United States Patent [19]

Morez

[11] **3,828,643**

[45] **Aug. 13, 1974**

[54] **SCANNER FOR ELECTRONIC MUSICAL INSTRUMENT**

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[22] Filed: **Feb. 20, 1973**

[21] Appl. No.: **333,984**

[52] **U.S. Cl.** **84/115,** 84/1.01

[51] **Int. Cl.** **G10f 5/00,** G10h 1/00

[58] **Field of Search** 84/1.01, 1.03, 1.28, 115, 84/DIG. 7, 1.09, 1.1

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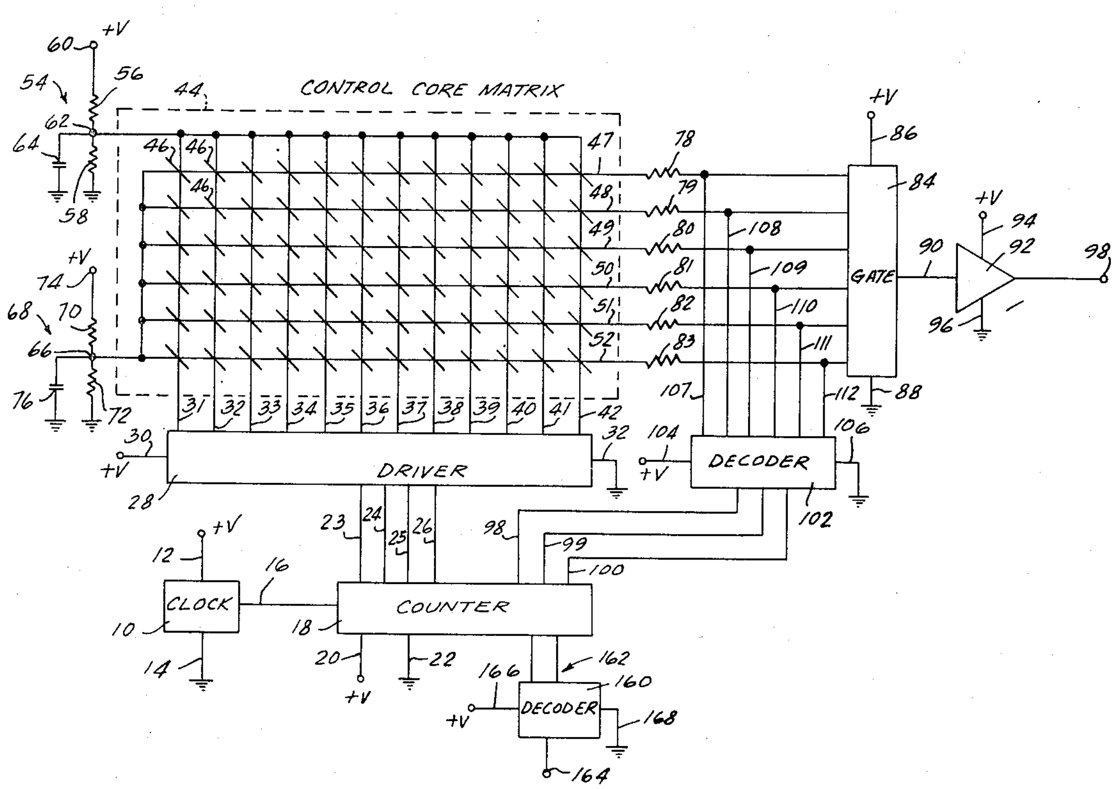
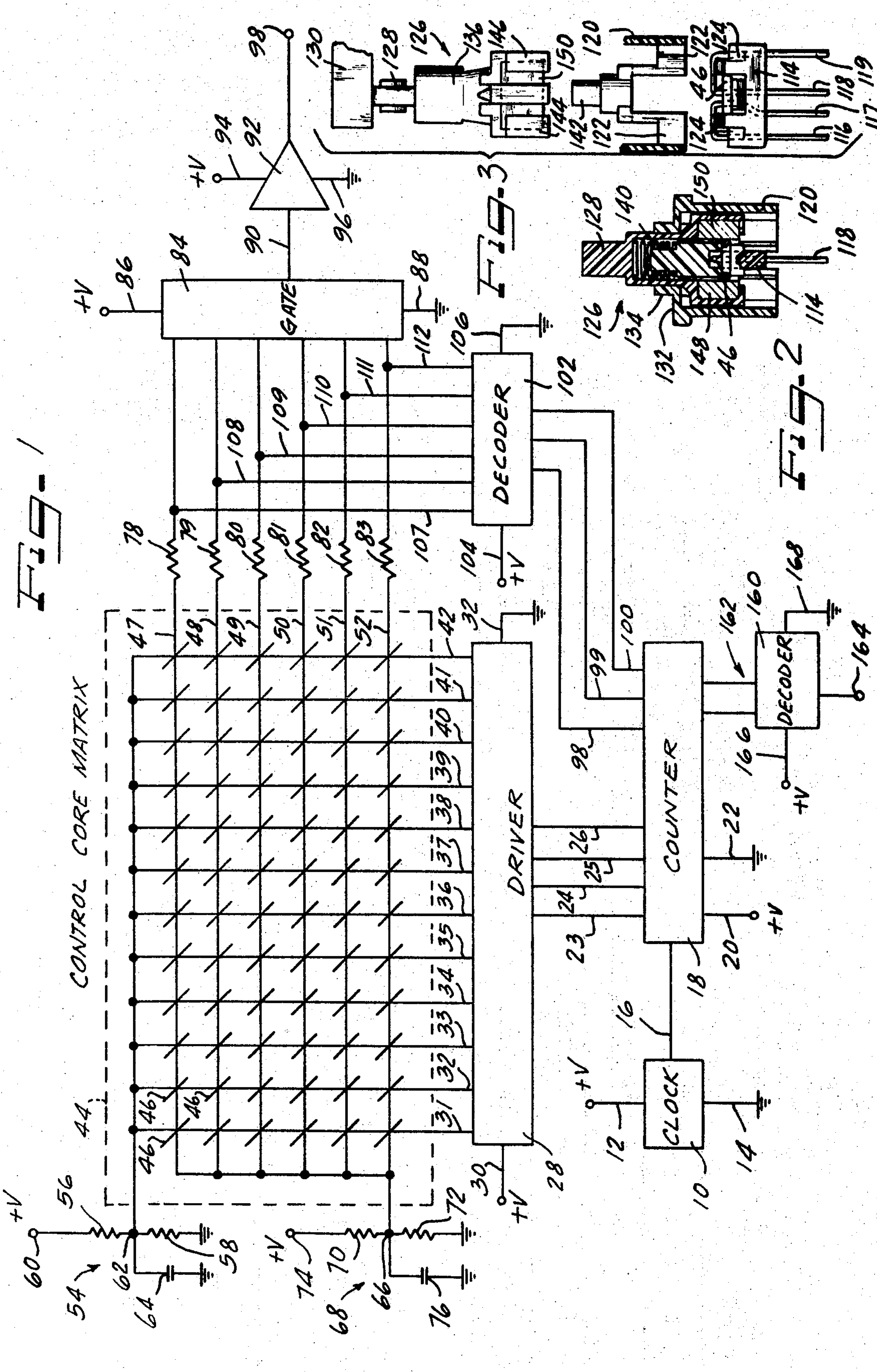
[57] **ABSTRACT**

A scanner for an electronic musical instrument employs a matrix having two sets of current conducting lines forming intersecting rows and columns, with a plurality of magnetic cores arranged at the intersections of the matrix. Individual ones of both sets of lines are energized successively to individually scan the cores, and the lines of one set are connected to a gate which produces a train of output pulses on a single output line, in response to cores which are operative to magnetically couple the lines of one set to the lines of the other set. The cores are normally maintained in inoperative condition by exposing them to a saturating magnetic field. The cores are each selectively rendered operative by moving the magnetic field, relative to the core enabling the core to effect a magnetic coupling between intersecting lines of the two sets by operation of a key of the keyboard of the instrument, or by operation of an actuating member of a switch for selecting a control function for the instrument.

