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Wetzel

[11] **3,821,712**

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[54] **MUSICAL SEQUENCER**

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[52] **U.S. Cl.** **340/172.5,** 84/1.01

[51] **Int. Cl.** **G11c 7/00**

[58] **Field of Search** 340/172.5; 84/1.01, 1.03, 84/1.24

[56] **References Cited**

UNITED STATES PATENTS

3,673,573 6/1972 Smith 340/172.5

Primary Examiner—Paul J. Henon
Assistant Examiner—Paul R. Woods
Attorney, Agent, or Firm—Lerner, David, Littenberg & Samuel

[57] **ABSTRACT**

A muscial sequencer for producing control voltages is disclosed together with an electronic device for producing music controlled by the electronic voltages. The electronic device disclosed includes a voltage controlled oscillator, a pair of voltage controlled amplifiers and a speaker normally actuated by a keyboard. The electronic device is electrically and mechanically adapted to be controlled by the musical sequencer. The musical sequencer consists of three rewrite memories and control circuitry therefor.

11 Claims, 2 Drawing Figures

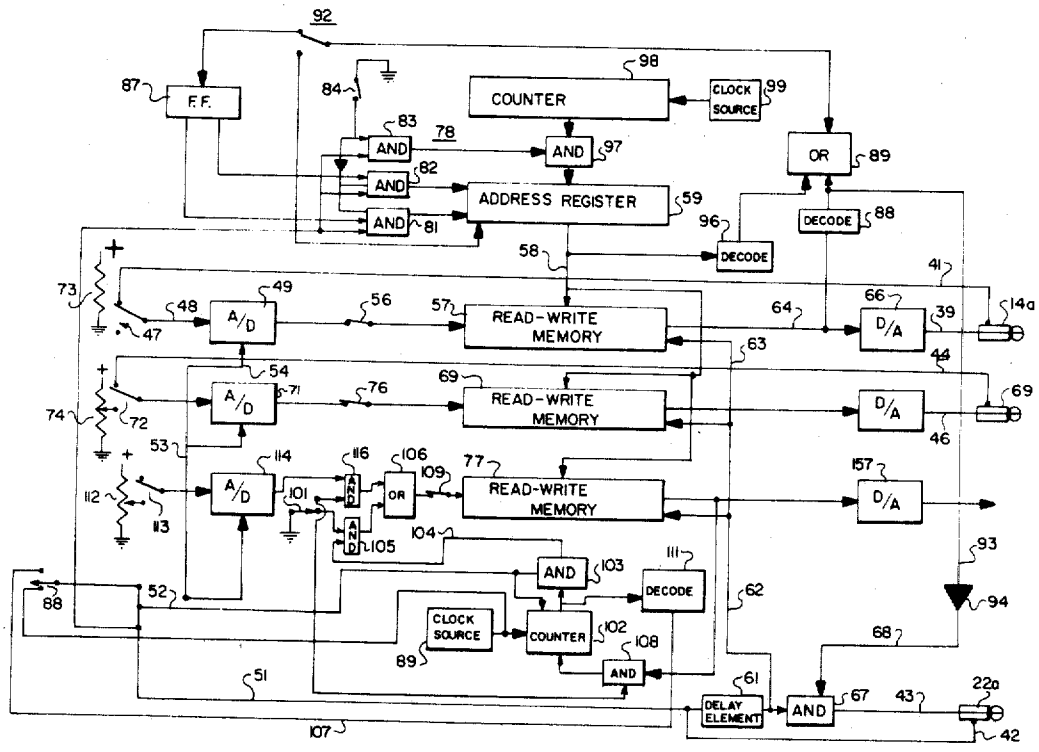


FIG. 1

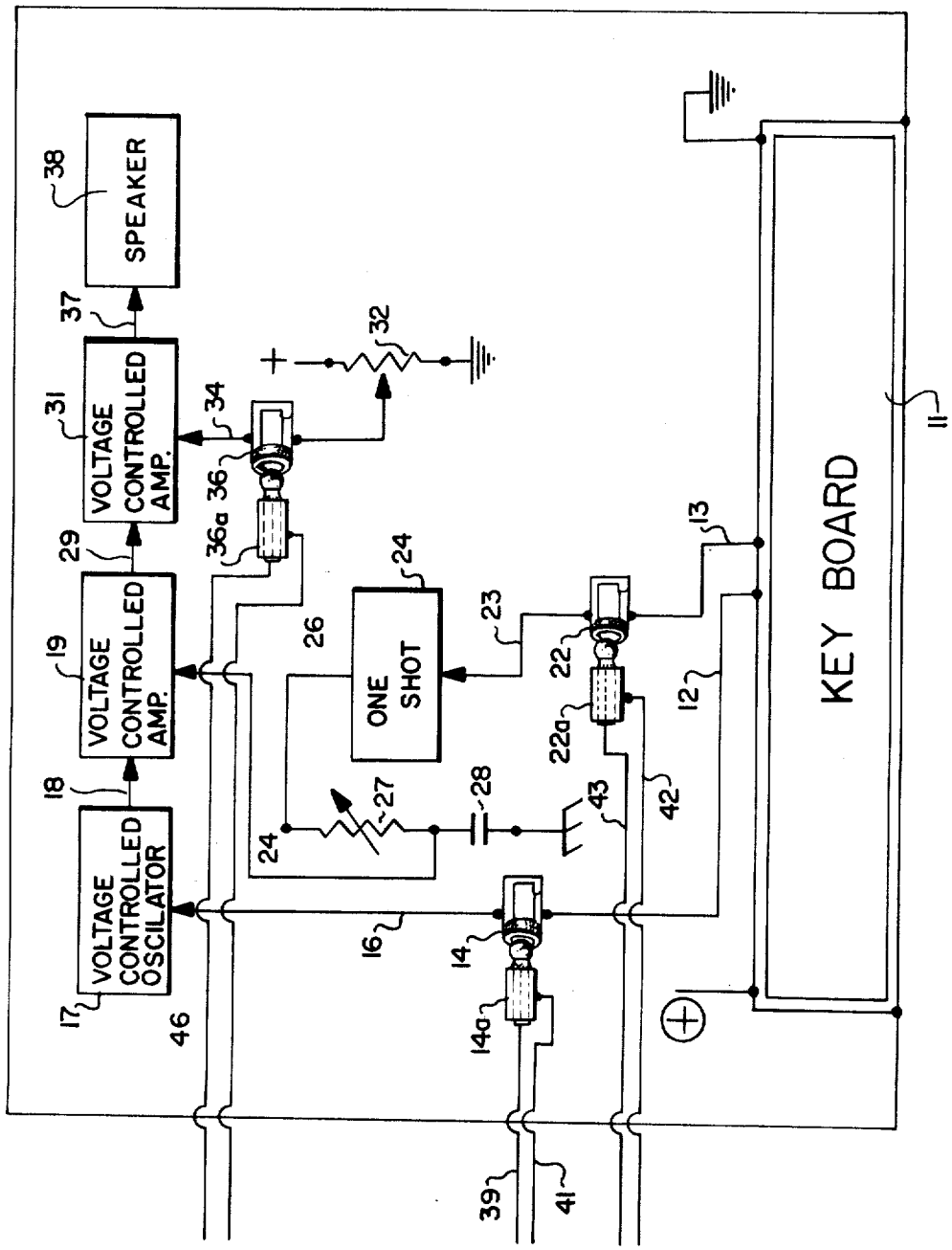
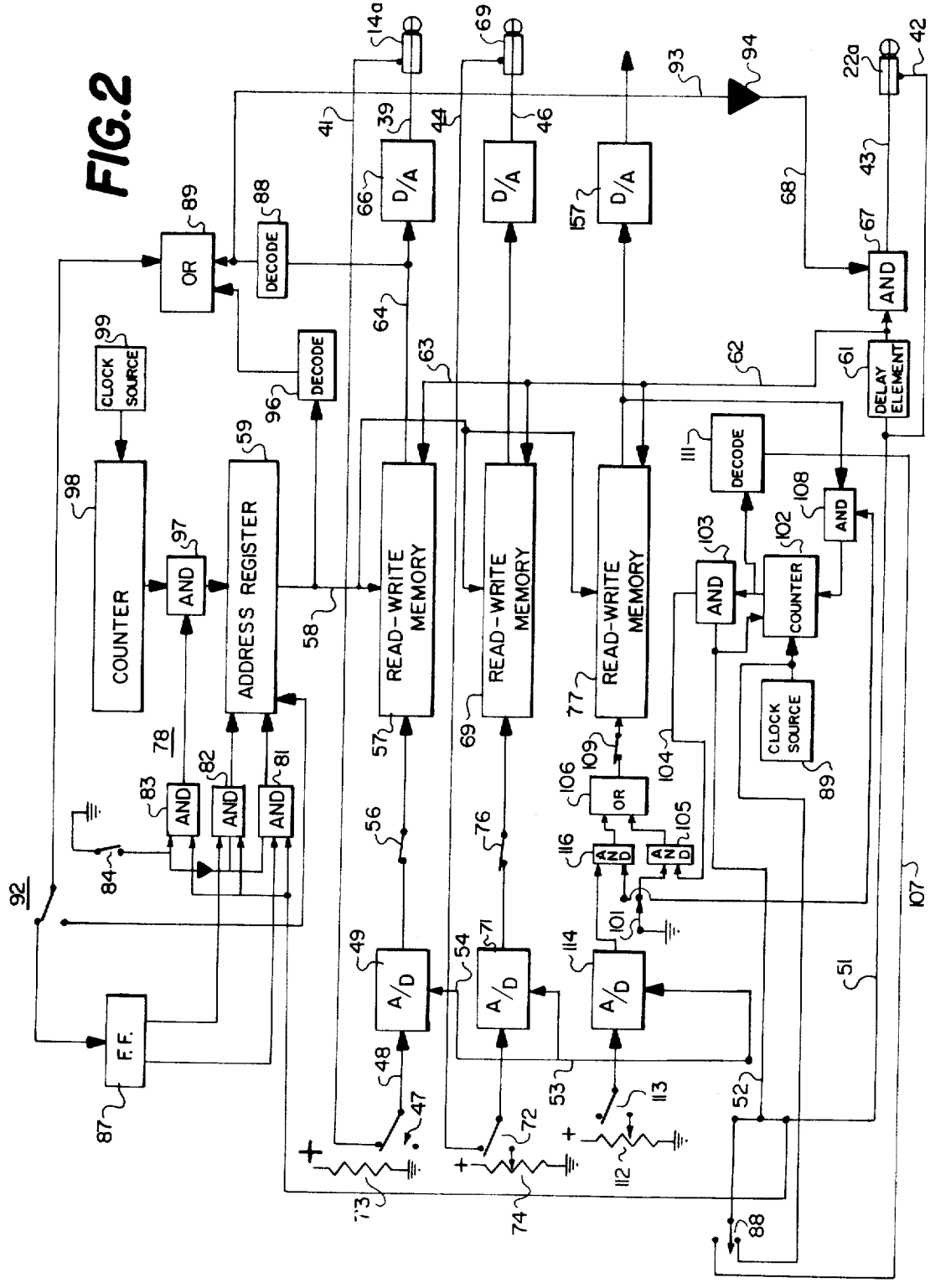

