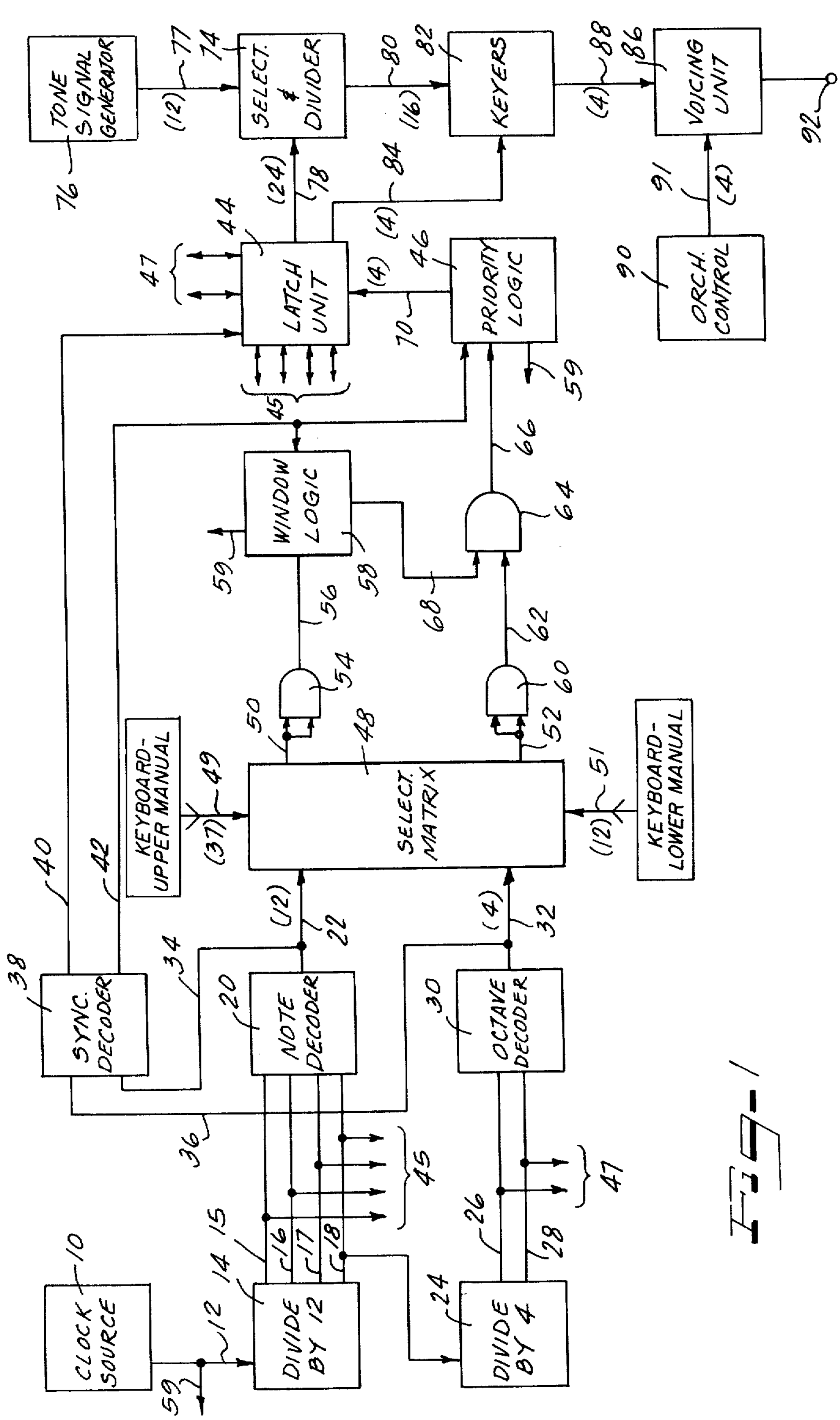

TONE SIGNAL GENERATOR
SELECT. & DIVIDER
KEYERS
VOICING UNIT
LATCH UNIT
PRIORITY LOGIC
ORCH. CONTROL
WINDOW LOGIC
KEYBOARD-UPPER MANUAL
SELECT. MATRIX
KEYBOARD-LOWER MANUAL
SYNC. DECODER
NOTE DECODER
OCTAVE DECODER
CLOCK SOURCE
DIVIDE BY 12
DIVIDE BY 4

