United States Patent [19]

Bonham

[11] **3,871,247**

[45] **Mar. 18, 1975**

[54] **MUSICAL INSTRUMENT EMPLOYING TIME DIVISION MULTIPLEXING TECHNIQUES TO CONTROL A SECOND MUSICAL INSTRUMENT**

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[21] Appl. No.: **423,935**

[52] **U.S. Cl.** **84/1.16,** 84/1.01, 84/1.03, 84/115, 84/171, 84/DIG. 30

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

[58] **Field of Search** .... 84/1.01, 1.03, 1.16, 1.17, 84/1.28, 2, 115, 170–172, 263, DIG. 29, DIG. 30

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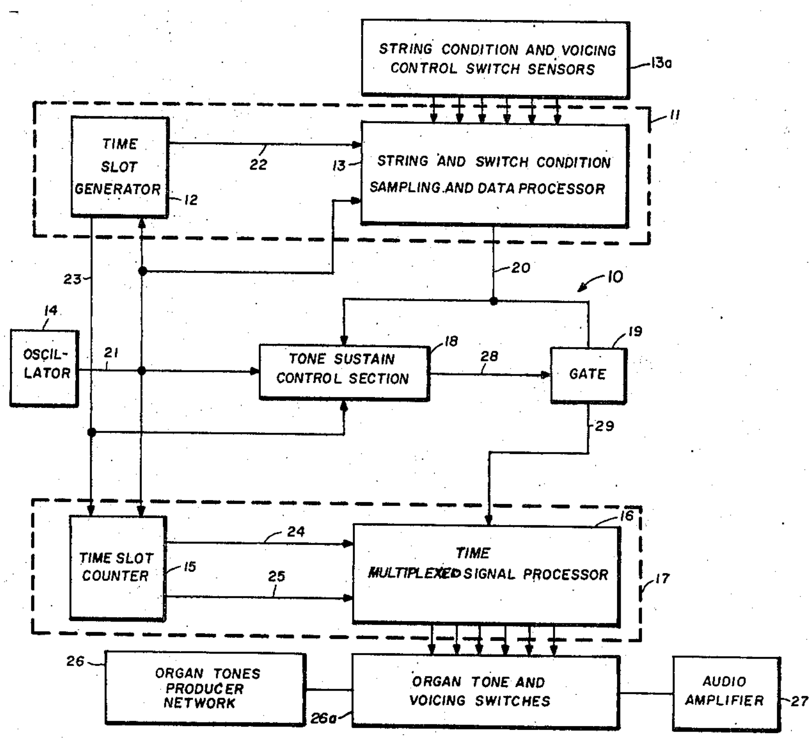
Primary Examiner—Richard B. Wilkinson
Assistant Examiner—Stanley J. Witkowski
Attorney, Agent, or Firm—Roger L. Martin, Esq.

[57] **ABSTRACT**

A system for controlling the operation of tone producing components of one musical instrument from the keyboard of a manually played musical instrument involves the use of an encoder that produces a series of time multiplexed signals during each time frame or operating cycle for the encoder. These signals are generated in response to the detected play of musical tones on the instrument and are transmitted to a decoder for decoding the signals and controlling the operation of the tone producing components of the controlled instrument. Conditions which develop from the play of each musical tone are monitored and sensed by an electronic sampling technique that stores electronic data indicative of the sampled conditions. This stored data is then screened to detect the tones being played at the time of the sample and an appropriate signal indicating the play of the tone is generated in a specific time slot that has been assigned to the tone. A system is disclosed for use with a manually played guitar which involves processing the data relative to the sensed condition so as to detect those conditions indicative of a tone being played on a guitar string. A system for use with a manually played accordian is also shown and which involves the use of radio transmission and receiving means for transmitting the time multiplexed signals, the embodiment disclosed involving the use of pulse width encoding and decoding means so as to enable transmission of control signals, clock pulses and generated time multiplexed signals in a composite form. A manually controlled system for sustaining the play of tones on the controlled instrument is also disclosed.