10
11
KEY BOARD
SPEAKER
38
37
VOLTAGE CONTROLLED AMP.
31
VOLTAGE CONTROLLED AMP.
29
VOLTAGE CONTROLLED OSCILATOR
18
19
17
ONE SHOT
24
26
23
32
34
36
36a
22
22a
12
13
27
28
43
42
24
16
14
14a
46
39
41

FIG. 2


14a
69
42
22a
93
94
41
39
44
46
43
68
66
D/A
D/A
157
D/A
OR
89
DECODE
88
67
AND
64
63
62
61
DELAY ELEMENT
CLOCK SOURCE
99
DECODE
96
111
DECODE
98
59
108
AND
97
AND
103
102
COUNTER
COUNTER
ADDRESS REGISTER
READ-WRITE MEMORY
READ-WRITE MEMORY
READ-WRITE MEMORY
58
57
69
77
78
82
83
81
AND
AND
AND
109
106
OR
104
CLOCK SOURCE
89
84
56
76
116
AND
AND
105
92
107
49
54
71
114
A/D
A/D
A/D
101
51
F.F.
87
48
47
53
52
113
72
112
73
74
88

MUSICAL SEQUENCER

FIELD OF THE INVENTION

This invention relates to a musical sequencer and particularly to a digitally controlled musical sequencer.

BACKGROUND OF THE INVENTION

Electronic equipment which produces music has been known for a long period of time. Public address systems amplify music, radios transmit and reproduce music at great distances, while recording equipment stores and plays back music at a later time.

Electronic circuitry is now well known which synthesizes wave forms for the reproduction of music. Some circuitry is known which randomly actuates an electronic synthesizer to produce the so-called machine generated music.