FIG-1

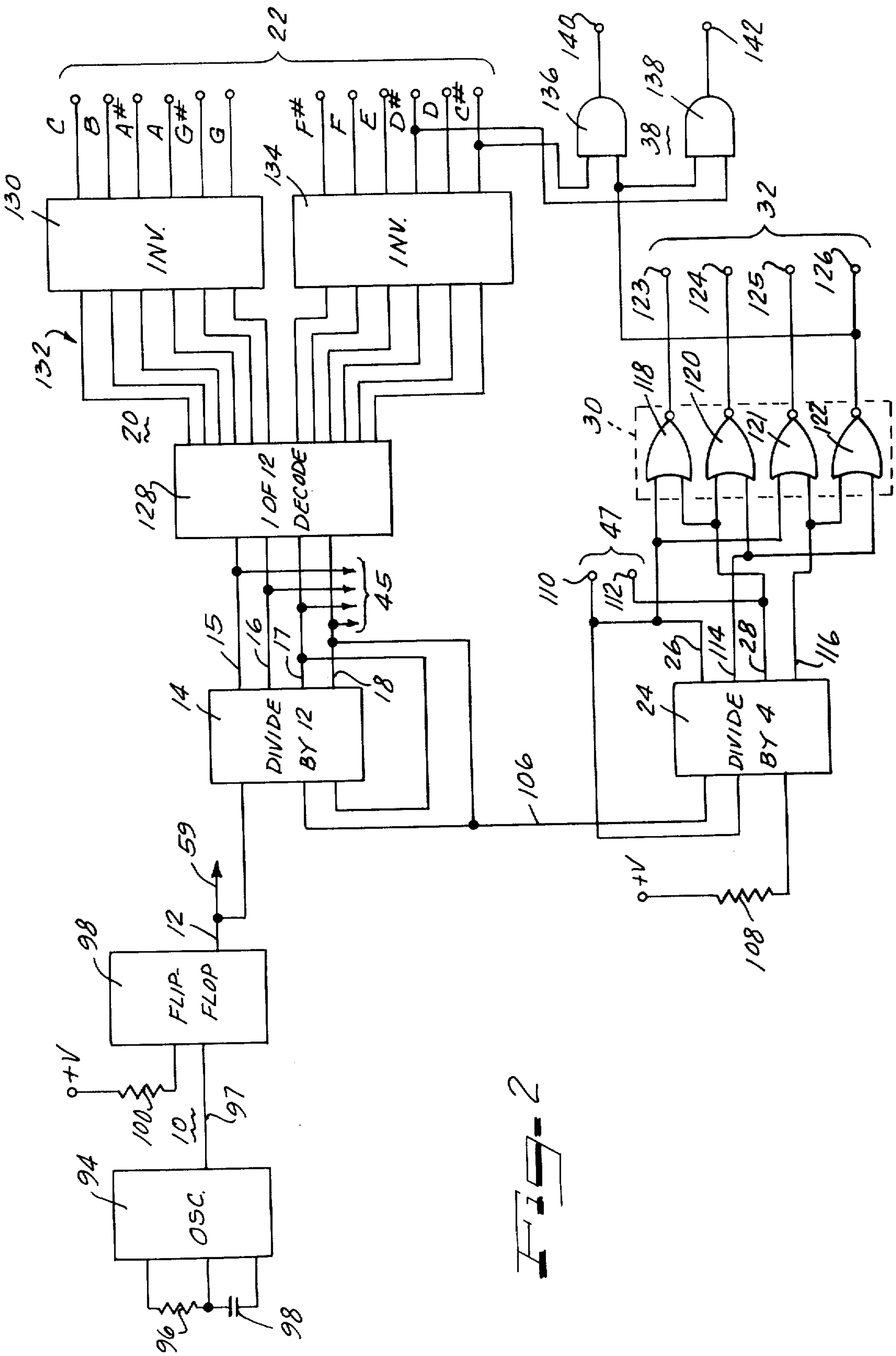

INV.
INV.
1 OF 12 DECODE
DIVIDE BY 12
DIVIDE BY 4
FLIP-FLOP
OSC.
C
B
A#
A
G#
G
F#
F
E
D#
D
C#
+V
+V

Fig. 2

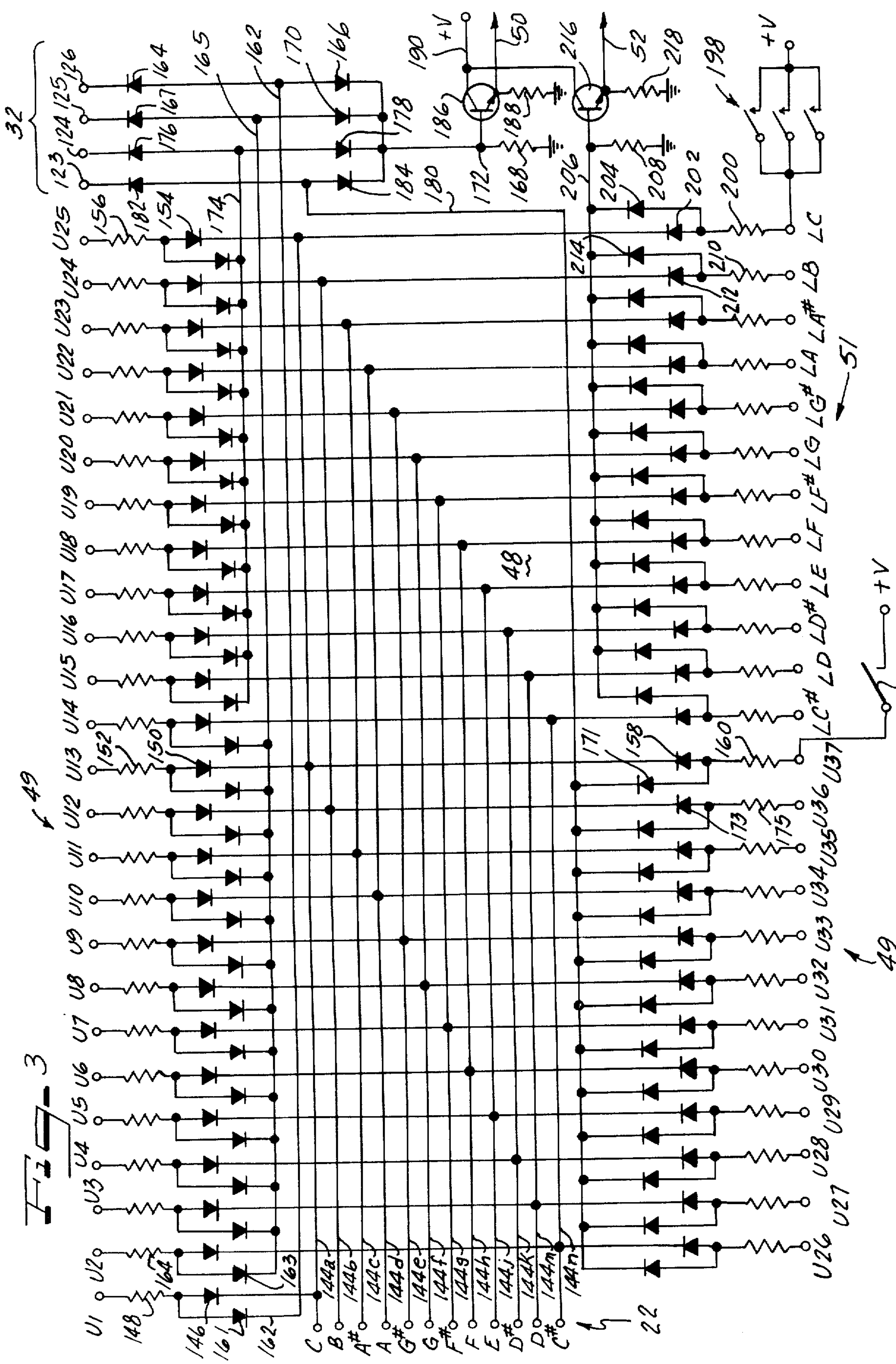


Fig. 3
U1 U2 U3 U4 U5 U6 U7 U8 U9 U10 U11 U12 U13 U14 U15 U16 U17 U18 U19 U20 U21 U22 U23 U24 U25
U26 U27 U28 U29 U30 U31 U32 U33 U34 U35 U36 U37
LC LB LA# LA LG# LG LF# LF LE LD# LD LC#
C B A# A G# G F# F E D# D C#
+V

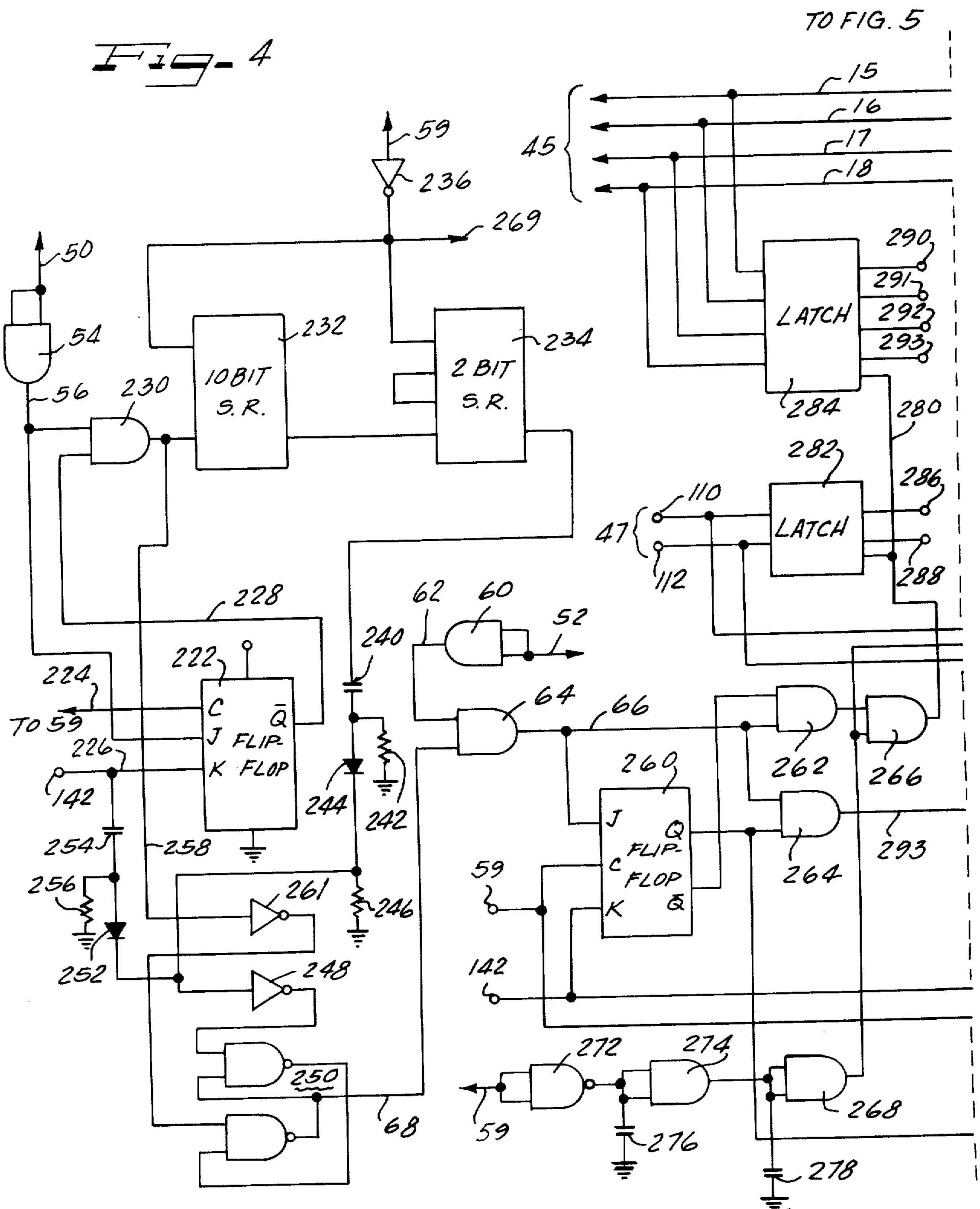
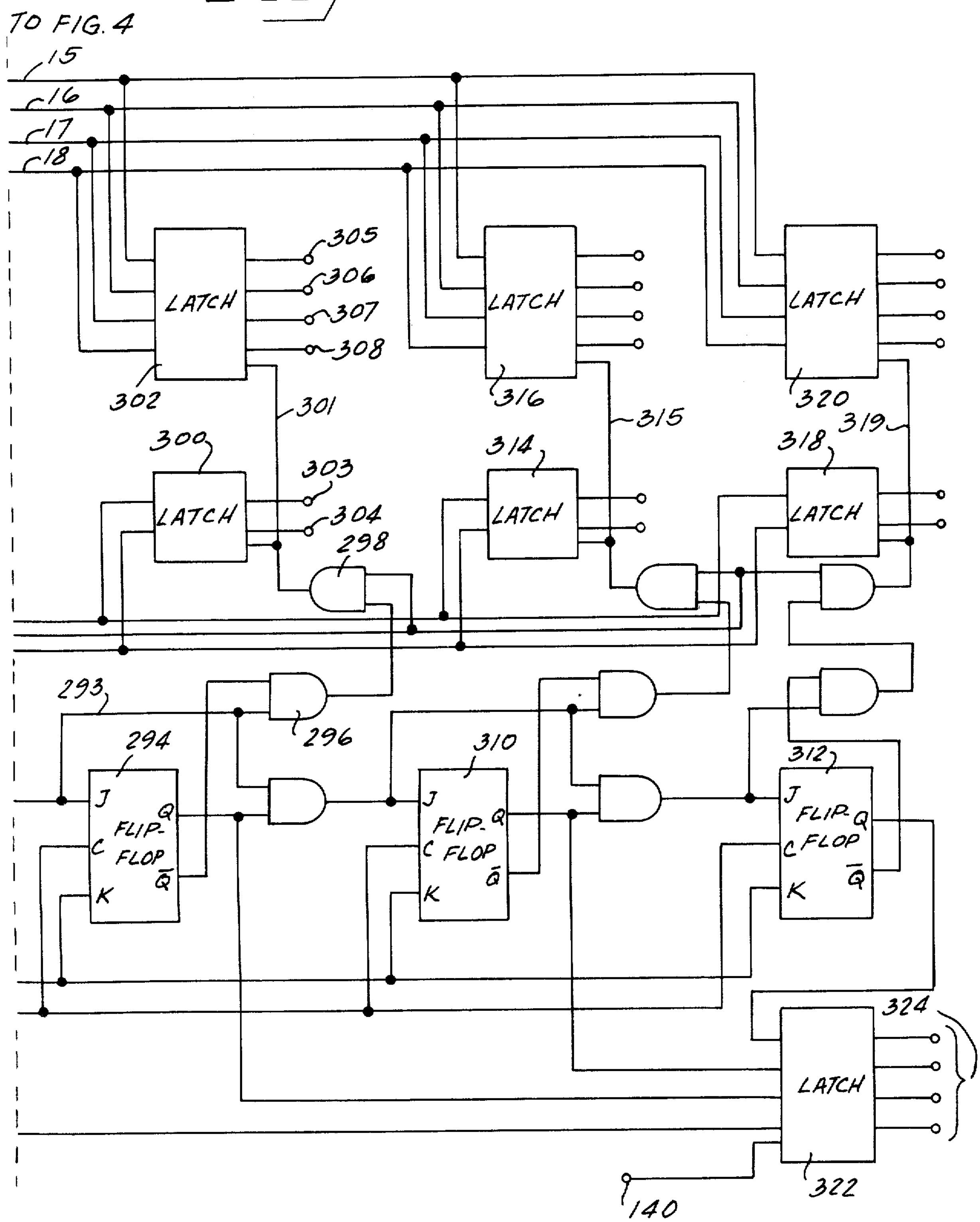


Fig. 4
TO FIG. 5
15
16
17
18
45
59
236
269
50
54
56
230
10 BIT S.R.
232
2 BIT S.R.
234
LATCH
284
290
291
292
293
280
282
LATCH
286
288
110
112
47
228
222
C
J
K
Q̄
FLIP-FLOP
224
TO 59
226
142
254
256
252
258
261
248
250
68
240
244
242
246
62
60
52
64
66
260
J
Q
C
FLIP-FLOP
K
Q̄
59
142
262
264
266
293
272
274
268
59
276
278

Fig-5


TO FIG. 4
15
16
17
18
LATCH
305
306
307
308
302
301
LATCH
316
LATCH
320
315
300
LATCH
303
304
298
314
LATCH
318
319
LATCH
293
296
294
J
Q
FLIP-FLOP
C
Q̄
K
310
312
LATCH
324
322
140

