

[54] **ELECTRONIC MUSICAL INSTRUMENT
WITH DIGITAL REVERBERATION SYSTEM**

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[58] Field of Search **84/1.04-1.06, 84/1.24-1.25, DIG. 26; 179/1 J, 1 M**

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3,515,792	6/1970	Deutsch	84/1.24 X
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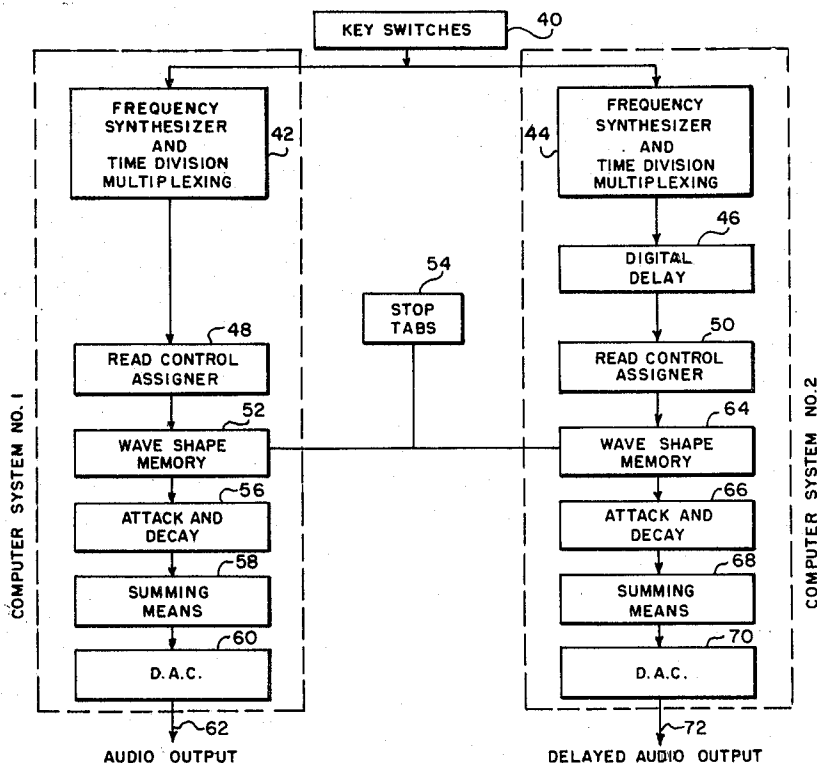
Assistant Examiner—Stanley J. Witkowski