5 Claims, 9 Drawing Figures



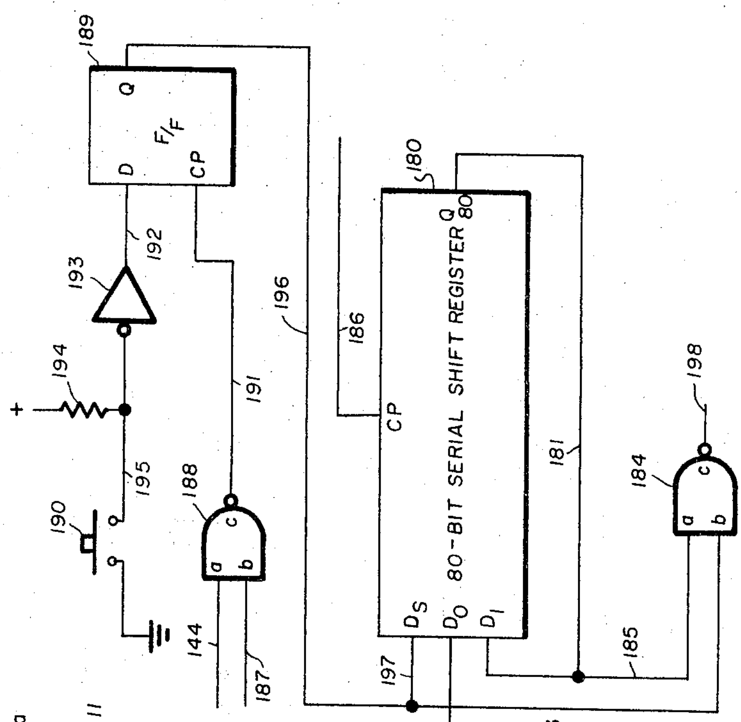

F/F
D
Q
CP
189
192
193
194
+
195
190
188
191
196
186
144
187
180
80-BIT SERIAL SHIFT REGISTER
Q80
CP
DS
DO
DI
181
184
198
185
197
183
182