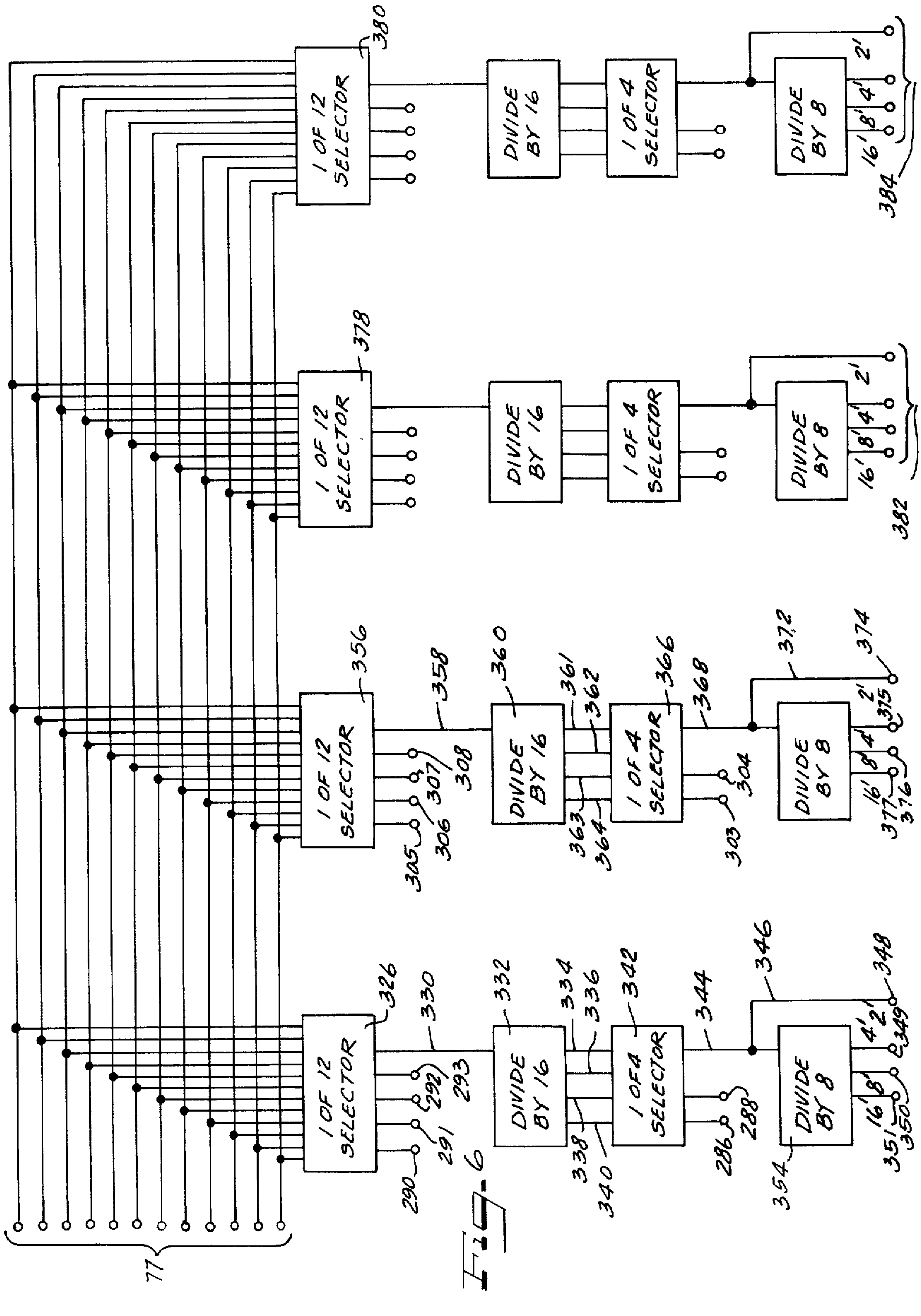

1 OF 12 SELECTOR
DIVIDE BY 16
1 OF 4 SELECTOR
DIVIDE BY 8
2'
4'
8'
16'
77
290
291
292
293
326
330
332
334
336
338
340
342
344
346
348
349
350
351
354
286
288
303
304
305
306
307
308
356
358
360
361
362
363
364
366
368
372
374
375
376
377
378
380
382
384

Fig. 6

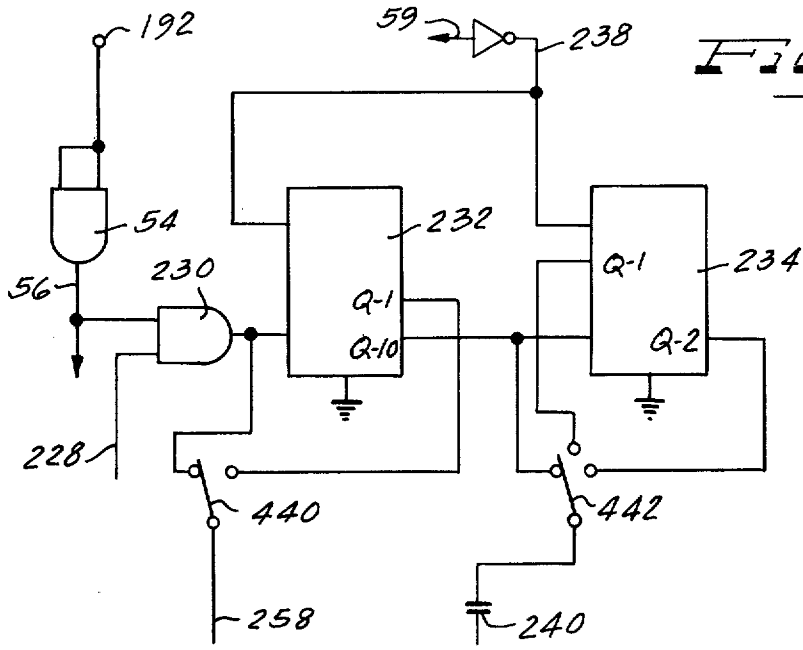

192
59
238
54
232
234
56
230
Q-1
Q-10
Q-1
Q-2
228
440
442
258
240

Fig-8

Fig-7

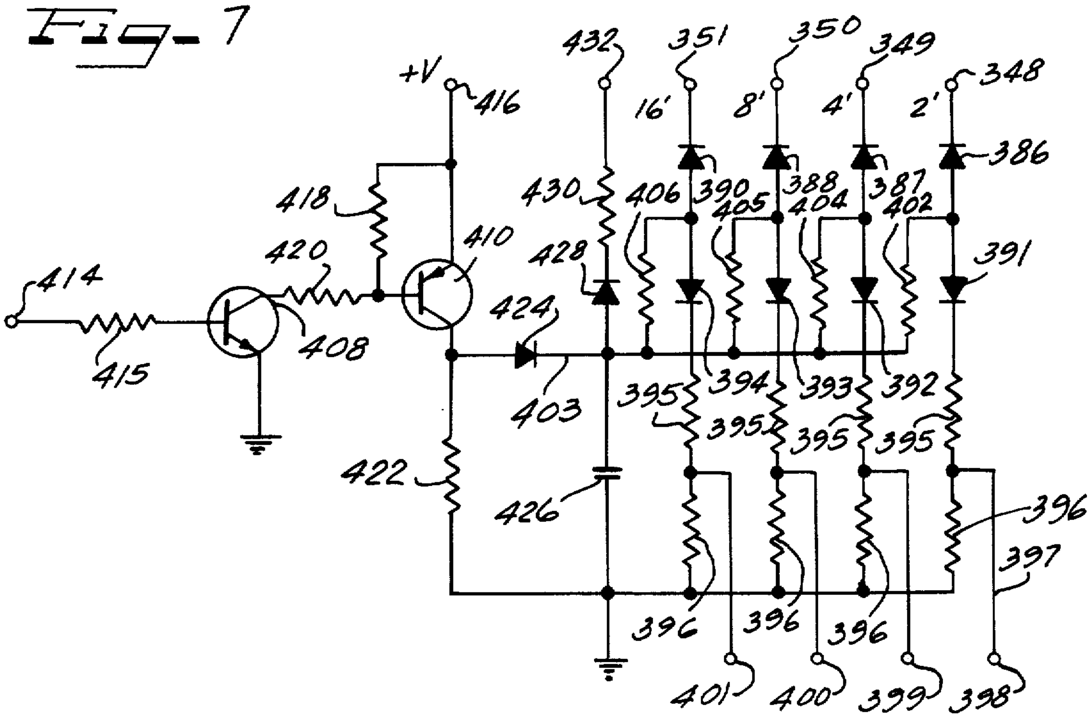
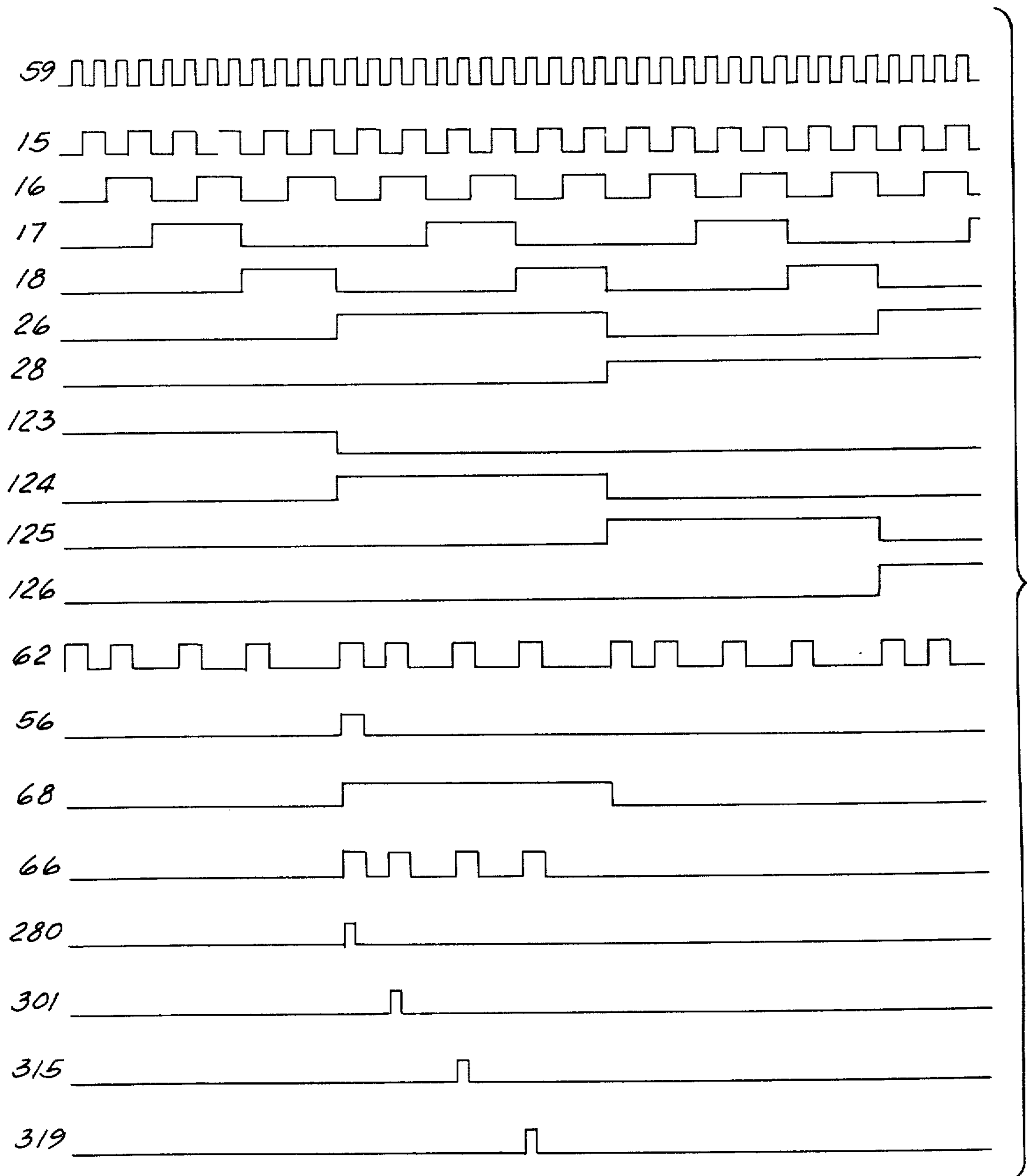