15 Claims, 3 Drawing Figures




CONTROL CORE MATRIX
DRIVER
DECODER
GATE
COUNTER
CLOCK
DECODER
+V
Fig-1
Fig-2
Fig-3

SCANNER FOR ELECTRONIC MUSICAL INSTRUMENT

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a scanner for electronic musical instruments and more particularly to such a scanner adapted for encoding the pulses of a pulse train in time position, in response to operated ones of the keys and control actuators of the instrument.

2. The Prior Art

In the copending commonly assigned application of Morez and Moore, Ser. No. 323,247 filed Jan. 12, 1973, for "Electronic Musical Instrument", a system for encoding and decoding pulse information in response to operated ones of the keys and the control selecting actuators is described. A scanner is employed to generate pulses successively on a plurality of outputs, which are connected independently to electrical switches associated with the keys of the keyboard of the musical instrument, and to actuating members of control selecting switches which are operative to select certain control functions for the instrument.

While the system described in the Morez et al. application operates satisfactorily, it requires an electrical switch for each key. Such switches require electrical contacts for making and breaking electrical circuits, and are thus subject to deteriorating performance due to oxidation and wear of the contacts, and the adverse influence of dust. While steps may be taken to increase the reliability of such switches, such steps generally result in a more complicated and expensive assembly. In addition, the springs employed in such switches, for causing them to resume a normal condition after actuation, may not be compatible with the "touch" desired for the keyboard of a musical instrument. Moreover, even with the economy of wiring achieved by the apparatus described in the Morez et al. application, at least one separate wire is required for each of the switches, and the switches do not lend themselves particularly well to a construction made up of print circuit boards.

SUMMARY OF THE INVENTION

It is a principal object of the present invention to provide a more simplified scanner for encoding the pulses of a pulse train in accordance with operated ones of the keys of the keyboard and actuating members of control selecting switches.

Another object of the present invention is to reduce the number of wires which are necessary to interconnect the units operated by the keys of the keyboard.

A further object of the present invention is to provide a scanner which does not require switches to make and break electrical circuits for the manually operable keys and control selectors.

Another object of the present invention is to provide a scanner employing elements which are particularly well adapted to printed circuit construction.

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

In one embodiment of the present invention there is provided a scanner comprising a matrix having first and

second sets of conductive lines forming intersecting rows and columns, a driver for driving the first set of lines in sequential fashion, a decoder for enabling the second set of lines in sequential fashion, a plurality of magnetic gate elements having magnetic members juxtaposed with the intersections of the matrix, a manually operable member for each of the magnetic members for selectively rendering the magnetic members operative to magnetically couple the rows and columns together, and an output gate connected to the lines of the second set to produce an output pulse train having pulses encoded in time position in response to the operative ones of the magnetic members.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a functional block diagram, partly in schematic form, of a scanner incorporating an illustrative embodiment of the present invention;

FIG. **2** is a cross-sectional view of a magnetic gate element associated with the matrix of FIG. **1**; and