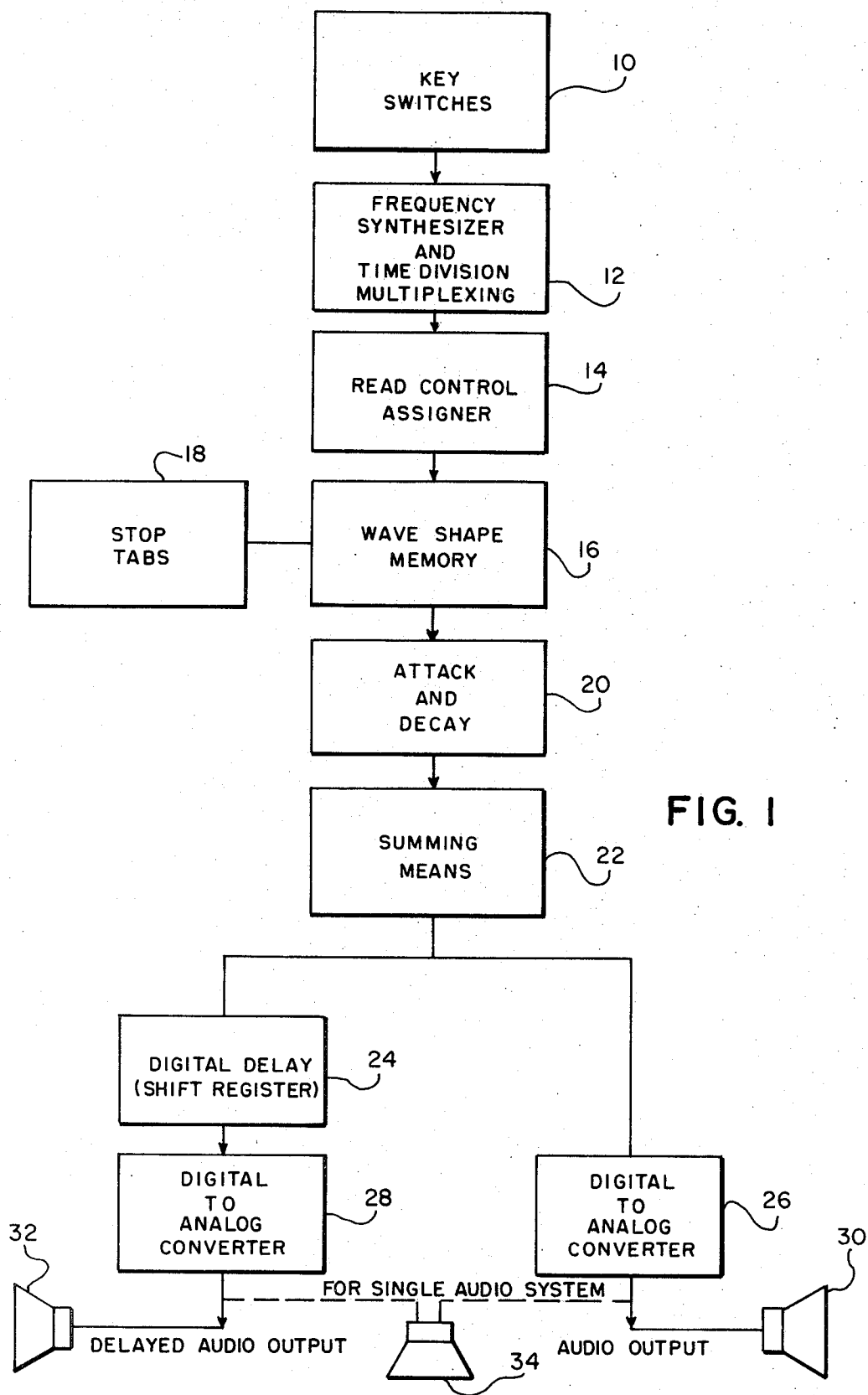
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