432
351
350
349
348
+V
416
16'
8'
4'
2'
386
418
430
406
390
388
387
405
404
402
420
410
428
391
414
424
408
415
403
394
393
392
395
422
426
396
397
401
400
399
398

Fig. 9



## MULTIPLEX HARMONY GENERATOR

### BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an electronic musical instrument and more particularly to an electronic musical instrument having means for automatically harmonizing tones in a predetermined relationship with one or more tones generated in response to depression of the keys of a keyboard of such instrument.

2. The Prior Art

Various systems have been developed in the past for generating a series of fill-in tones simultaneously in response to operation of a number of keys of a keyboard. Typically, such systems require the provision of multiple switches or multiple poles of a single switch simultaneously operative to close multiple conductive circuits and sometimes to open others, in response to depression of various keys of the keyboard. Depression of such keys changes the condition of all of the switches, or all of the poles of a single switch, associated with the operated key, to open and close a variety of electrical circuits. While such systems have operated satisfactorily, they are relatively complex and expensive in construction, and they are operable in only a relatively limited manner which is not always the manner desired by the operator-player.

Moreover, in the previously known systems, the various tones were typically sounded either in the same voice as the tones normally selected, or in a plurality of voices selected in accordance with the degree of separation, in terms of the chromatic musical scale, between the pitches of the various tones which are sounded.

### SUMMARY OF THE INVENTION

One illustrative embodiment of the present invention comprises a scanner adapted for successively scanning the condition of a plurality of switches adapted to be individually operated in response to depression of the keys of a keyboard of a musical instrument, means connected to the scanner and operative to provide an indication of which key of those depressed corresponds to the tone having the highest pitch of any of the depressed keys, and means for automatically generating a harmony in a plurality of individual voices below said highest tone in response to one or more additional keys simultaneously depressed, each of said individual voices being selected only in response to the relative pitches of said tones.

It is accordingly a principal object of the present invention to provide an electronic musical instrument having means for generating a plurality of harmonizing tones which does not require a multiplicity of separate switches or switch poles for each key.

Another object of the present invention is to provide apparatus for generating such tones which has a simplified construction.

A further object of the present invention is to provide means for sounding a plurality of tones below the highest pitch tone played in response to depression of a key of a solo keyboard, the relationship of the voices such tones being automatically selected in accordance with the relative pitch of such tones.

A further object of the present invention is to provide a harmony generator adapted for sounding a plurality of tones forming a chord in response to depression of



certain keys of a solo keyboard and an accompaniment keyboard, in which the key for the tone having the highest pitch is sounded in a first predetermined voice, and the key for the tone having the second highest pitch is sounded in a second predetermined voice, irrespective of which tones are sounded.

These and other objects and advantages of the present invention will become manifest upon an examination of the following description and the accompanying drawings.

### BRIEF DESCRIPTION OF THE DRAWINGS

Reference will now be made to the accompanying drawings in which:

FIG. **1** is a functional block diagram of a portion of an electronic musical instrument incorporating an illustrative embodiment of the present invention;

FIG. **2** is a functional block diagram of certain portions of the apparatus of FIG. **1**, shown in more detail;

FIG. **3** is a schematic circuit diagram of a diode selection matrix employed in the apparatus of FIG. **1**;

FIGS. **4** and **5** taken together comprise a functional block diagram of a logic control unit embracing several of the functional units employed in the apparatus in FIG. **1**;

FIG. **6** is a functional block diagram of a plurality of note selectors and dividers employed with the apparatus of FIG. **1**;

FIG. **7** is a schematic circuit diagram of an illustrative keyer which may be employed with the apparatus of FIG. **1**;

FIG. **8** is a functional block diagram of an alternative arrangement which may be employed with the apparatus of FIG. **1** in an alternative embodiment of the present invention; and

FIG. **9** is a series of wave forms forming a timing diagram illustrating the sequence of certain operations within the system.

In FIG. **1**, which is a functional block diagram of an illustrative embodiment of the present invention, a clock pulse generator **10** generates a succession of clock pulses and applies such pulses over an output line **12** to the input of a divide-by-twelve unit **14**. The divide-by-twelve unit **14** comprises a four stage binary counter, and four output lines **15–18** connect the output terminals of the divide-by-twelve unit **14** to four inputs of a note decoder unit **20**, which comprises a 1-of-12 decoder. The twelve output lines **22** leading from the note decoder **20**, which are energized individually in response to unique combinations of high and low potentials on the lines **15–18**, are illustrated as a single line in FIG. **1** in the interest of simplifying the drawings. The number of separate lines represented by the line **22** is indicated parenthetically. The same is true for the other multi-conductor lines of FIG. **1**.

The output line **18** of the divide-by-twelve unit **14** is connected to the input of a divide-by-four unit **24**. The divide-by-four unit **24** is a two-stage binary counter which produces output signals on two output lines **26** and **28**. The lines **26** and **28** are connected to the two inputs of an octave decoder unit **30**, which produces signals on four output lines **32**. The decoder unit **30** is a one-of-four decoder, so that one of the four lines **32** is energized, in accordance with the potentials on the lines **26** and **28**.

Outputs of the decoders **20** and **30** are supplied, respectively, to lines **34** and **36**, which are connected to the inputs of a synchronization decoder **38**. The decoder 38 produces pulses on two output lines 40 and 42 in response to unique combinations of output signals produced by the decoders 20 and 30. The pulses on the line 40 and 42 are used for synchronization purposes, as more fully described hereinafter, and are applied respectively to inputs of a plurality of latches within a latch unit 44, to an input of a priority logic unit 46, and to the window logic unit 58.

The twelve output lines 22 of the note decoder 20 and the four output lines 32 of the octave decoder 30 are applied to inputs of a selection matrix 48, which is adapted to produce output signals on two output lines 50 and 52. The matrix is connected by lines 49 to 37 individual switches controlled by the keys of the upper manual (or solo) keyboard, and by twelve lines 51 to the switches operated by the keys of the lower manual (or accompaniment) keyboard.

The output line 50 is connected to the input of a shaper unit 54, and the output of the shaper unit 54 is connected over a line 56 to the input of a window logic unit 58. The pulses supplied to the logic unit 58 over the line 56 correspond to operated keys of the upper manual of the instrument. The output line 52 is connected through a shaper unit 60, and the output of the shaper unit 60 is connected over a line 62 to the input of an AND gate 64. The pulses on the line 62 are representative of the operated keys of the lower manual of the instrument, and of all other keys which are octavely related thereto. The shapers 54 and 60 are preferably AND gates of the saturated logic type, such as transistor transistor logic (TTL), so that they inherently function as shapers to produce a rectangular pulse output in response to an input pulse.

An output of the window logic unit 58 is connected over a line 68 to a second input of the AND gate 64, and the AND gate 64 provides input signals to the priority logic unit 46 over a line 66. The window logic unit 58, together with part of the matrix 48, forms a first scanning means for scanning the upper manual keys, while the gate 64, together with another part of the matrix 48, forms a second scanning means for scanning the keys of the lower manual.

The function of the window logic unit 58 is to identify the uppermost key (i.e., the key corresponding to the tone of highest pitch) depressed by the operator, and to provide a signal on the line 68 corresponding to a window through which up to twelve pulses may be passed through the AND gate 64, from the line 62 to the line 66. The pulses present on the line 62 are representative of all keys octavely related to the depressed keys in the lower manual, so that the pulses produced on the line 66 are representative of the keys of the upper manual which are octavely related to depressed keys of the lower manual, and which are within the window, i.e., within the first twelve pulse times following the first pulse present on the line 56. The window logic unit 58 has an input from the line 42 in order to synchronize its operation and another input to the clock generator 10 over a line 59.

The priority logic unit 46 is also connected to the line 42 for synchronization purposes. It produces four signals on output lines 70, which are connected to the latch unit 44. An output latch within the unit 44 produces a signal which identifies which of the other latches within the unit 44 are set during each cycle of operation, and when such setting occurs. Periodically, the output latch is reset by a signal provided thereto over the line 40. When the latches are set, they are each set in accordance with the simultaneous levels present on the lines 15–18, via four input lines 45, and on the lines 26 and 28 via two additional input lines 47.

Twenty-four output lines are connected to the latches 44, and these 24 lines are represented by a line 78 interconnecting the latches 44 to a selector and divider unit 74, which incorporates a number of selectors and dividers. The selectors and dividers are connected to a signal generator 76 over a plurality of twelve lines 77. The tone signal generator 76 produces on each of its 12 output lines a signal having a frequency which corresponds to a harmonic of the frequency of one of the 12 notes of the chromatic scale, and selectors and dividers 72 manipulate such signals, in response to the signals received from the latches 44 over the lines 78, to provide signals on 16 output lines 80. The 16 output lines 80 are connected to inputs of a keying unit 82 incorporating a plurality of keyers, which also receive four inputs over lines 84 from the latches 44. The keyers are connected to a voicing unit 86 incorporating a plurality of voicing circuits by four lines 88. When a composite voice is desired, several lines 88 may be provided for each keyer. The voicing circuits within the unit 86 are selected by means of signals produced by an orchestration control unit 90, interconnected with the voicing unit 86 over lines 91. The voicing circuits are connected with an output terminal 92, which is adapted to be connected to the output system of the electronic musical instrument for producing tones in accordance with the output signals of the voicing circuits. The four signals produced as outputs from the keyers 82 correspond with four tones of a chord selected by depressing four keys of the lower manual, and each tone is separately voiced by means of the voicing circuits 86 before being connected to the output system via the terminal 92. One signal is produced from the keyers 82 for each key which is depressed, so that less than four signals are produced if less than four keys are depressed.