FIG. 5

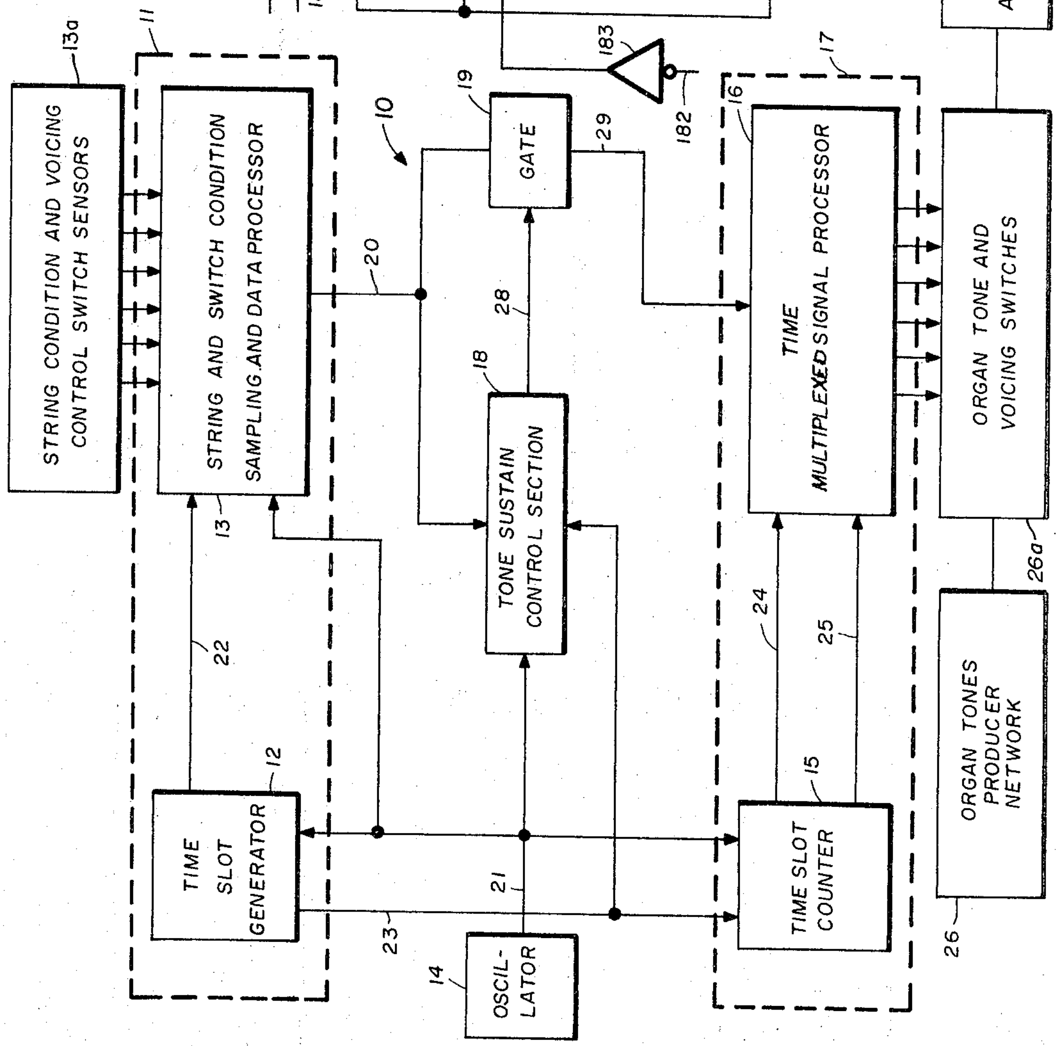

STRING CONDITION AND VOICING CONTROL SWITCH SENSORS
13a
11
STRING AND SWITCH CONDITION SAMPLING AND DATA PROCESSOR
13
10
GATE
19
20
29
28
TONE SUSTAIN CONTROL SECTION
18
17
16
TIME MULTIPLEXED SIGNAL PROCESSOR
ORGAN TONE AND VOICING SWITCHES
26a
AUDIO AMPLIFIER
27
22
TIME SLOT GENERATOR
12
21
23
OSCIL-LATOR
14
24
25
TIME SLOT COUNTER
15
ORGAN TONES PRODUCER NETWORK
26