Presently existing equipment for driving electronic synthesizers, however, are not capable of recording music as it is being played by an individual on the synthesizer. The presently available machines further are not capable of taking such recorded music and playing it back in accordance with predetermined manipulations or randomly.

Therefore, it is an object of this invention to provide a new and improved musical sequencer.

It is a further object of this invention to provide a new and improved musical sequencer which can record musical sequencers in real time while the operator thereof is listening to the music.

It is yet another object of this invention to provide a musical sequencer which can manipulate stored musical sequencers in accordance with desired algorithms.

BRIEF DESCRIPTION OF THE INVENTION

With these and other objects in view the present invention contemplates a musical sequencer for providing drive signals to a voltage controlled musical device. The musical sequencer includes a first memory which is rendered effective by an address signal and responsive to a store signal for storing information signals applied to the input in an address location therein dependent upon the address signal. The first memory is further responsive to a resignal for providing the information signal stored in the address location therein dependent upon the address signal at an output. Circuitry is provided for applying an address signal to the first memory. The store signal to the first memory and circuitry which is responsive to the store signal for providing the read signal to the first memory a predetermined time interval after the occurrence of the store signal. In this way musical sequencers being stored in the first memory can be applied to the voltage controlled musical device so that the person programming the first memory can hear the music that is being stored therein.

The musical sequencer has additional circuitry therein which increments the address signal being applied to the memory each time the store signal is applied thereto.

In the preferred embodiment of this invention, the musical sequencer has a second memory located therein, a clock signal generator and a counter. The counter counts the clock signals from the clock signal

generator for providing rhythm information which is stored in the second memory.

The preferred embodiment of this invention has additional circuitry therein so that the information stored in the first memory can be read out to drive the voltage controlled musical device in predetermined sequences or at random.

DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the invention, reference should be made to the following detailed description of the invention and drawings in which:

FIG. **1** is a schematic block diagram of an electronic musical device modified in accordance with the teachings of this invention to be adaptable to a musical sequencer of this invention; and

FIG. **2** is a schematic block diagram of a musical sequencer constructed in accordance with the teachings of this invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to FIG. **1** we see an electronic synthesizer **10** modified to be compatible with a sequencer constructed in accordance with the teachings of this invention. The synthesizer **10** shown in FIG. **1** has only a limited circuitry therein sufficient to explain the functioning of the sequencer of FIG. **2.** Of course, it should be understood that synthesizers which are commercially practical are substantially more complicated that the synthesizer **10,** having various additional tracks, components and switches for additional interconnection.

The synthesizer **10** includes a keyboard **11** which provides an analog voltage on a lead **12** each time a key (not shown) on the keyboard **11** is depressed. The value of the analog voltage appearing on the lead **12** is dependent upon which key of the keyboard **11** is depressed. Each time a key on the keyboard **11** is depressed, a pulse is supplied on the lead **13** which is used for timing purposes. Therefore, the signal on the lead **12** is indicative of the tone which the player of the synthesizers desire while the timing of the pulse on the lead **13** indicates the time which the player desires the tone to be played. The signal on the lead **12** is passed by a normally conducting jack **14** to a lead **16** which applies the voltage to a voltage controlled oscillator **17.** The voltage controlled oscillator **17** provides a signal on a lead **18** having a frequency dependent upon the signal supplied to the voltage controlled oscillator **17** on the lead **16.** The amplitude of the signal, however, on a lead **18** is constant. The signal on the lead **18** is passed through a voltage controlled amplifier **19** which passes the signal on the lead **18** as modified by a signal applied to the voltage controlled amplifier **19** on a lead **21.**

The timing pulse provided on the lead **13** is passed by a normally conducting jack **22** and a lead **23** to trigger a one-shot multivibrator **24.** The one-shot multivibrator provides a square wave on a lead **26,** the edges of which are shaped by a circuit including a variable resistor **27** and a capacitor **28.** The lead **21** is connected to the junction of the variable resistor **27** and the capacitor **28** so that the square wave having the shaped edges is applied to the voltage controlled amplifier **19.** Therefore, it can be seen that each time a key is depressed on the keyboard **11,** a tone is provided by the voltage controlled oscillator **17** in accordance with the particular key depress while the voltage controlled amplifier

is supplied a single cycle of a half square wave having shaped edges at that time thereby passing a shaped tone therethrough providing such a signal on a lead **29**. The variable resistor **27** is a front panel control on the synthesizer **10** controlling the attack of the tone alternately produced. The signal on the lead **29** is passed through a voltage controlled amplifier **31**, the gain of which is controlled by the setting of a variable resistor **32**. The signal from the variable resistor **32** connected between a source of potential and ground is provided to the voltage controlled amplifier by the leads **33** and **34** and a normally conducting jack **36**. The signal provided by the voltage controlled amplifier **31** on a lead **37** actuates a speaker **38** for producing music in response to the keyboard **11**.