In FIG. 2 a more detailed functional block diagram of certain portions of the apparatus of FIG. 1 is illustrated. The clock generator 10 incorporates an oscillator 94 which is conveniently an astable multivibrator having a period determined by the time constant of an RC circuit including a resistor 96 and a capacitor 98. The oscillator 94 furnishes an output on a line 97 which is connected to the toggle input of a flip-flop 98. The flip-flop 98 furnishes a clock signal on an output line 12 which is connected to the input of the divide-by-twelve unit 14 and also to a line 59, which is connected to other points throughout the system where clock pulses are needed.

The clock pulse generator illustrated in FIG. 2 is conventional, and may readily be formed of conventional components. For example, the oscillator 94 preferably comprises a type 8601 multivibrator. The flip-flop 98 preferably comprises a J-K flip-flop, such as one-half of an integrated circuit type 74107, having its J and K input terminals connected to a positive potential via a resistor 100, and its clock input connected to the line 97. By use of the flip-flop 98, the clock signal applied to the line 12 and 59 is made a square wave, having equal positive-going and negative-going portions although the output of the oscillator 94 has a less symmetrical waveform.

The divide-by-twelve unit 14 is preferably a unit such as a type 7493 (nominally a four-stage binary counter) with two of its outputs connected to inputs to reduce the radix of the counter from sixteen to twelve.

The four outputs made available on the output lines **15–18** are the four outputs produced individually by the four binary stages of the counter. One is connected to the divide-by-four unit **24** over a line **106**. The divide-by-four unit comprises a pair of J-K flip-flops, both having their J and K inputs connected to a source of positive potential through a resistor **108**. The clock input of the first flip-flop is connected to the line **106**, and the clock input of the other flip-flop is connected to the Q output of the first flip-flop. The Q outputs of the two flip-flops are connected over lines **26** and **28** to terminals **110** and **112**, respectively. In addition, the $\bar{Q}$ outputs of the two flip-flops are connected to lines **114** and **116**. The lines **26, 28, 114,** and **116** are connected in unique combinations to the inputs of four NOR gates which comprise the octave decoder **30**. The NOR gate **118** has its inputs connected to the lines **26** and **28**; the NOR gate **120** has its inputs connected to the lines **28** and **114**; the NOR gate **121** has its inputs connected to the lines **26** and **116**; and the NOR gate **122** has its inputs connected to the lines **114** and **116**. The NOR gates **118–122** produce an individual output at four output terminals **123–126**.

The four output lines **15–18** of the divide-by-twelve unit **14** are connected to the four inputs of the note decoder **20**. The note decoder **20** incorporates a **1-of-**12 decoder **128** which may be formed of a conventional integrated circuit unit such as type **8311**. Six of the twelve outputs **132** of the decoder **128** are connected to six input terminals of a group of six inverters **130** which functions to individually invert the signals present on six of the lines **132** and to convey them individually to six of the output lines **22**. The other six of the twelve output lines **132** from the decoder **128** are connected to six inputs of a second group of six inverters **134**, and they are thereby inverted and presented to the other six of the output lines **22.** The 12 output lines of the inverters **130** and **134** are each associated with a different note of the chromatic scale, as illustrated in FIG. **2**, for a purpose more fully described hereinafter.

Two of the outputs of the inverter unit **134** are connected individually to two AND gates **136** and **138**, both of which have their second inputs connected to the output of the NOR gate **122** of the octave decoder unit **30.** The gates **136** and **138** are operative to produce output signals on lines **40** and **42** for synchronization purposes. The line **40** is connected to a terminal **140** and the line **142** is connected to a terminal **142.** The terminals **140** and **142** are connected to various points within the system where the synchronization pulses supplied thereto are required.

Referring now to FIG. **3**, which is an illustration of the diode matrix incorporated in the apparatus of FIG. **1**, the 12 lines **22** are connected from the inverters **130** and **134** (FIG. **2**) to twelve parallel lines of the matrix **144***a*-**144***n*. The line **144***a* will sometimes be referred to hereinafter as the "C" line, the line **144***b* as the "B" line, and so on, with the line **144***n* being referred to as the "C#" line. These lines are energized in succession by the operation of the decoder **20**, so that only one of the line **144***a*-**144***n* at a time has a high potential thereon.

The C line **144***a* of the matrix is connected through a diode **158** and a resistor **160** to a terminal U-**37**, which is adapted to be connected to the normally open contact of a key operated switch **149** associated with the highest C key of the upper manual keyboard. When that key is depressed, the switch functions to apply high potential to the terminal U-**37**. This high potential permits the line **180** to go high, via a diode **171**, provided that the C input line **22** is high, and also provided that the line **180** is not clamped to a low potential via the terminal **123**, as more fully described hereinafter. The C line **144***a* is also connected to a terminal U-25 through a diode **154** and a resistor **156**, and to a terminal U-**13** through a diode **150** and a resistor **152.** In a similar fashion, the C line **144***a* is connected to a terminal U-**1** through a diode **146** and a resistor **148.** The U-**25** terminal is connected to a switch actuated by the second highest C-key of the upper manual keyboard, and the U-**13** and the U-**1** lines are connected to the key operated switches of the next two lower C keys of the upper manual. Depression of the key associated with the terminal U-**25** causes the line **174** to go high when the C line **144***a* and the terminal **124** are both high. Depression of the other C keys has a similar effect on lines **162** and **165**, provided the lines **126** and **125** are high, respectively.

In similar fashion, the B line **144***b* is connected in circuit to a terminal U-**36** through a diode **173** and a resistor **175**, corresponding to the diode **158** and the resistor **160**, and also to the terminals U-**24** and U-**12** through corresponding diodes and resistors. The terminal U-**36** goes high whenever the highest one of the B keys of the upper manual is depressed, resulting in a high potential on the line **180** when the line **144***b* is high, provided that the terminal **123** is also high. The other B terminals U-**24** and U-**12** are connected in similar fashion, as are all of the other terminals U-**1**, U-**37**, which correspond to the 37 lines **49** of FIG. **1**.

The terminal U-**1** is also connected through a diode **161** to the line **162**, and the line **162** is connected through a diode **164** to the terminal **126** (FIG. **2**) and through a diode **166** connected in series with a resistor **168** to ground. The line **162** is referred to hereinafter as the "lower octave" line, and its level goes high whenever the key connected with the terminal U-**1** is depressed, to connect a high potential through the resistor **148** and the diode **161**, provided there is at that time a high potential on the terminal **126**. As described above, the terminal **126** is connected to an output of the octave decoder **30**, and the terminal **126** is rendered high only when both inputs to the NOR gate **122** are low. This occurs during each cycle during an interval devoted to decoding the notes of the lowest octave of the instrument.

The 12 terminals U-**2** through U-**13** are each connected through an individual diode like the diode **163**, to the line **165**. The diode **163** is connected from the U-**2** input resistor **164** to the line **165**. The line **165** is connected through a diode **167** to the terminal **125** and through a diode **170** to a point **172**, located at the junction between the diode **166** and the resistor **168**. The line **165** goes high whenever a key within the first octave above the lowest octave of the instrument (namely, the keys corresponding to the terminals U-**2** - U-**13**) is depressed, provided that the terminal **125** is high. The terminal **125** goes high when the second highest octave is being scanned, at which time the inputs to the two inputs of the NOR gate **121** are both low.

The remaining two octaves of the upper manual are similarly treated. The switches associated with the terminals U-**15** to U-**25** are connected through diodes to the line **174**, and the line **174** is connected to the terminal **124** through a diode **176** and through a diode **178** to the point **172**. Similarly, the switches of the highest octave of the upper manual, corresponding to terminals **U-26** - **U-37**, are all interconnected through individual diodes to the line **180**, which is connected by a diode **182** to the terminal **123** and by a diode **184** to the point **172**. The diodes **166**, **170**, **178**, and **184** all pass positive potentials to the point **172**, from their respective lines **162**, **165**, **174**, and **180**, whenever, during the interval devoted to each respective octave, a key within such octave is simultaneously depressed. There is, therefore, present at the point **172** a train of pulses corresponding to every depressed key of the upper manual, with the time position of each such pulse corresponding to one particular key.

The arrangement of the connections between the octave decoder **30** and the divide-by-four unit **24** is such to energize the four output terminals **123–126** in sequence, with the output terminal **123** being energized first, followed in order by the terminals **124**, **125**, and **126**.

The point **172** is connected to the base of a transistor **186**, the emitter of which is connected to ground through a resistor **188**, and the collector of which is connected to a source of positive potential by a line **190**. The emitter is also connected to the output line **50**, so that a pulse train of positive pulses is presented on the line **50**, corresponding to actuated ones of the keys of the upper manual, such pulses being encoded in time position.

An additional set of twelve input terminals **51** is provided for the matrix **48**, and each of the terminals **51** is associated with a series of octavely related keys of the lower manual. The terminal identified as LC is supplied with a positive potential whenever any C key of the lower manual is actuated, and is conveniently connected with a plurality of switches **198** operated individually by the C keys of the lower manual, with all of such switches being connected in parallel between a source of positive potential and the terminal LC. Thus, the terminal LC receives a positive potential whenever any C key is depressed in the lower manual. Similarly, the terminal LB is supplied with a positive potential whenever any B key of the lower manual is depressed, and the same is true for the other terminals **51**.

The terminal LC is connected through a resistor **200** and a diode **202** to the C line **144***a* . The terminal LC is also connected through the resistor **200** and a diode **204** to a line **206**, which is connected to ground through a resistor **208**. The LB terminal is connected through a resistor **210** and a diode **212** to the B line **144***B*, and through the resistor **210** and a diode **214** to the line **206**. The remainder of the twelve input terminals **51** are also connected through individual diodes to the line **206**, and through individual diodes to individual ones of the line **144***c*-**144***n*. Only one of the twelve lines **144***a*-**144***n* is high at any given time, and the others are clamped to ground. Accordingly, the positive signals applied to the terminals **51** are clamped to ground through the resistors **200**, **210**, etc., except when the corresponding line **144***a*-**144***n* is supplied with a high potential over one of the lines **22**. Accordingly, when one of the lines **144***a*-**144***n* is high, if any corresponding key of the lower manual is depressed, the line **206** goes high, to produce a positive-going pulse. Accordingly, the line **206** is provided with a pulse train corresponding to the operated keys of the lower manual, such pulse train being repeated for each of the several octaves which are scanned.