FIG. **3** is a side elevation of the magnetic gate element of FIG. **2**, illustrated in exploded fashion.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In FIG. **1** a source of clock pulses **10** is shown connected to a voltage source by a line **12** and to ground by a line **14**. The output of the source **10** appears on a line **16** which is connected to the input of a counter **18**. The counter **18** is preferably a seven stage binary counter, but alternatively may have more stages if desired. The counter **18** is connected to a source of positive voltage by a line **20** and to ground by a line **22**. The counter **18** changes its state with each pulse supplied to it over the input line **16**, and causes the condition of its outputs to change in accordance with the binary representation of the number of pulses supplied over the line **16**. The counter **18** counts up to its full capacity (i.e. to its radix), and then resets to zero by counting the next pulse, and continues counting in the same manner. Outputs from the four lowest stages of the counter **18** are supplied to output lines **23, 24, 25** and **26**, and are connected to the inputs of a driver unit **28**. The driver **28** is connected to a source of positive voltage by a line **30** and to ground by a line **32**. The function of the driver **28** is to convert the binary representation on the four input lines **23–26** to a one-of-twelve energization of 12 output lines **31–42**. There are 16 combinations of voltage levels on the lines **23–26**, which combinations are manifested successively. The 12 output lines **31–42** of the driver **28** are energized in response to 12 of them. The other four are ignored, as far as the present invention is concerned, and none of the outputs **31–42** is energized in response to these four. The driver **28** comprises a plurality of gates connected in a manner well known in the art to produce the described outputs on the lines **31–42**, and therefore, they need not be described in detail. In one form of utilization, the 12 lines **31–42** are used in the keying of the 12 notes of the chromatic musical scale, one line being common to octavely related keys.

The lines **31–42** form one set of lines of a matrix **44**, which comprises an assembly of **72** magnetic cores **46**. Each of the cores **46** is located at an intersection between one of the lines of the set comprising the lines **31–42** and one of the lines of the set comprising the lines 47–52. The lines 31–42 form the columns of the matrix 44, while the lines 47–52 form the rows.

Each of the lines 31–42 is connected, at its upper end, which is remote from the driver 28, to a reference potential established at a junction 62 by a voltage divider 54. The voltage divider 54 incorporates a pair of resistors 56 and 58, interconnected between a source of positive voltage connected to a terminal 60 and ground. The junction 62, between the resistors 56 and 58, is connected in common to the upper end of the lines 31–42. The junction 62 is also connected to ground by way of a capacitor 64, which stabilizes. the voltage level at the junction.

The left-hand end of each of the lines 47–52 is connected to the junction 66 of a voltage divider 68 having resistors 70 and 72 connected in series between a source of positive potential, connected to a terminal 74, and ground. A capacitor 76 is connected from the junction 66 to ground, to stabilize the voltage.

The right-hand end of each of the lines 47–52 is connected through one of a plurality of resistors 78–83 to six separate inputs of a gate 84. The gate 84 is connected to a source of positive voltage by a line 86 and is also connected to ground by a line 88. It produces an output pulse on an output line 90 in response to the occurrence of a pulse on any of the lines 47–52.

The line 90 is connected to the input of an amplifier 92. The amplifier 92 is connected to a source of positive voltage by a line 94, and to ground by a line 96. The output of the amplifier 96 is connected to an output terminal 98, which is adapted to be connected to the apparatus for decoding the pulse train in the manner described in the aforementioned Morez et al. application.

The gate 84 functions simply as a mixer and allows a signal present on any one of its six inputs to be passed to the output line 90, while maintaining the other input lines isolated from the output signal.

Three lines 98–100, connected to the highest order stages of the counter 18, are connected to the inputs of a decoder unit 102. The decoder 102 is connected to a source of positive potential by a line 104 and is also connected to ground by a line 106. The function of the decoder 102 is the same as that described above for the driver 28, and its output lines 107–112 are energized successively in response to eight distinct combinations of signal levels on the lines 98–100. Six of the eight combinations of voltage levels on the lines 98–100 bring about an energization of one of the six output lines 107–112 of the decoder 102. (The other two levels are not used in this embodiment). The energized condition of each of the output lines 107–112 persists for a period of 16 pulses, i.e., for a complete cycle of the 16 combinations manifested on the output lines 23–26 of the counter 18. The six lines 107–112 are thus each in turn, supplied with a high potential for 16 cycles of the source 10, during which the four lines 23–26 manifest 16 separate combinations, bringing about the sequential energization of the output lines 31–42 of the driver 28.