FIG. 1

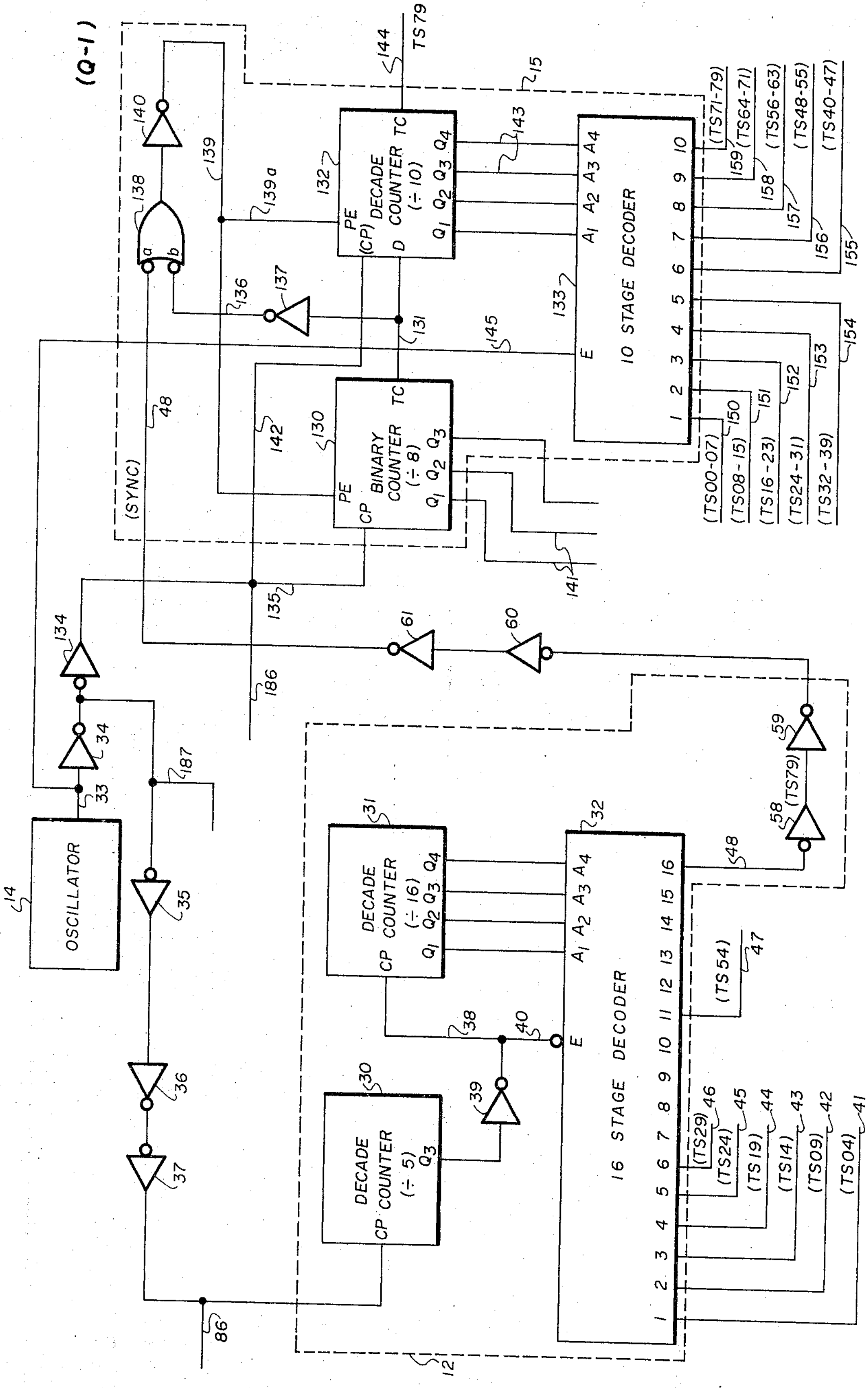

(Q-I)
(SYNC)
OSCILLATOR
DECADE COUNTER (÷10)
BINARY COUNTER (÷8)
10 STAGE DECODER
DECADE COUNTER (÷16)
DECADE COUNTER (÷5)
16 STAGE DECODER
TS79
(TS71-79)
(TS64-71)
(TS56-63)
(TS48-55)
(TS40-47)
(TS00-07)
(TS08-15)
(TS16-23)
(TS24-31)
(TS32-39)
(TS54)
(TS29)
(TS24)
(TS19)
(TS14)
(TS09)
(TS04)
(TS79)