The line **206** is connected to the base of a transistor **216**, the collector of which is connected by the line **190** to a source of positive potential. The emitter of the transistor **216** is connected to ground through a resistor **218**, and is also connected to the output line **52**. Accordingly, the output line **52** is supplied with a train of pulses corresponding to operated ones of the keys of the lower manual. The pulse trains present at the two output terminals **50** and **52** thus correspond respectively to the actuated keys of the upper and lower manuals.

Referring now to FIGS. **4** and **5**, which together make up the logic unit employed, the upper manual pulse train is applied from the terminal **50** through the AND gate **54** to the line **56**. Similarly, the lower manual pulse train is applied from the terminal **52** through an AND gate **60** to the line **62**. The line **56** is connected to the J input of a J-K flip-flop **222**, which has its clock input connected to the line **59** (FIG. **2**) over a line **224**. The K input terminal is connected to the terminal **142** (FIG. **2**) over a line **226**, to receive synchronization pulses therefrom.

The pulses present at the terminal **142** operate to reset the flip-flop **222**, and signals applied to the J input over the line **56** function to set the flip-flop **222**, at the time of the next concurrent clock pulse applied to the line **224**. The $\overline{Q}$ output of the flip-flop **222** is connected over a line **228** to the input of an AND gate **230**, which has its second input connected to the line **56**. The AND gate **230** is normally in condition to pass pulses from the line **56** to the input of a ten bit shift register **232**. Only the first pulse is passed, however, since the first pulse operates to set the flip-flop **222**, after which a low potential is present on the line **228** and the gate **230** is disabled. The output of the shift register **232** is connected to the input of a two bit shift register **234**. Both shift registers **232** and **234** are supplied with clock pulses by being connected to the line **59** via an inverter **236**. The shift register **232** is preferably an integrated circuit unit such as a type **8273**, and the shift register **234** is preferably a unit such as the type **7479**.

The output of the shift register **234** is passed through a capacitor **240** and a resistor **242** to ground. The circuit including the capacitor **240** and the resistor **242** forms a differentiating circuit, and positive-going pulses passed by the capacitor **240** are connected by a diode **244** through a resistor **246** to ground. The junction of the diode **244** and the resistor **246** is connected to the input of an inverter **248**, the output of which is connected to the reset input of an RS flip-flop **250**. The input of the inverter **248** is also connected through a diode **252** to the output of a differentiator circuit including a capacitor **254** and a resistor **256**, the input of which is connected to the line **226**. Thus a positive-going input on the line **226** (from the terminal **142**) and a positive-going output pulse from the shift register **234** both serve to produce a negative pulse at the output of the inverter **248**.

The output of the AND gate **230** is connected by a line **258** to the input of an inverter **260**, the output of which is connected to the set input of the RS flip-flop **250**. The line **258** passes the first pulse presented to the terminal **50**, corresponding to the highest operated key of the upper manual. This pulse is inverted by the inverter **261** and passed to the RS flip-flop **250**, and thus serves to set it into a state in which an output line **68** goes high. The flip-flop **250** has previously been reset, at the beginning of the cycle, by a positive-going pulse applied to the terminal **142.** The flip-flop **250** is again reset when the output of the shift register **234** goes high, which occurs twelve pulse times after the first pulse appears at terminal **50.** Thus, the line **68** is high only for twelve pulse times, beginning with the first pulse applied to the terminal **50.**

The line **68** is connected to the AND gate **64,** as is the line **62,** leading from the output of the shaper AND gate **60.** The input of the shaper **60** is connected to the terminal **52,** to which is supplied the lower manual pulse train. Accordingly, the gate **64** is able to pass pulses from the terminal **52** to its output line **66** only during the twelve pulse times when the line **68** is high. This corresponds to the twelve pulse times representative of the first octave below the highest operated key of the upper manual.

The pulses present on the line **66** are connected to the J input of a J-K flip-flop **260** and to one input of the AND gate **262.** The K input terminal of the flip-flop **260** is connected to terminal **142** for resetting the flip-flop **260** at the beginning of each cycle, and the clock terminal is connected to the terminal **59.** The first pulse which arrives on the line **66** during each cycle is therefore effective to set the flip-flop **260,** causing its output terminals to be reversed with the trailing edge of the clock pulse which is coincident with the first pulse occurring on the line **66.** The $\overline{Q}$ output of the flip-flop **260** is connected to an input of an AND gate **264,** the second input of which is connected to the line **66,** and the Q output of the flip-flop **260** is connected to the second input of the AND gate **262.** The $\overline{Q}$ output is high when the flip-flop **260** is in its reset condition, and therefore the AND gate **262** is enabled to pass the first pulse, with subsequent pulses being passed by the AND gate **264,** after the flip-flop **260** has been set. The output of the AND gate **262** is connected to one input of an AND gate **266,** the second input of which is connected from the output of an AND gate **268.** The line **59** is connected through a shaper unit **272,** and the output of the shaper unit **272** is connected in common to two input terminals of an AND gate **274,** which also functions as a shaper. The outputs of the shaper **272** and **274** are connected to ground respectively by capacitors **276** and **278,** and the output of the shaper **274** is also connected in common to two inputs of an AND gate **268,** which functions as a further shaper. The capacitors **276** and **278** function as a delay mechanism so that clock pulses appear at the output of the gate **268** slightly delayed in time from their appearances on the line **59.**

The AND gate **266** produces a high output on the line **280** only when high signals are simultaneously presented to its two inputs. Because of the delay introduced by the shapers **274** and **268,** the duration of the output pulse presented by the gate **266** to the line **280** is relatively short, and occurs only during the intervals when the levels in the lines **45** and **47** are constant, i.e., when they are not changing.

The line **280** is connected to the strobe inputs of two latches **282** and **284.** The latch **282** is preferably one-half of an integrated circuit, such as one-half of a type 7475, and the latch 274 is preferably a full unit, such as a type 7475. The two data input terminals of the latch **282** are connected from the terminals **110** and **112** which are the two outputs **47** of the divide-by-four unit **24,** and are energized in accordance with the binary representation of the octave being scanned at any given time. The condition of the terminals **110** and **112** which is present at the time that a pulse appears on the line **280** is stored in the latch **282,** and thereafter is continuously manifested by its output terminals **286** and **288.** Thus, a representation of the octave during which the latch **282** was last operated by a pulse on the line **280** is manifested by the output terminals **286** and **288.**

The four data input terminals of the latch **284** are connected to the terminals **15–18** which are the four outputs **45** of the divide-by-twelve counter **14** (FIG. 2). These outputs present a binary representation of the note being scanned at any given time. The latch **284** operates in the same manner as the latch **282,** and manifests on its four output terminals **290–293** the binary representation of the note which was being scanned at the time the latch was last set by a pulse appearing on the line **280.** Such manifestation is maintained until such time as a subsequent pulse appears on the line **280.** It is apparent that no pulse can occur subsequently on the line **280** until the flip-flop **260** has been reset, thus enabling the gate **262** to pass pulses from the line **66.**

The second pulse appearing on the line **66** is passed through the gate **264** to the J input terminal of a flip-flop **294.** The flip-flop **294** has its clock input terminal connected to the terminal **59** and its K input terminal connected to terminal **147.** It is set by the first pulse appearing on the line **293,** at the output of the AND gate **264.** The $\overline{Q}$ output of the flip-flop **294** is connected to one input of an AND gate **296,** the other input of which is connected to the line **293.** The output of the gate **296** is connected to one input of an AND gate **298,** the second input of which is connected to the output of the AND gate **268.** The output of the AND gate **298** is connected to the strobe inputs of two latch units **300** and **302,** by a line **301,** which latch units are identical in construction and operation to the units **282** and **284,** respectively. The data input terminals of the latch **300** are connected to the terminals **110** and **112,** and the data inputs of the latch **302** are connected to the terminals **15–18,** in parallel with corresponding connections of the latches **282** and **284** described above. Accordingly, the second pulse on the line **66,** which is the first pulse on the line **293,** functions to set the latches **300** and **302,** to present at their output terminals, **303–304** and **305–308,** respectively, the binary representations of the octave and note being scanned at the time of occurrence of the second pulse on the line **66.**

Another flip-flop **310** is connected in the same manner as the flip-flops **260** and **294,** and functions to cause latches **314** and **316** to be set by a pulse on a line **315,** so that they produce outputs which are the binary representation of the octave and note being scanned at the time that the third pulse appears on the line **66.** A fourth flip-flop **312** is similarly connected via line **319** to set the latches **318** and **320,** to cause them to manifest outputs representative of the octave and note being scanned at the time of the fourth pulse arriving on the line **66.**

The Q outputs of the four flip-flops **260, 294, 310,** and **312** are each connected to one of the four data inputs of an output latch **322,** the strobe input of which is connected to the terminal **140** (FIG. 2). A pulse appears at the terminal **140** a short time before the pulse occurs at the terminal **142,** so that the latch **322** is energized with the binary representation of the Q outputs of the four flip-flops **260, 294, 310,** and **312** during the end of the scanning cycle. In this way, data is stored in the latch 322 corresponding to which of the several latches have been set during the preceding cycle. This data is employed to operate only the keyers which are necessary to handle the data stored in the several latches, and to avoid operation of keyers in response to obsolete data which may remain manifested by one or more latches as a result of a previous cycle of operation. Such binary representation is applied to the keyer in the manner described hereinafter.

Referring now to FIG. 6, a one-of-twelve selector 326 has its four control terminals connected to the terminals 290–293 from FIG. 4. The data input terminals are connected to twelve lines 77 which are connected to a frequency synthesizer unit, or the like, which is adapted to produce, on the twelve lines 77, signals having frequencies which are harmonics of the twelve notes of the chromatic scale. All of the tones to be reproduced by the electronic musical instrument may be derived from the signals present at the terminals 77 by dividing the pulse repetition rate of such signals. The pulse repetition rates of the signals present at the terminals 77 are preferably the second harmonics of the highest desired frequencies, so that the signals required for the production of the tones of the top octave of the musical instrument are derived by dividing the pulse repetition rate of the signal present on the terminals 77 by a factor of two. The frequencies required for the next lower octave are derived by dividing the frequencies of the signals on the terminals 77 by a factor of four. Lower octaves are treated in the same way, using different divisions.

The **1-of-12** selector 326 is adapted to connect one of its twelve data inputs to an output line 330, in accordance with the binary representation present on its control terminals 290–293. For example, when low potentials are present at all four terminals 290–293, a first one of the twelve input lines 77 is selected. When the terminals 290–292 are low and the terminal 293 is high, a second one of the terminals 77 is selected for connection to the output line 330, and so on. In this manner, one of the twelve terminals 77 is connected to the output line 330 in response to the manifestation of the outputs of the latch 284 (FIG. 4), which stores a binary representation of the note represented by the first pulse appearing on the line 66.