The outputs of the decoder 102 are high impedance (i.e., constant current) outputs. As long as the current flowing on an energized one of the lines 107–112 is permitted to flow through its associated resistor 78–83 and then through its associated cores of the matrix 44 to the junction 66 of the voltage divider 68, there is insufficient current supplied to the inputs of the gate 84 to cause it to produce an output on the line 90. However, when one of the cores 46 is effective to produce a pulse on the energized line 47–52 which opposes the current produced by the decoder 102, current flow through the matrix 44 is blocked, and more current is supplied to an input of the gate 84. Such pulses are produced by the cores 46, under certain conditions, in response to the pulses on the lines 31–42. Accordingly, as the matrix is scanned during each cycle of the counter 18, a train of pulses is produced on the line 90 at the output of the gate 84, each of said pulses being produced by a core located at the intersection of two lines which are energized simultaneously.

The cores 46 are normally not able to magnetically couple the lines 31–42 with the lines 47–52, as they are normally saturated by a relatively intense magnetic field. Because of their saturated condition, the magnetic flux in the cores 46 is not changed as a result of pulsing any of the lines 31–42, and accordingly no voltage pulse is induced in any of the lines 47–52. When the magnetic field is removed from a core, however, such that the core is no longer saturated, the core is then operative as a transformer to magnetically couple one of the lines 31–42 to one of the lines 47–52, and to induce a pulse in one of the lines 47–52, resulting in the application of a pulse on one of the six inputs of the gate 84. Accordingly, the cores 46 act as magnetic gates, interconnecting the input lines 31–42 with the output lines 47–52 only when the saturating magnetic field is removed. As described hereinafter, the movement of the magnetic field is accomplished by depression of a key of the keyboard, or movement of a control selector actuator.

The apparatus for supporting a core 46, and for moving the saturating magnetic field, relative to the core, is shown in FIGS. 2 and 3. The core 46 is supported by a bracket 114 formed of plastic or another insulating material. The bracket supports a pair of wire loops, one having ends 116 and 117, and the other having ends 118 and 119, in a position so that the loops link the core 46. The two loops are connected in circuit with one of the lines 31–42 and with one of the lines 47–52, respectively. The bracket 114 is held in position relative to a housing 120, by means of flaps 122 which are disposed below projections 124 extending from the surface of the bracket 114. The flaps 122 are secured to the housing 120.

A plunger assembly 126 is mounted within the housing 120 in slidable relationship therewithin. The plunger assembly 126 has a projection 128 adapted to be engaged by an actuating member 130 such as a key of the keyboard or an actuating member provided for the selection of a control function, and the plunger 126 is adapted to slide vertically within the housing 120, in response to depression of the key 130. The upper surface of the housing 120 is defined by an upper wall 132, having an upwardly extending tubular projection 134 in which a cylindrical portion 136 of the plunger 126 is slidably mounted. A spring 140 operates to maintain the plunger 126 in its upper position. The spring 140 is located with its upper end disposed in a recess within the portion 136, and its lower end held in place by a pilot 142 which is supported by the flaps 122 above the core 46.

The lower portion of the plunger assembly 126 includes a pair of brackets 144 and 146 adapted to support a pair of permanent magnets 148 and 150, respectively. When the plunger assembly **126** is in its upper position, shown in FIG. **2**, the magnets **148** and **150** are positioned so that the core **46** is between them. The magnets **148** and **150** are poled in aiding relationship, to establish a magnetic field in which the flux flows from the magnet **148** across the space occupied by the core **46** and then to the magnet **150.** The flux returns from the magnet **150** to the magnet **148,** to form a complete magnetic circuit, by flowing through the air and other paramagnetic material in the vicinity of the magnets, to the surfaces of the magnets **148** and **150** which face away from the core **46.** As a result, the magnetic field established by the magnets **148** and **150** is most intense in the space directly between the magnets where the core **46** is located when the plunger is in its upper position.