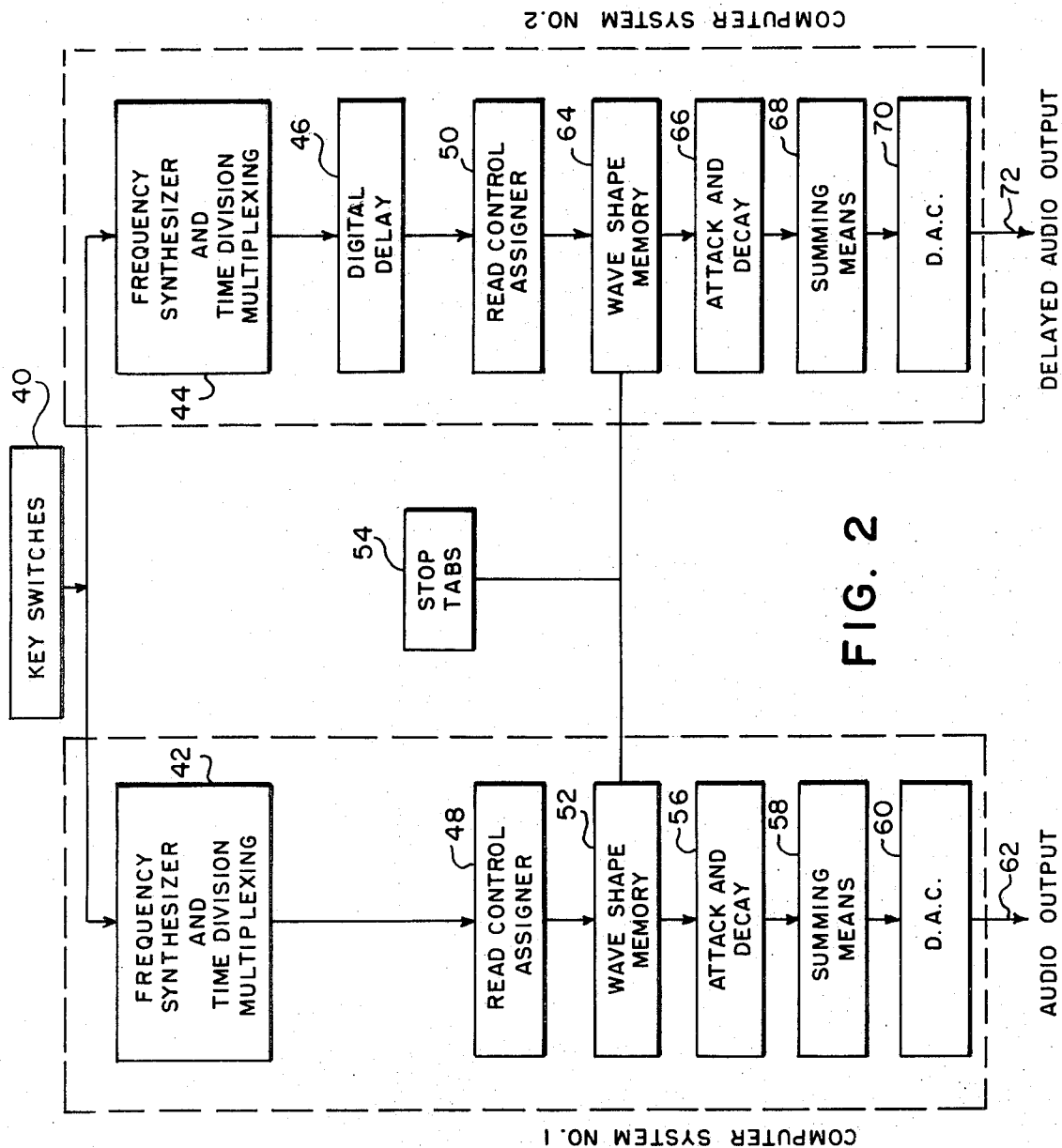
[57] **ABSTRACT**