The jacks **14, 22** and **36** are provided in the synthesizer **10** so that the circuits can be interrupted and external circuitry connected in. Therefore, mating portions for the jacks **14, 22** and **36** are **14***a*, **22***a* and **36***a* which render the jacks **14, 22** and **36** nonconducting by pushing the backs thereof away and connecting the leads attached to the jacks **14, 22** and **36** to independent leads which are then connected to other circuitry. Therefore, when the jack **14***a* is mated with the jack **14**, a lead **39** is connected to the lead **16** while a lead **41** is connected to the lead **12**. In a like manner, the jacks **22***a* and **22** connect a lead **42** to the lead **13** and a lead **43** to the lead **23** and the jacks **36***a* and **36** connect the lead **33** to a lead **44** and the lead **34** to a lead **46**. It should of course be understood that with these connections the leads **12** and **16, 23** and **26** and **33** and **34**, respectively, are no longer electrically connected.

Referring now to FIGS. **1** and **2** together we see that when a key on the keyboard **11** is depressed, an analog voltage representing that key is passed by the lead **12**, the jacks **14***a* and **14**, the lead **41** to a terminal of a switch **47**. With the switch **47** in the position shown, the analog voltage is passed therefrom by a lead **48** to an analog-to-digital converter **49**. In a like manner, the timing signal provided on the lead **13** by the keyboard **11** is passed by the combination of the jacks **22***a* and **22** to the lead **42** and then by leads **51, 52, 53** and **54** to actuate the analog-to-digital converter **49**. Thereupon the analog-to-digital converter **49** converts the analog signal provided on the lead **48** to a digital signal which is passed by the closed switch **56** to be stored in a location of a read/write memory **57** determined by a signal applied thereto on a plurality of leads designated **58**. The signal on the leads **58** is supplied by an address register **59**.

The timing signal supplied by the keyboard **11** to lead **42** is also applied thereby to a delay element **61**. The delay element **61** could be a delay line or a digital delay device such as a shift register. The output of the delay element is passed by leads **62** and **63** to the read/write memory **57**. The application of the delayed pulse from the delay element **61** to the read/write memory **57** interrogates the read/write memory **57** to provide the information stored therein at locations determined by the address register **59** on a set of output leads **64** in digital form. A digital-to-analog converter **66** converts the signals applied thereto to analog form and applies it to the lead **39**. The lead **39** being connected to the lead **16** applies the analog voltage to the voltage controlled oscillator **17** in the synthesizer **10**.

An And gate **67** which normally has an enabling signal applied at one input thereof by a signal on a lead **68** passes the pulse from the delay element **61** to the lead **43** and from there to the lead **23** in the synthesizer **10** thus firing the one shot **24**. Therefore, it can be seen that the equipment above described enables a signal to be stored in the memory **57** indicating which key of the keyboard **11** had been depressed but at the same time energizes the synthesizer **10** to play the note as though the equipment shown in FIG. **2** were not present. It should be noted that the note played by the synthesizer **10** is not a direct result of the key being depressed in the keyboard **11** but rather is resultant from the information having just been written into the read/write memory **57**. Therefore if the wrong information had been stored in the read/write memory **57**, the wrong note would have been played by the sequencer **10**. This insures that the user of the equipment knows whether or not the appropriate information is being stored in the memory **57**.