The line 330 is connected to the input of a four-stage binary counter 332 which is operative to divide the pulse repetition rate of the signal present on the line 330 by powers of two. An output line is connected to the output of each of the four stages of the unit 332. An output line 334 is connected to the output of its first stage; an output line 336 is connected to the output of its second stage; and output line 338 is connected to the output of its third stage; and an output line 340 is connected to the output of its fourth stage. The four outputs 334–340 of the unit 332 produce pulse trains in response to the pulse train present on the line 330, but having reduced pulse repetition rates. The signal present on the line 334 has one-half the pulse repetition rate of that present on the line 330; the pulse repetition rate of the signal on the line 336 is one-fourth of that present on the line 330, and so on. Thus, the four lines 334, 336, 338, and 340 represent four different octaves.

The lines 334–340 are connected to four inputs of a 1-of-4 selector unit 342, which functions in a manner similar to the unit 326, to connect one of its data input lines 334–340 to an output line 344, in response to the signal supplied to its control input terminals 286, and 288, which are the output terminals of the latch 282, which stores a binary representation of the octave corresponding to the note represented by the first pulse present on the line 66 (FIG. 4). If the first pulse arrives on the line 66 during the time that the top octave is being scanned, the signals present at the terminals 286 and 288 cause the unit 342 to select the line 334 for connection to the output line 344. If the second highest octave is the one being scanned when the first pulse appears on the line 66, the potential levels at the terminals 286 and 288 are different, and cause the selector unit 344 to select the line 336 for connection to the output line 344. In similar fashion, if either of the two lower octaves correspond to the octave of the note represented by the first pulse to arrive on the line 66, one of the lines 338 and 340 is selected by the unit 342 for connection to the output line 344.

The line 344 is connected directly to an output terminal 348 by a line 346, and to three additional output terminals 349, 350 and 351, via a three-stage binary counter 354. The counter 354 functions in the same manner as the counter 332, except that only three output lines are provided, one from each of three stages of the counter. The output lines are connected to the terminals 349–351, and furnish signals thereto which have pulse repetition rates which are derived from the signal on the line 344 by dividing the pulse repetition rate thereof by powers of two. The output of the first stage of the counter 354 is connected to the terminal 349; the output of the second stage is connected to the terminal 350; and the output of the third-stage is connected to the terminal 351.

The pulse repetition rate of the signal present at the terminal 349 is, therefore, half of that present at the terminal 348, and the pulse repetition rates of the signals present at the terminals 350 and 351 are, in each case, half that of the pulse repetition rate applied to the preceding output terminal. The terminal 348 may be referred to as the "2-foot" output terminal. The terminal 349 may be referred to as a "4-foot" output terminal. Similarly, the terminals 350 or 351 may be referred to as the "8-foot" and "16-foot" output terminals, and are similarly connected. The four terminals 348–351 are connected by means of a keying unit within the group of keyers 82 (FIG. 1) to a voicing unit within the group 86.

The voicing unit may be of any known type, such as clarinet, horn, or the like, with the output of the voicing unit connected to the output system of the musical instrument in the conventional manner. The **1-of-12** selector 326 is preferably an integrated circuit such as a 75150, and **1-of-4** selector is preferably an integrated circuit such as a 74151. The dividers 332 and 354 are conventional binary counters, with an output terminal connected to each stage thereof.

A second **1-of-12** selector 356 has its control input terminals connected to the terminals 305–308 (FIG. 5), which manifest the binary representation of the note corresponding to the second pulse appearing on the line 66. The data input terminals of the unit 356 are connected in common with those of the unit 326, so that one of the twelve signals presented to the terminals 77 is connected to the output line 358 of the unit 356, in accordance with the condition of the control terminals 305–308. A four-stage binary counter 360 has its input connected to the line 358 and supplies output signals on four lines 361–364, which differ in their pulse repetition rates by powers of two, just as described in connection with the counter 332. The 1-of-4 selector 366 has its four data input terminals connected to the lines 361–364, and its two control input terminals connected to the terminals 303 an 304, which manifest the binary representation of the octave stored in the latch 300, corresponding to the octave of the second pulse appearing on the line 66. One of the four data inputs of the unit 366 is connected to its output line 368, which is connected to the input of a three-stage binary counter 370. The line 368 is connected by a line 372 directly to a terminal 374, and the outputs of the stages of the counter 370 are connected to the terminals 375–377. The output terminal 374 is the "2-foot" output terminal; the output terminal 375 is the "4-foot" output terminal; the output terminal 376 is the "8-foot" output terminal; and the terminal 377 is the "16-foot" output terminal. Their operation and function is the same as described in connection with the units 332, 342, and 354.

The second pulse to appear on the line 66 corresponds to the second key of the lower manual to be encountered during the downward scan of such keys. Accordingly, the frequency selected by means of the 1-of-4 selector 356 corresponds to a harmonic of the tone corresponding to the second pulse appearing on the line 66. The octave in which such tone is being played, as indicated by the condition of the latch unit 300 (FIG. 5), controls the potentials applied to the control inputs 303 and 304 of the selector 366, so that the signals presented at the output terminals 374–377 correspond to four different footages of a second note being played by depressing a key of the lower manual. The output terminals 374–377 are connected to a voicing unit different from that to which the output terminals of the unit 354 is connected, and this second voicing unit has its output connected in common with the output of the first voicing unit at the input terminal of the output system of the musical instrument. Two additional 1-of-12 selector units 378 and 380 are illustrated in FIG. 6, each of which have their data inputs connected in common with the data inputs of the units 326 and 356, and their control inputs connected to the outputs of the latches 316 and 320, respectively. The units 378 and 380 are both connected successively to a four-stage binary counter, a 1-of-4 selector, and a three-stage binary counter, just as described above with reference to the selector units 326 and 356. A set of four output terminals 382 is energized in response to operation of the system connected with the selector unit 378, and an additional set of four output terminals 384 is energized in response to operation of the system connected with the selector unit 380. The signals presented to the output terminals 382 and 384 represent the various footages of the third and fourth notes of the chord selected by depression of the keys on the lower manual. Each of these terminals is connected by means of a tab switch, or the like, to the inputs of third voicing units, respectively, so that up to four notes of a chord may be sounded in individual voices, the outputs of such voicing units being connected to the input terminal of the output system of the electronic musical instrument.

It is apparent from the foregoing that the four notes of a chord selected by depression of the keys of the lower manual are each sounded in individual and independent voices, by being passed through individual voicing units before reaching the output system. The first voice, i.e., that produced in response to the output terminals 348–351, always corresponds to the highest note of a chord selected on the lower manual which is below a note octavely related with the highest note being played on the upper manual at any given time. In other words, the first voice is always the highest voice below the top solo note. Accordingly, a melody can be readily played with a single note at a time on the upper manual, such note being sounded in a normal solo voice being selected by means of tab switches, or the like, in the conventional manner, and up to four additional notes are sounded within the first octave below such single note, each of the additional notes being sounded in an independent voice, with the first one below the single note being sounded in the first voice, the second in the second voice, and so on. When the voices of the notes selected in response to operation of the keys of the lower manual are employed with voicing units representing a clarinet, a horn, and two other individual voices, the net effect of operation of the system is to simulate the simultaneous reproduction of a number of instruments, each playing a separate part of the harmony, with each part maintained in the same relation to the other parts.

The particular voicing units which are employed with the system of the present invention may be selected from any known or commercially available voicing units, so that they need not be described in detail therein.

FIG. 7 illustrates a schematic circuit diagram of a keyer unit which may be employed for interconnecting the four outputs 348–351 with four inputs of a voicing unit. The four terminals 348–351 are each connected to the cathode of an individual one of four diodes 386–390. The anodes of the diodes 386–390 are each connected, respectively, through four diodes 391–394, and through an individual voltage divider, incorporating a pair of resistors 395 and 396, to ground. The outputs of the four voltage dividers are connected by lines 397 individually to four output terminals 398–401. The junction between the diodes 386 and 391 is connected by a resistor 402 to a line 403, and the junction of each of the other pairs of diodes is connected to the line 403 through individual resistors 404, 405 and 406, respectively. The diodes 386 and 391 are connected with their anodes in common so that a current which passes one of the diodes is blocked by the other. When, however, a positive potential is applied to the line 403, both of the diodes are forward biased, so that a signal applied to the terminal 348 causes a corresponding signal to be produced at the output terminal 398. When the potential on the line 403 is low, however, the connection between the input terminal 348 and the output terminal 398 is effectively blocked by the reverse poled diodes 386 and 391.

The control circuit for controlling the potential on the line 403 includes a pair of transistors 408 and 410. An input signal applied to an input terminal 414 is connected through a resistor 415 to the base of the transistor 408, which has its collector connected to a source of positive potential at a terminal 416, through a pair of series connected resistors 418 and 420. The junction of the resistors 418 and 420 is connected to the base of a pnp transistor 410, which has its emitter connected to a positive potential at a terminal 416 and its collector connected through a resistor 422 to ground. Its collector is also connected through a diode 424 to the line 403. Accordingly, when a positive potential is applied to the input terminal **414**, the transistors **408** and **410** both become conductive, the voltage across the resistor **422** increases, and the potential on the line **403** increases correspondingly. A capacitor **426** is connected from the line **403** to ground to maintain the potential on the line **403**, until the charge on the capacitor **426** is dissipated through the circuit connected in parallel therewith, which includes the voltage divider resistors **395** and **396**.

The input terminal **414** is connected to one of the four output terminals **324** of the latch unit **322** (FIG. **5**), and particularly to the one which goes high in response to a signal developed at the Q output of the flip-flop **260** (FIG. **4**), signifying that the flip-flop **260** has been set during the current cycle of operation, beginning with a pulse at the terminal **140** which clears the latches of the latch unit **322**. The latch unit **322** is preferably an integrated circuit such as type 7475, like the other latches described above. Other keyers like that shown in FIG. **7** are connected to receive the other three sets of outputs from FIG. **6**, (viz., **374–377**, **382**, and **384**), and each of such other keyers is controlled with appropriate ones of the outputs **324** from the latch unit **322**, so that only the keyers associated with notes occuring in the current cycle are activated. The clear pulse applied to the latch unit **322** at the beginning of each cycle functions to disable the unused keyers.

The line **403** is connected through a diode **428** and a resistor **430** to a control terminal **432**, which is adapted to be connected to ground when a more rapid discharge of the capacitor **426** is desired. When the potential at the terminal **432** is high, the diode **428** is blocked, and the rate at which the capacitor **426** is discharged is controlled by the resistance of the voltage divider circuits. When the potential at the terminal **432** is low, the rate of discharge of the capacitor is controlled only by the relatively low value of the resistor **430**.