An electronic musical instrument with a digital reverberation system in which one of the digital signals in a pair of digital signal information channels is delayed. The system is particularly adapted for use in an electronic musical instrument in which a digital multiplex signal is generated by actuation of the keys of the instrument. The digital multiplex signal is used to address a digital wave shape memory which stores signals representative of a musical note in digital form. The signals read out of the digital wave shape memory are, after processing, converted to an analog signal by means of one or more digital to analog converters. A pair of digital channels, one of which has a digital delay means therein, may be incorporated into an electronic musical instrument at various stages. The delay may be incorporated into one of the digital channels before or after the reading of the digital wave shape from memory. In addition, means may be provided to selectively switch between the delayed and undelayed signals as desired for the pedals, great or lower manual, and the swell or upper manual by means of a multiplex keyboard selector which in conjunction with an electronic switch selectively switches in the delay for the portion of the multiplex signal corresponding to a particular keyboard.

6 Claims, 3 Drawing Figures







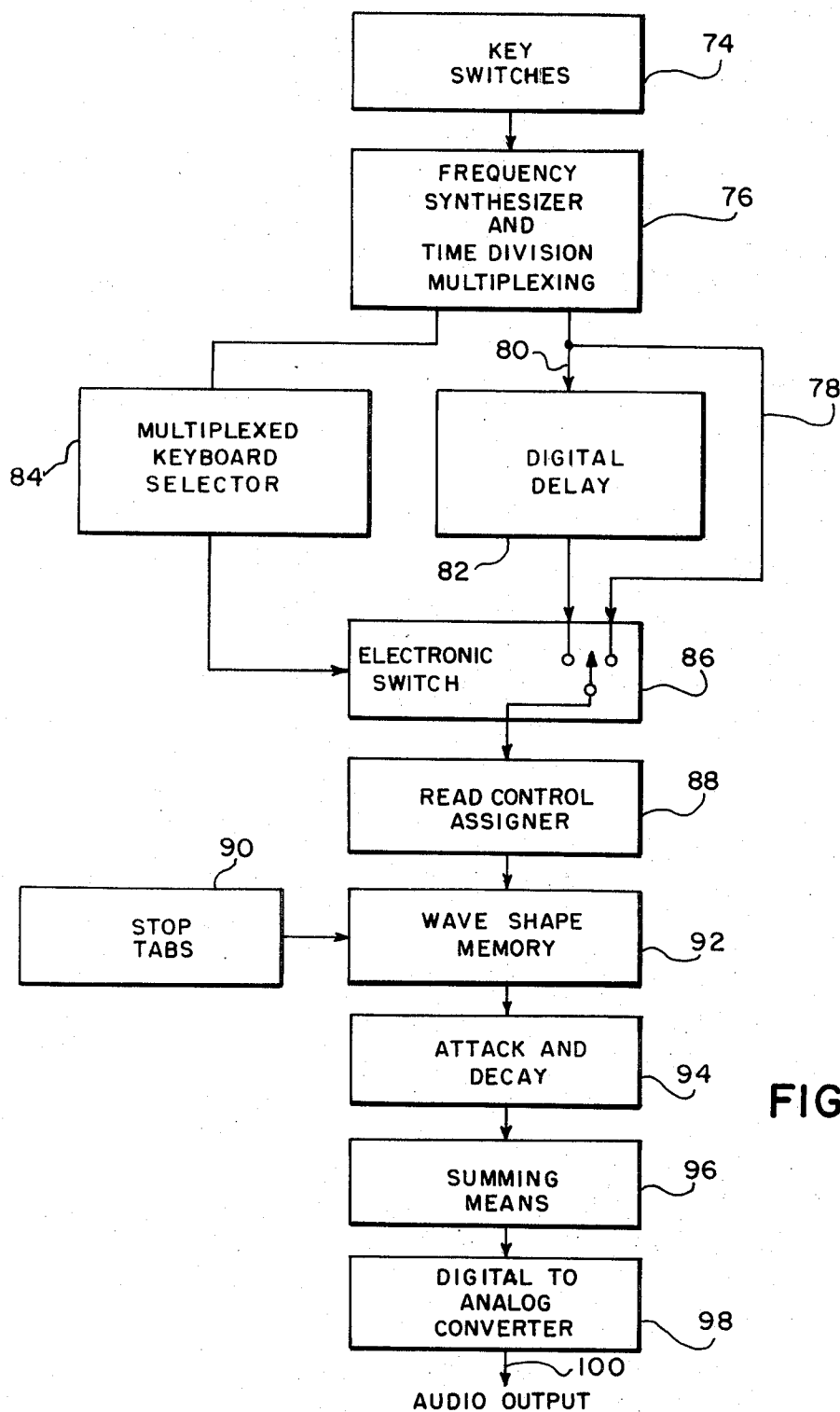


FIG. 3

ELECTRONIC MUSICAL INSTRUMENT WITH DIGITAL REVERBERATION SYSTEM

This invention relates to an electronic musical instrument with a digital reverberation system. More particularly, this invention relates to an electronic musical instrument with a digital reverberation system in which the digital information in one of a pair of digital information channels is delayed by a digital delay means.

The reverberation or echo effect is produced by having a pair of sounds, one of the sounds being delayed with respect to the other. The reverberation or echo effect is often desired in musical instruments in order to simulate the effect of a music hall.

This invention may be adapted for use in any type of a suitable digital electronic instrument. However, the present invention is particularly suited for use in producing a reverberation effect in a digital organ system of the general type described in U.S. Pat. Nos. 3,515,792 and 3,610,799 wherein actuation of an organ key effects the gating of a pulse into a time slot of a time division multiplex system, each key of the instrument being assigned a particular time slot.

A reverberation effect is produced in one of the channels by digitally introducing a time delay between the depression of a key on the keyboard and the beginning of the musical note. Similarly, a time delay of equal magnitude is introduced between the release of the key and the end of the musical note. The delays associated with attack and decay are of equal magnitude and may be adjusted over a wide range of time.

It has been known in the prior art to produce a reverberation or echo effect by analog techniques. For example, it has been known to provide analog delay lines in audio systems. In addition, U.S. Pat. No. 3,506,773 discloses use of a delayed gating network to delay one of the pair of signals. However, the prior art does not teach the use of a digital delay means in one of a pair of digital information channels in a digital electronic musical instrument.