It should be noted that the voltage applied to the voltage controlled amplifier is similarly being recorded and stored in a second read/write memory **69** which is driven by an analog-to-digital converter **71** and is controlled by the same signals as is the read/write memory **57**. In this way the setting of the pot **32** on the synthesizer **10** is recorded in the read/write memory **69** at a corresponding location to the key or tone information stored in the read/write memory **57** so that when the read/write memories **57** and **69** are read out, the appropriate amplitude as well as frequency of tone is provided by the sequencer **10**. It should be noted that the switch **47** or a corresponding switch **72** could be manipulated so that the information being stored in the read/write memories **57** and **69** are controlled by the potentiometer **73** and **74** on the sequencer rather than the keyboard **11** or the potentiometer **32** in the synthesizer **10**. It should be further noted that if the jacks **36** and **36***a* were not engaged, the amplitude provided by the synthesizer **20** would be controlled by the potentiometer **32** but that the information therefrom would not be stored in the read/write memory **69**. Further, upon playback the information from the read/write memory **57** would control the voltage controlled oscillator **17** but the potentiometer **32** could be used to control the amplitude of the voltage controlled amplifier **31**. It is of course obvious that the various jacks can be individually plugged in and controlled so that for example, information can be stored in the read/write memory **57** by the keyboard by plugging the jack **14***a* into the jack **14** without recording in the read/write memory **69**. This would be accomplished by opening up a switch **76**. After the information were stored in the read/write memory **57**, the switch **56** could be opened and the switch **76** closed, the jack **14***a* removed from the jack **14** and the jack **36***a* substituted therefor so that then the keyboard **11** could be used to write in the rear/write memory **69**. In this way, information could be independently put into the two memory channels **57** and **69**.

It, of course, now becomes quite clear that tremendous flexibility is provided by the structure thus far described. It should be further noted that other parameters of the synthesizer **10** can be controlled by the sequencer of FIG. **2**.

Two important functions remain for the sequencer of FIG. **2** to perform. One is to control the timing of signals provided on the leads **39** and **46** while the second is to control the memory locations addressed by the register **59**. The timing information is stored and con-

trolled in a third channel associated with a third read/write memory **77** while the addressing function performed by the address register **59** is controlled by circuitry designated generally **78.**

The address register **59** is normally advanced one location each time a pulse is applied to the lead **42** during the writing operation. The pulse applied to the lead **42** is passed by the lead **51** to a lead **79** which enables three And gates **81, 82** and **83.** The And gate **83** is normally disabled until a switch **84** is closed. An inverting amplifier **86** inverts the signal applied to the And gate **83** so that appropriate signals are applied to the And gates **81** and **82** to enable them. The And gates **81** and **82** are driven at their third inputs by a lead from a flip-flop **87.** The signals applied to the And gates **81** and **82** are compliments of each other so that only one of these And gates can pass signals at a particular time. The And gates **81** and **82** drive up and down inputs to the address register **50** so that depending upon which of the And gates **81** or **82** is enabled by the flip-flop **87,** the address register **59** will advance in either an up or a down direction each time a pulse is applied by the lead **79** to the And gates **81** and **82.** Therefore, it can be seen that each time information is applied to the A to D converters **49** and **71** in response to the actuation of the keyboard **11,** the address register **59** will advance to a new location. In order to recover the information stored in the read/write memory **57** and **69** at a later time in a playback mode, the switches **56** and **76** are open while a switch **88** is thrown to connect the wiper arm to a lower contact shown in FIG. **2** connecting a clock source **89** to the leads **51, 52** and **79.** The clock source **89** would then provide periodic timing signals to advance the address register **59** and would also provide a signal to the delay element **61** which would read out the read/write memories **57** and **69** and provide a timing signal via lead **43** to synthesizer **10.** Therefore, the timing as well as amplitude and frequency signals would be applied to the synthesizer **10** to control the synthesizer for playing the information stored in the memories **57** and **69.** It should of course be appreciated that this would provide only evenly spaced notes rather than any sort of rhythm.

When all the notes are played from the read/write memory **57** and the next memory location is reached, a predetermined coded piece of information is provided by the read/write memory **57** on a lead **64.** It should be noted that this information can either be written into all the memory cells or the end of the music can be specifically written into the read/write memory **57** by providing either a digitally coded signal directly thereto or providing a specific analog voltage to the lead **48.** When the predetermined coded signal is supplied on the lead **64** a decode circuit **88** provides a signal to an Or gate **89.** The Or gate **89** provides a signal on a lead **91** which either resets the address register **59** or compliments the flip-flop **87** in accordance with the position of a switch **92.** If the address register **59** is reset, the same musical sequence is repeated when the next series of clock pulses is provided by the clock source **89.** If the switch **92** is located in a position to compliment the flip-flop **87,** the one of the And gates **81** or **82** which is advancing the address register **59** is disabled and the other is enabled so that the address register now advances in its reverse direction. Therefore, in this condition the sequence of musical notes is played in reverse. When the decode circuit **88** provides its pulse to the Or gate **89** it also provides a signal on a lead **93** which is inverted by an inverting amplifier **94** for disabling And gate **67.** Therefore, the timing pulse provided by the delay element **61** is not provided for this time interval so that the end of code coding information provided by the read/write memory **57** is not played by the synthesizer **10.**