At a location slightly above the magnets **148** and **150,** the intensity of the magnetic field drops to zero. Above this location the field intensity increases as a result of the return flux flowing in the opposite direction. The point at which the magnetic field intensity is substantially zero is between the area of concentrated flux between the magnets and the area occupied by the return flux.

The magnetic gate is actuated by depressing the projection **128,** to move the plunger assembly **126** downwardly relative to the core **46,** and the magnetic field established by the magnets **148** and **150** is moved downwardly with the plunger assembly. The length of stroke of the plunger assembly **126** is sufficient to bring the location of minimum field intensity into the vicinity of the core **46,** so that depression of the projection **128** effectively removes the core **46** from the region of intense magnetic field between the two magnets **148** and **150,** to a region of negligible magnetic field slightly above the magnets **148** and **150.** Accordingly, depression of the projection **128** is effective to permit the transformation of a pulse from one of the input lines **31–42** to one of the output lines **47–52.**

As described and claimed in the aforementioned Morez et al. application, the pulse train produced at the output terminal **98** is manipulated and then, decoded in order to cause selected musical tones to be sounded, and to execute certain control functions.

A decoder unit **160** is connected to the counter **18** via lines **162,** and functions to produce, at an output terminal **164,** a pulse at the same point during each cycle of the counter **18.** The decoder unit **160** is connected to a source of positive voltage by a line **166** and to ground by a line **168.** The input lines **162** are conveniently connected to the appropriate outputs of the counter **18,** so as to produce a pulse at the output terminal **164** in response to the counter reaching a predetermined count. The decoder **160** is preferably a gate of conventional design, so that the details of its construction need not be described. The output of the decoder **160** marks the beginning of each cycle of operation, and is effective for synchronizing the decoding apparatus, as explained in the aforementioned Morez et al. application.

By the use of the present invention the electrical apparatus associated with a keyboard of an electronic musical instrument may be more simply wired than by the use of the key switches typically used in the prior art. One of the magnetic gates illustrated in FIGS. **2** and **3** is disposed under each key of the keyboard of the instrument and depression of the key produces a pulse on the output **90** of the gate **84.** Thus, only 18 wires are needed to connect all of the cores **72** associated with the keyboard with the driver **28** and the decoder **102,** only 12 wires are required for the set including lines **31–42,** and only six for the other set.

In the disclosed embodiment, **61** of the **72** cores and magnetic gates are actuated by keys of a keyboard, and the remainder are available to be actuated by other actuating members to select control functions as explained in the Morez et al. application. Of course, more key and more control selecting switches may be added to the apparatus illustrated in FIG. **1** by enlarging the size of the matrix **44,** and making corresponding increases in the size of the driver **28,** the decoder **102** and the counter **18.**

In the embodiment illustrated in FIG. **1,** the 18 wires required to wire the keyboard may pass along the length of the keyboard, and be connected to various ones of the leads **116–119** as appropriate. Preferably, the magnetic gate units are mounted on a printed circuit board extending the full length of the keyboard of the instrument, and the 18 wires of the matrix **44** then take the form of printed circuit conductors passing along the printed circuit board with the various conductors being soldered to the leads **116–119.** This supports the magnetic gates in proper position under the keys of the keyboard.

It is to be understood that less than all of the features of the invention herein described can be utilized to advantage, if desired, but that the preferred form of the invention is that which has been described.

Although various minor modifications might be suggested by those versed in the art, it should be understood that I wish to embody within the scope of the patent warranted hereon, all such embodiments as reasonably and properly come within the scope of my contribution to the art.

What is claimed is:

1. Apparatus for generating a plurality of pulses in a pulse train, each of said pulses being encoded in time position in response to actuation of one of a plurality of keys of a musical instrument, comprising in combination:

a. a plurality of ferromagnetic cores arranged in a matrix having two sets of intersecting conducting lines, each of said cores occupying a position juxtaposed with an intersection of said sets;

b. a magnetic field generator for normally maintaining each of said cores in saturated condition to render it incapable of transforming a signal from a line of said first set to a line of said second set;

c. a movable member connected with each of said keys for selectively unsaturating one of said cores to permit said core to transform a signal from a line of said first set to a line of said second set; and

d. a driver connected to one of said sets of lines for successively energizing individual ones of said cores to produce said pulse train in accordance with operated ones of said keys.