In accordance with the present invention, the reverberation effect is produced in a digital electronic musical instrument. The digital electronic musical instrument is provided with keys which are selectively actuable to cause the production of sounds corresponding to the respective notes of the musical scale. The digital electronic musical instrument is provided with a first and second channel of digital information corresponding to a selected note of the musical scale. The second channel is provided with a digital delay means which may be a shift register or other suitable digital delay means. The digital information from the first and second channels eventually produce an analog signal which may be applied to an acoustical transducer. The first and second digital channels may be incorporated in various sections of the digital electronic musical instrument. The digital delay may be incorporated into the digital signal prior to the musical wave form being read out of a digital wave shape memory.

For the purpose of illustrating the invention, there are shown in the drawings forms which are presently preferred; it being understood, however, that this invention is not limited to the precise arrangements and instrumentalities shown.

FIG. 1 is a schematic diagram, in block diagram form, of one embodiment in accordance with the present invention.

FIG. 2 is a schematic diagram, in block diagram form, of another embodiment of the invention.

FIG. 3 is a schematic diagram, in block diagram form, of still another embodiment of the present invention.

Referring now to the drawings in detail, there is shown in FIG. 1 a set of key switches or keys 10. The key switches or keys 10, which will be referred to hereinafter as keys, may be the keys of the various keyboards of a digital electronic organ. Digital electronic organs or digital electronic musical instruments in which the present invention may be applied and used are described in detail in U.S. Pat. No. 3,515,792 of which the inventor was Ralph Deutsch and U.S. Pat. No. 3,610,799 of which the inventor was George A. Watson. Reference may be had to these patents for a detailed description of the components referred to herein other than the reverberation effect producing structural relationships in accordance with the invention.

As each key or key switch 10 is depressed, an input is applied to the frequency synthesizer and time division multiplexing means 12. Key switches 10 may contain groups of keys for the various keyboards on the electronic musical instrument. For example, in the case of a digital electronic organ, there may be keys or switches associated with the pedals, the great or lower manual and the swell or upper manual. A frequency synthesizer and time division multiplexing means 12 provides a discrete frequency related output signal for each input from a selected keyboard switch. The discrete frequency related output signal from the various keyboards are time division multiplexed to form a multiplexed signal. The multiplex signal output of the frequency synthesizer and time division multiplexing means 12 is a digital signal.

The digital multiplexed signal from frequency synthesizer and time division multiplexing means 12 is fed to read control assigner 14. Read control assigner 14 functions to select unused input and output means to address wave shape memory 16. Such circuitry is well known in the art, e.g., as illustrated by the circuitry in FIGS. 7A, 7B and 8 of U.S. Pat. No. 3,610,799.

Wave shape memory 16 contains digital representations of various musical notes reproduced by the depression of various keys 10. That is, a particular digital representation of a wave shape may be stored in wave shape memory 16 for each of the keys 10. In addition, several different wave shapes may be stored in wave shape memory 16 for each of the keys. In the case where several different wave shapes are stored in wave shape memory 16 for each particular key, the particular wave shape to be read out is selected by means of stop tabs 18.

The digital representations of wave shapes read out of wave shape memory 16 are processed by attack and decay circuitry 20. The output of attack and decay circuitry 20 is fed to summing means 22. Attack and decay circuitry 20 operates on the digital signal read out of wave shape memory 16 so as to shape the rise time and fall time of each note being generated. Summing means 22 combines the plurality of notes which may be simultaneously depressed on key switches 10. Summing means 22 therefore produces a single digital output representing the sum of the wave forms associated with each note in a chord.

The output of summing means 22 is fed to digital delay means 24 and to digital to analog converter 26. Digital delay means 24 may be a shift register or any other suitable type of digital delay means. In the case where digital delay means 24 is a shift register, the amount of delay is a function of the length of the shift register. Delays may be obtained from a few milliseconds to any practical length. The output of digital delay means 24 is fed to digital to analog converter 28.