When the address register gets to its zero position, a second decode circuit **96** provides pulse to the Or gate **89** to again either compliment the flip-flop **87** or reset the address **59.** Normally the decode circuit **89** decodes the zero position from the address register **59** so that the resetting thereof is a redundant operation. However, when the switch **92** is in the position as shown the pulse from the decode circuit **96** compliments the flip-flop **87** so that the musical sequence is again played in its original direction when the flip-flop **87** is complimented. Therefore, it can be seen that the decode circuits **88** and **96** periodically reverse the flip-flop **87** when the switch **92** is in a position as shown so that the musical sequencer stored in the memories **57** and **69** are played back and forth repeatedly. When the switch **92** is in a position not shown, the decode circuit **88** resets the address register to zero when the end of the sequence of music is reached so that the sequence is played in its predetermined direction repeatedly. In this mode, the decode circuit **96** is redundant.

An additional mode of control for the address register **59** can be provided by throwing the switch **84** to its closed position. When the switch **84** is in its closed position, the inverting amplifier **86** disables both of the And gates **81** and **82** while the closing of the switch **84** enables the And gate **83** to pass the timing pulse provided on the lead **79.** Therefore, each time the timing pulse appears on the lead **79,** the And gate **83** enables an And gate **97** to transfer information in a counter **98** directly to the address register **59.** It should of course be appreciated that the And gate **97** is representative of a plurality of And gates as are other leads and gates which pass signals and multibit binary forms. The counter **98** is driven by a clock source **99.** The clock source **99,** for example, provides pulses at a rate of 1 million per second where the normal timing of the pulses on the lead **79** is in the range of about ten per second. Therefore, it can be seen that the particular number at which the counter **98** will be when a pulse appears on the lead **79** is arbitrary so that the numbers passed by the And gate **97** from the counter **98** to the address register **59** will be random. In this mode therefore the information stored in the memories **57** and **69** will be randomly applied to the sequencer **10.** It should be appreciated that in this mode the music played by the sequencer **10** will have the same density of notes and amplitudes stored in the read/write memories **57** and **69** but the sequence of playing these notes will be random. This is different, of course, than the random selection of all notes.

As mentioned above, the read/write memory **57** can be employed to control the timing of the signals supplied by the read/write memories **57** and **69.** In this regard during the recording mode when the keyboard **11** is employed to insert information signals into the read/write memories **57** and **69,** the switch **88** is left in the position as shown while a switch **101** is left as shown also in FIG. **2.** With the switches in this position when a timing signal is supplied by the keyboard **11** ultimately onto lead **42, 51** and **52** the currents of the tim-

ing signal reset the counter **102** and transfers whatever signal is present in the counter **102** at that time through an And gate **103**, lead **104** and And gate **105** to the Or gate **106** which applies it to the read/write memory **57** at the location determined by the address register **59.** The clock source **79** then advances the counter **102** at a predetermined rate so that upon the next occurrence of a pulse provided by the keyboard **11**, the number contained in the counter **102** is dependent upon the interval between which keys were depressed on the keyboard **11.** At this time, the number contained in the counter **102** is again transferred into the position of the read/write memory **77** determined by the address register **59.** Therefore, the interval between the depressions of keys on the keyboard **11** is stored in the read/write memory **77** at a position related to the position in the read/write memories **57** and **69** that the particular information connected with depression of such keys is located.