As described above, the present invention is adapted to select the four notes of the harmonizing chord within the twelve notes immediately below the top note selected by depression of a key of the upper manual. There are occasions, however, when it is desired that the first or second note below the top note selected on the upper manual should not be selected, so as to avoid creating an undesired dissonance. Accordingly, it is, in certain conditions, desirable to prevent selection of the first few notes below the highest selected note of the upper manual. Such notes correspond to the pulses which are received within the first few pulse times following the setting of the flip-flop **232** (FIG. **4**), which is set in response to detection of the highest selected note of the upper manual.

The circuit for accomplishing this function is illustrated in FIG. **8**. FIG. **8** includes a portion of the apparatus illustrated in FIG. **4**, and the apparatus which is unmodified is indicated by the same reference numerals. The structure of FIG. **8** which is not illustrated in FIG. **4** includes a single pole, double-throw switch **440** and a single pole, triple-throw switch **442**. The common terminal of the switch **440** is connected to the line **258**, and the common terminal of the switch **422** is connected to the capacitor **240**. The left-hand contact of the switch **440** is connected to the output of the AND gate **230**, and the right-hand contact is connected to the Q-**1** output of the 10 bit shift register **252**.

The three contacts of the switch **442** are connected, respectively, to the Q-10 output of the 10 bit shift register **252**, the Q-**1** output of the two bit shift register **234**, and the Q-2 output of the 2 bit shift register **234**.

The switch **440** is operative to select a pulse for setting the RS flip-flop **250**. When the switch is in its left-hand position, the operation is in the same as that described above. When the switch **440** is operated to its other position, however, the pulse presented to the line **258** is delayed by one pulse time, so that the gate **64** does not become enabled until one pulse time later.

The switch **442** is operative to select a pulse for resetting the RS flip-flop **250**. When the switch is in its right-hand position, the resetting of the flip-flop **250** occurs at the same time as described above. When the switch **442** is in its middle position, the flip-flop **260** is reset one pulse time earlier, and when the switch **442** is in its left-hand position, the flip-flop **250** is reset two pulse times earlier.

By operation of the switches **440** and **442**, the starting and ending times of the window pulse are made adjustable, so that notes octavely related to notes immediately above or below the solo note are inhibited as their pulses do not coincide with the window pulse.

FIG. **9** illustrates waveforms of pulses developed at various locations throughout the system during each cycle of operation. The reference numeral accompanying each waveform is the same as that of the line or terminal on which the waveform appears.

It will be appreciated from the foregoing that the present invention is eminently suitable for generating harmony beneath the uppermost solo note played by an operator with the right-hand or solo keyboard. Of course, the present invention may also be employed with an instrument having only a single keyboard, and, in that event, the right-hand portion of the keyboard is regarded as the upper manual and the left-hand portion as the lower manual. The separate voicing of the harmonizing notes closely simulates an orchestration effect in which each part of the harmony is played by a separate instrument, so that the effect of a so-called combo or ensemble may be created by an operator of a single instrument. The notes selected by the operator's left hand may be sounded simultaneously with the solo and harmonizing notes, with yet another different voice, or in one of the voices selected for the solo or harmonizing notes. Alternatively, the notes selected by the operator's left hand may be employed only for selection of the harmonizing notes, and not sounded independently. A switch is provided for enabling the operator to select the desired operation of the keys of the lower manual.

The components of the present invention are readily available in the form of integrated circuits, so that construction and assembly of the apparatus is greatly simplified. In addition, only a single switch is required for each key of the keyboard or keyboards, so that physical organization of the components is also simplified.

It will be appreciated that various additions and modifications may be made in the apparatus described herein without departing from the essential features of novelty thereof, which are intended to be defined and secured by the appended claims.

The present invention may be employed with an organ having key switches which close d.c. circuits for operating the keyers, as described herein, or also with organs in which the tones to be sounded are selected in accordance with the time encoded position of pulses of a pulse train, as described in the copending application of Morez and Moore, Ser. No. 323,245., for Electronic Musical Instrument.

The logic components illustrated and referred to herein are preferably transistor transistor logic (TTL), made by a variety of manufacturers, such as Texas Instruments Company and others.

What is claimed is:

1. In an electronic musical instrument having a source of tone signals, an output system, and a keyboard with an upper manual portion and a lower manual portion, a system comprising:
   a. drive means for producing a plurality of signals for use in scanning the keys of the keyboard,
   b. scanning means connected to said drive means for receiving said signals, and operative to scan the keys of the keyboard for producing first signals in response to operation of the keys of the upper manual and second signals responsive to operation of the keys of the lower manual,
   c. means connected with said scanning means and responsive to said first signals and said second signals for producing third signals in accordance with the operated keys of the upper manual and of the lower manual only when keys of both the upper and lower manuals are simultaneously operated,
   d. said third signals comprising a train of pulses encoded in time position in response to operated keys of both the upper manual and the lower manual, means synchronized with said scanning means and responsive to said third signals for producing a combination of output signals uniquely dependent on the time positions of pulses in said train of pulses, and
   e. a plurality of keyers responsive to said output signals for keying selected ones of said tone signals to said output system.

2. Apparatus according to claim 1 wherein said scanning means comprises means for selectively energizing a plurality of scanning lines, and means for connecting said scanning lines in circuit individually with key operated switches operating in response to depression of the keys of said upper manual.

3. Apparatus according to claim 1, wherein said scanning means comprises means for selectively energizing a plurality of scanning lines, connecting means for connecting each of said lines in circuit with key operated switches operated in response to depression of octavely related keys of said lower manual, and output means connected in circuit with said connecting means for producing said first signals.

4. Apparatus according to claim 1, including a plurality of latch means connected with said scanning means by said synchronized means which includes means for operating said latch means individually in response to successive ones of the pulses of said pulse train, each of said latch means being adapted to manifest a representation of the time position of the pulse to which it is responsive.

5. Apparatus according to claim 4, wherein each of said latch means includes a first latch adapted to manifest the binary representation corresponding to a note represented by the time position of a separate pulse of said pulse train, and a second latch adapted to manifest the binary representation corresponding to a predetermined group of pulses of said pulse train which contains said separate pulse.

6. Apparatus according to claim 5, including a tone signal generator for generating a plurality of tone signals, each having frequency which is octavely related to tones of the chromatic scale, and signal selector means having a plurality of first input terminals connected to the said tone signal generator and a plurality of control terminals connected to said first latch for selecting one of said plurality of signals in response to the binary representation manifested by said first latch.

7. Apparatus according to claim 6, including a multistage binary counter having its input connected to the output of said signal selector means, and octave selector means having a plurality of input terminals individually connected to each stage of said binary counter and adapted to connect the output of a selected one of said stages to an output terminal in response to the binary representation manifested by said second latch.

8. Apparatus according to claim 7, including a second multi-stage binary counter having its input connected to the output of said octave selector means, and means for connecting the output of each stage of said second binary counter individually with one of a plurality of output terminals.

9. Apparatus according to claim 1, including a plurality of voicing units, means for connecting a separate one of said voicing units with each of a plurality of said keyers, and means for connecting the outputs of said voicing units to the output system of said instrument.

10. In an electronic musical instrument having a source of tone signals, an output system, and a keyboard having a plurality of keys adapted to select certain ones of said tone signals for connection with said output system, a system comprising:
   a. drive means for producing a plurality of pulses for use in scanning keys of the keyboard,
   b. pulse producing means connected to a first portion of said keyboard and to said drive means and responsive to depression of the endmost one of the operated keys of one portion of said keyboard means for producing a pulse encoded in time position in accordance with the identity of said endmost key, second pulse producing means connected to a second portion of said keyboard and to said drive means and responsive to depression of all of said keys for producing pulses encoded in time position in accordance with the identity of said keys, c. initiating means connected to said pulse producing means and responsive to production of said pulse for initiating a predetermined time interval less than the interval required for a complete scan of said keyboard,
   d. selecting means connected to said initiating means and to said second pulse producing means and operative during said predetermined time interval for producing a pulse train composed of a plurality of pulses encoded in time position in accordance with the identity of one or more operated keys of said second portion of said keyboard means, means synchronized with said drive means and responsive to said third signals for producing a combination of output signals uniquely dependent on the time positions of pulses in said train of pulses, and
   e. a plurality of keyers responsive to said output signals for selectively connecting selected ones of said tone signals with said output system.

11. Apparatus according to claim 10, wherein each of said keyers is connected to a tone signal corresponding to a key located within a predetermined number of keys adjacent said endmost key.

12. Apparatus according to claim 11, including selectively operable switch means connected with said selecting means for selecting said predetermined number of keys.

13. Apparatus according to claim 11, including selectively operable switch means connected with said selecting means for inhibiting the production of pulses within said pulse train which are octavely related with keys located within a second predetermined number of keys adjacent said endmost key.

14. Apparatus according to claim 10, wherein said endmost key is the most right-hand key of said keyboard means which is depressed.

15. Apparatus according to claim 10, wherein said second portion of said keyboard means comprises that portion of said keyboard means which is customarily played with the left hand of the player-user.

16. Apparatus according to claim 10, wherein said keyboard means comprises a single keyboard.

17. In an electronic musical instrument having a source of tone signals, an output system, and a keyboard having a plurality of keys adapted to select certain ones of said tone signals for connection with said output system, a system comprising:

a. means for generating a plurality of pulses in time sequential fashion,

b. first means connected to said generating means and to said keyboard and responsive to operation of a first group of keys of said keyboard which are customarily played with the right hand of a player-user,

c. second means connected with said generating means and with said keyboard and responsive to operation of a second group of keys of said keyboard which are customarily played with the left hand of a player-user,



d. third means connected with said first and second means and responsive to operation of one of said first group of keys and one of said second group of keys for producing a coded representation of a plurality of tones which correspond to the range of frequencies of tones normally selected by said first group of keys and which correspond to the note names of tones normally selected by said second group of keys, and

E. a fourth means synchronized with said generating means for coupling said coded representation of said plurality of tones to a plurality of keyers for selectively connecting certain ones of said tone signals with said output system.

18. Apparatus according to claim 17, including a plurality of voicing means individually connected to said keyers and to said output system, for sounding each of said plurality of tones in an individual voice.

19. Apparatus according to claim 17, wherein said third means comprises means for producing said coded representation in response to a predetermined maximum number of depressed keys of said second group of keys.

20. Apparatus according to claim 19, wherein said third means includes means for producing said coded representation in response to the keys of said second group of keys which are depressed, and in accordance with the relation of the depressed key of said second group to the depressed key of said first group representative of the highest pitch of all the depressed keys of said first group.

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