Digital to analog converters 26 and 28 convert their digital signal inputs to analog audio frequency output signals. Digital to analog converters 26 and 28 may contain amplifier means in order to amplify the signals. The outputs of digital to analog converters 26 and 28 may be applied to separate acoustical transducers or speakers 30 and 32, respectively. Alternatively, if speakers 30 and 32 are not provided, the outputs of digital to analog converters 26 and 28 may be applied to acoustical transducer 34 as shown by the dotted lines.

In operation, the digital output signal representative of a musical note may be produced as described above and in accordance with the disclosure in U.S. Pat. No. 3,515,792. The digital output of the summing means 22 is fed to a pair of digital channels. One of the channels has a digital delay means 24. The signals in both channels are then converted to analog audio frequency signals by digital to analog converters 26 and 28. The providing of digital delay means 24 produces a reverberation or echo effect in the output since there are two acoustical sounds produced, one being delayed with respect to the other.

Referring now to FIG. 2, there is shown another embodiment of this invention in which similarly labeled components operate and function in a manner similar to those described for FIG. 1. There is shown in FIG. 2 key switches 40 which provide inputs to frequency synthesizer and time division multiplexing means 42 in computer system No. 1 and frequency synthesizer and time division multiplexing means 44 in computer system No. 2. The digital output of frequency synthesizer and time division multiplexing means 44 is delayed by digital delay means 46. As a specific example, but not as a limitation, this digital delay means may be connected in series with the output of encoder 15 as shown in block diagram form in FIG. 1 of U.S. Pat. No. 3,610,799 to form one computer system of an organ with a reverberation system. A second system as described in U.S. Pat. No. 3,610,799 could be used for the second computer system. Of course, the remaining drawings and description may be referred to for detailed circuit information. The output of frequency synthesizer and time division multiplexing means 42 is fed to read control assigner 48. The output of digital delay means 46 is fed to read control assigner 50.

Read control assigner 48 in computer system No. 1 addresses wave shape memory 52 in conjunction with stop tabs 54. The output of wave shape memory 52 is processed by attack and decay circuitry 56 and fed to summing means 58. The output of summing means 58 is fed to digital to analog converter 60. The output of digital to analog converter 60 is an undelayed analog audio frequency output signal on output 62 which may be fed to a speaker or other suitable acoustical transducer.

Referring now to computer system No. 2, the delayed digital signal output from digital delay means 46 is fed to read control assigner 50. Wave shape memory 64 is therefore addressed at a predetermined time after wave shape memory 52 in computer system No. 1 is addressed in response to the depression or actuation of a particular key switch 40. The delayed digital signal read out of memory 64 is fed to attack and decay circuit 66. The output of attack and decay circuit 66 is fed to summing means 68. The output of summing means 68 is fed to digital to analog converter 70. The output of digital to analog converter 70 is a delayed analog audio frequency signal on line 72. That is, the audio signal on line 72 is delayed with respect to the same audio signal on line 62. The audio signals on lines 62 and 72 may be fed to separate acoustical transducers or may be combined in a single acoustical transducer. One example of a single acoustical transducer is a speaker.

In operation, the embodiment shown in FIG. 2 produces a reverberation effect by using two separate digital electronic instruments or computer systems which are both operated in response to the same key switches 40 and stop tabs 54 with one of the systems having a digital delay means 46 inserted before wave shape memory 64 is addressed.

Referring now to FIG. 3, there is shown another embodiment of the present invention in which components labeled similar to FIG. 1 operate and function as described with respect to FIG. 1. There is shown in FIG. 3 keys or key switches 74 which provide inputs to frequency synthesizer and time division multiplexing means 76. The output of frequency synthesizer and time division multiplexing means 76 is applied to a first channel 78 and a second channel 80 having a digital delay means 82. An output from frequency synthesizer and time division multiplexing means 76 is provided to multiplexed keyboard selector 84. Multiplexed keyboard selector 84 controls electronic switch 86 which selects either the output of digital delay means 82 or the output of first digital channel 78 depending upon whether a delay is selected for the particular keyboard by means of multiplexed keyboard selector 84. As a specific example, but not by way of limitation, digital delay means 82, digital channel 78, and electronic switch 86 may be located at the output of encoder 15 as shown in block diagram form in FIG. 1 of U.S. Pat. No. 3,610,799. The multiplexed signal output of encoder 15 would be applied to the digital delay 82 and digital channel 78 as shown in FIG. 3 herein. Of course, the remaining figures and description in U.S. Pat. No. 3,610,799 may be referred to for detailed information.