To employ the information contained in the read/write memory **77** on playback, the switch **88** is put to its upper position so that the timing for the system is supplied on a lead **107.** The lead **101** is put to its upper position enabling an And gate **108** while a switch **109** is opened so that new information is not transferred to the read/write memory **77.** In this mode the clock source **89** advances the counter **102** until a predetermined number determined by the decode circuit **111** is reached. When this number is reached, the decode circuit **111** supplies a pulse on the lead **107** which is now the basic system timing which advances the address register **59** and is delayed by delay element **61** to provide a read pulse on lead **62** and **63** and an output pulse on the lead **43.**

When the read pulse is applied to the read/write memory **77** the number stored therein is passed by And gate **108** to the counter **102** so that the counter **102** is not preset to the value determined by the information in the read/write memory **77.** The clock source **89** again counts the counter **102** until the predetermined number determined by the decode circuit **111** is reached. Therefore it can be seen that since the interval between pulses from the clock source **89** is constant, the timing between pulses provided by the decode circuit **111** will be determined by the information stored in the read/write memory **77.** In this way it is clear that the read/write memory **77** in this mode of operation determines the rhythm or timing of the music played by the synthesizer **10.**

Of course, the potentiometer **112** can be used in other modes of operation in connection with switch **113,** analog-to-digital converter **114** to provide other information through the And gate **116,** Or gate **106,** switch **109** to the read/write memory **77.** The digital-to-analog converter **117** can also be employed to provide analog signals for operation of other functions in the synthesizer **10.**

From the above, it should be clear that the sequencer shown in FIG. **2** can be employed in numerous modes by the manipulation of switches provided therein to provide a device which can be of wide application when used in connection with a synthesizer.

It is of course understood that numerous changes can be made in the details of the sequencer of FIG. **2** without departing from the spirit or scope of this invention. For example, the functions performed by all of the analog-to-digital converters and digital-to-analog converters can be performed by one analog-to-digital converter which is appropriately time shared by well known techniques.

It should of course be understood that while this invention has been described with respect to particular embodiments thereof, numerous others will become obvious to those of ordinary skill in the art in light thereof.

What is claimed is:

1. In combination: a musical sequencer including:

a first memory having an input and an output; said first memory being rendered effective by an address signal and responsive to a store signal for storing information signals applied to said input in an address location therein dependent upon said address signal; said first memory being further responsive to a read signal for providing said information signals stored in said address location therein dependent upon said address signal at said output;

first means for providing said address signal to said first memory;

second means for applying said store signal to said first memory; and

third means responsive to said store signal for providing said read signal to said first memory a predetermined time interval thereafter, and

a voltage controlled musical device responsive to said information signals at said output of said first memory for providing tones in accordance therewith; said voltage device having a means for providing said information signals to said input of said first memory.

2. The combination as defined in claim **1** in which said first means is responsive to said store signal for changing said address signal applied to said memory.

3. The combination as defined in claim **2** also including fourth means for rendering said second means inoperative.

4. The combination as defined in claim **3** also including:

fifth means responsive to predetermined information being provided at said output for resetting said first means to provide a predetermined address signal.

5. The combination as defined in claim **3** in which said first means is normally responsive to said store signal for changing said address signal in a first sense, said musical sequencer also including:

fifth means responsive to predetermined information being provided at said output for enabling said first means to change said address signal in a second sense in response to said store signal.

6. The combination as defined in claim **3** in which said store signal changes said address signal randomly.

7. The combination as defined in claim **2** also including:

a second memory having an input and an output; said second memory being rendered effective by said address signal and responsive to said store signal for storing information signals applied to said input thereof in an address location therein dependent upon said address signal; said second memory being further responsive to a read signal for providing said information signals stored in said address

location therein dependent upon said address signal at said output thereof;

fourth means for applying said address signal to said second memory;

fifth means for applying said store signal to said second memory;

sixth means responsive to said store signal for providing said read signal to said second memory a predetermined time interval thereafter;

seventh means for providing a clock signal; and

a counter for counting said clock signal to provide said information signal to said input thereof.

8. The combination as defined in claim **7** also including eighth means for rendering said second means inoperative.

9. The combination as defined in claim **8** also including:

ninth means responsive to predetermined information being provided at said output for resetting said first means to provide a predetermined address signal.

10. The combination as defined in claim **8** in which said first means is normally responsive to said store signal for changing said address signal in a first sense, said musical sequencer also including:

ninth means responsive to predetermined information being provided at said output for enabling said first means to change said address signal in a second sense in response to said store signal.

11. The combination as defined in claim **8** in which said store signal changes said address signal randomly.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,821,712 Dated June 28, 1974

Inventor(s) William H. Wetzel

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

The Assignee should read

-- Ionic Industries Incorporated, Morristown, N. J. --.

Signed and sealed this 12th day of November 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

RM PO-1050 (10-69)

USCOMM-DC 60376-P69
U.S. GOVERNMENT PRINTING OFFICE 869-930