2. Apparatus according to claim **1** wherein said magnetic field generator comprises a permanent magnet juxtaposed with said core for normally maintaining it in a saturated condition.

3. Apparatus according to claim **1,** wherein the cores of said matrix are arranged in a linear array, and said keys are arranged in a linear array directly above said cores.

4. Apparatus according to claim 3, wherein each of said cores is provided with a bracket for supporting said core, first and second conductors extending through said core, said conductors being mounted on said bracket, and having terminals extending outwardly from said bracket by which said conductors are connected to the lines of said two sets.

5. In an electronic musical instrument having a plurality of selectively operable actuating members including selectively operable keys and control actuators, the combination comprising:

a. a matrix formed with a plurality of conducting lines arranged in first and second sets, the lines of the first set intersecting the lines of the second set;

b. a plurality of ferromagnetic core members juxtaposed with intersections of said matrix;

c. a driver for applying pulses sequentially to the lines of said first set;

d. a decoder for sequentially enabling the lines of said second set to successively and individually scan said core members;

e. a plurality of movable magnetic field generators connected with said actuating members for selectively being movable to a position enabling individual ones of said core members to transform signals from the lines of said first set to the lines of said second set; and

f. means connected to said matrix for producing output signals, when pulses are applied to said core members over the lines of said first set, in response to each enabled magnetic core member which is juxtaposed with an intersection of an enabled line of said second set.

6. Apparatus according to claim 5, wherein said actuating members comprise a plurality of keys arranged as a keyboard of a musical instrument.

7. Apparatus according to claim 5, including a gate having inputs connected to the lines of said second set and arranged to provide, on a single output line, a train of pulses encoded in time position in response to operated ones of said actuating members.

8. Apparatus according to claim 5, including a counter and a source of clock pulses connected to said counter, said driver being connected to said counter and responsive to the state of said counter for successively energizing a plurality of outputs connected to the lines of said first set.

9. Apparatus according to claim 5, including a source of clock pulses and a counter connected to said clock pulses, said decoder being connected with said counter and connected to energize individual lines of said second set in response to the state of said counter, for enabling each of the lines of said second set for a plurality of cycles of said clock pulse source.

10. Apparatus according to claim 9, wherein said decoder is connected to the lines of said second set through individual resistors, and including a gate connected directly to the outputs of said decoder for producing an output signal whenever a signal is present on any of said second plurality of lines by the transforming action of one of said ferromagnetic members.

11. Apparatus according to claim 5, wherein said ferromagnetic members comprise ferromagnetic cores linking said lines at a plurality of intersections thereof.

12. Apparatus according to claim 5, wherein said magnetic field generators comprise a permanent magnet for each of said ferromagnetic members, said magnet being movable relative to its ferromagnetic member between a first position in which said magnetic member is magnetically saturated by the flux produced by said permanent magnet, and a second position at which said magnetic member is not magnetically saturated.

13. Apparatus according to claim 12, including a housing for supporting said magnetic member in fixed condition, and a movable assembly connected with said actuating members for carrying said magnet, said assembly supported to be movable in rectilinear relationship relative to said ferromagnetic member, said magnet being juxtaposed with said ferromagnetic member when said actuating member is in said first position, and displaced from said ferromagnetic member when said actuating member is moved to said second position.

14. Apparatus according to claim 5, including a second decoder, connected with the first decoder and with said driver for generating a synchronizing pulse at a predetermined time within each cycle of said driver and said first decoder.

15. Apparatus according to claim 5, wherein said decoder provides a constant current signal on one of said lines of said second set, to enable said line to conduct pulses transformed by said cores.

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