The digital information or data output of frequency synthesizer and time division multiplexing means 76 is a serial digital time multiplexed signal containing information from the various keyboards in various predetermined time slots. As a specific example, but not by way of limitation, there may be three time slots corresponding to three different keyboards. For example, the first time slot may correspond to information received from actuation of keys on the pedal keyboard. The second time slot may contain information in response to actuation of keys on the great or lower manual keyboard. The third time slot may contain information responsive to actuation of keys on the swell or upper manual keyboard. By the operator or performer using the digital electronic musical instrument actuating various keys

on the multiplexed keyboard selector 84, electronic switch 86 selects either the output of digital delay means 82 or the output of first digital channel 78 for the keyboard as selected on multiplexed keyboard selector 84.

The output of electronic switch 86 is fed to read control assigner 88. Read control assigner 88 in conjunction with stops tabs 90 address and read out the proper wave shape in digital form from wave shape memory 92. The output of wave shape memory 92 is processed in attack and decay circuitry 94. The output of attack and decay circuitry 94 is fed to summing means 96. The output of summing means 96 is fed to digital to analog converter 98 which converts the digital output of summing means 96 to an analog audio frequency signal on line 100. The output on line 100 may be fed to any suitable type of acoustical transducer.

The present invention may be embodied in other specific forms without departing from the spirit or essential attributes thereof and, accordingly, reference should be made to the appended claims, rather than to the foregoing specification as indicating the scope of the invention.

I claim:

1. In a digital electronic musical instrument having keys selectively actuable to cause the production of sounds corresponding to respective notes of the musical scale, apparatus for producing a reverberation effect, comprising:

a first channel of digital information corresponding to a selected note of the musical scale, said first channel including a frequency synthesizer and time division multiplexing means responsive to said keys;

a second channel of digital information corresponding to said selected note of the musical scale, said second channel including a frequency synthesizer and time division multiplexing means responsive to said keys and digital delay means for delaying said digital information in said second channel; and

means for producing analog signals corresponding to said musical note in response to said digital signal in said first and second channels, said means including at least one digital memory for storing signals representative of musical notes, means for addressing said digital memory in response to digital information corresponding to said selected note of the musical scale and means for converting the signals read out of said digital memory to an analog signal.

2. A digital electronic musical instrument in accordance with claim 1 wherein the outputs of said analog signal producing means responsive to the digital signals in said first and second channels are applied to a single acoustic transducer.

3. A digital electronic musical instrument in accordance with claim 1 wherein the outputs of said analog signal producing means responsive to the digital signals in said first and second channels are applied to at least one acoustic transducer per channel.

4. A digital electronic musical instrument in accordance with claim 1 wherein said digital delay means comprises a shift register.

5. In a digital electronic musical instrument having keys selectively actuable to cause the production of sounds corresponding to respective notes of the musical scale, apparatus for producing a reverberation effect, comprising:

a frequency synthesizer and time division multiplexing means responsive to said keys for producing a digital time division multiplexed signal corresponding to a selected note of the musical scale;

a first channel for the digital time division multiplexed signal output of said frequency synthesizer and time division multiplexing means;

a second channel for the digital time division multiplexed signal output of said frequency synthesizer and time division multiplexing means, said second channel including digital delay means for delaying said digital information in said second channel;

switching means for selectably using either said first or second channel for the output of said frequency synthesizer and time division multiplexing means; and

means for producing analog signals corresponding to said musical note in response to said digital signal in said first or second channel as selected by said switching means, said means including a digital memory for storing signals representative of musical notes, means for addressing said digital memory in response to digital information corresponding to said selected note of the musical scale and means for converting the signals read out of said digital memory to an analog signal.

6. A digital electronic musical instrument in accordance with claim 5 wherein said switching means is responsive to keys for selecting delay in at least one of a plurality of keyboards.

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