FIG. 2

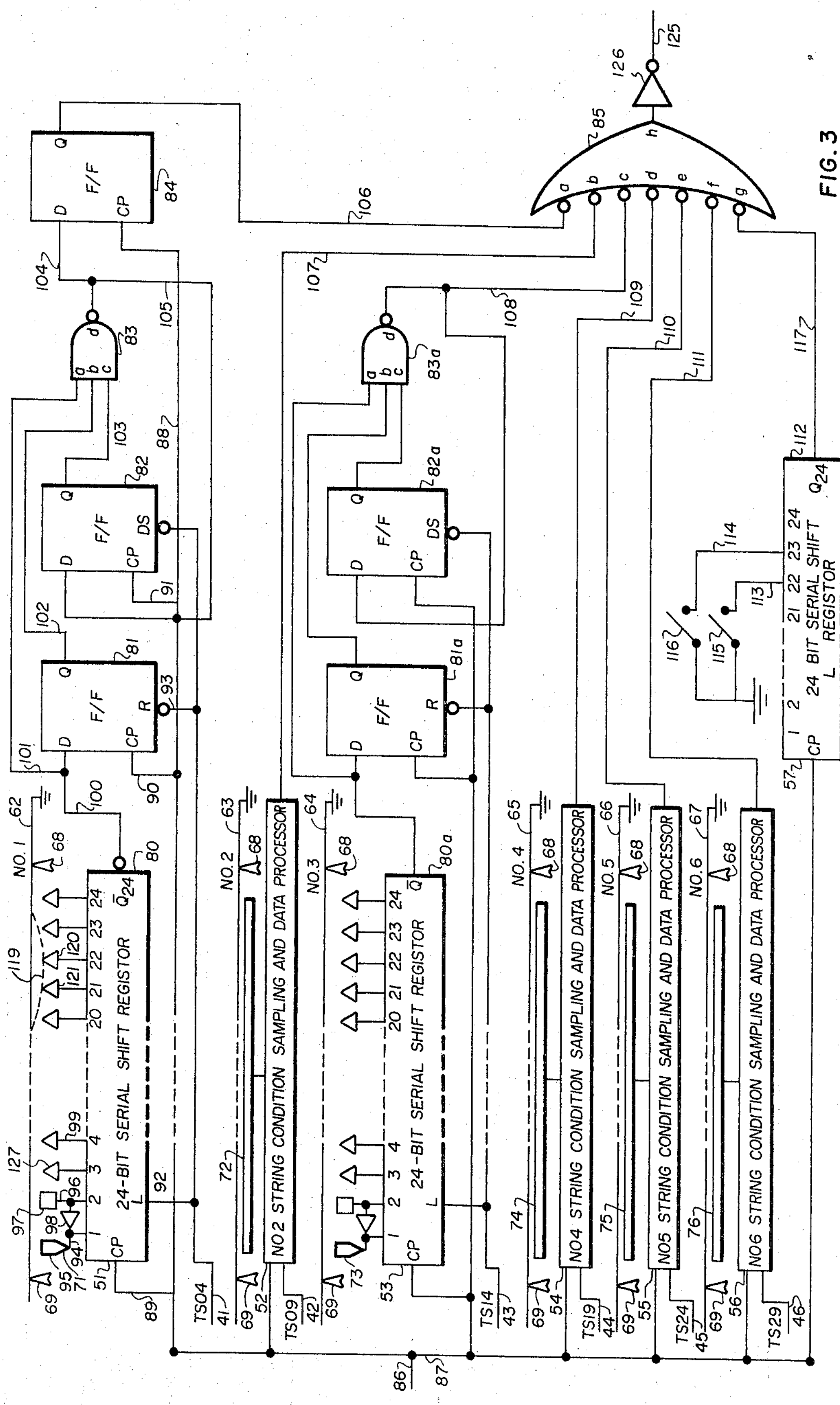

24-BIT SERIAL SHIFT REGISTOR
24-BIT SERIAL SHIFT REGISTOR
24 BIT SERIAL SHIFT REGISTOR
NO 2 STRING CONDITION SAMPLING AND DATA PROCESSOR
NO4 STRING CONDITION SAMPLING AND DATA PROCESSOR
NO5 STRING CONDITION SAMPLING AND DATA PROCESSOR
NO6 STRING CONDITION SAMPLING AND DATA PROCESSOR
F/F
F/F
F/F
F/F
F/F
NO. 1
NO. 2
NO. 3
NO. 4
NO. 5
NO. 6
TS04
TS09
TS14
TS19
TS24
TS29
TS54

FIG. 3

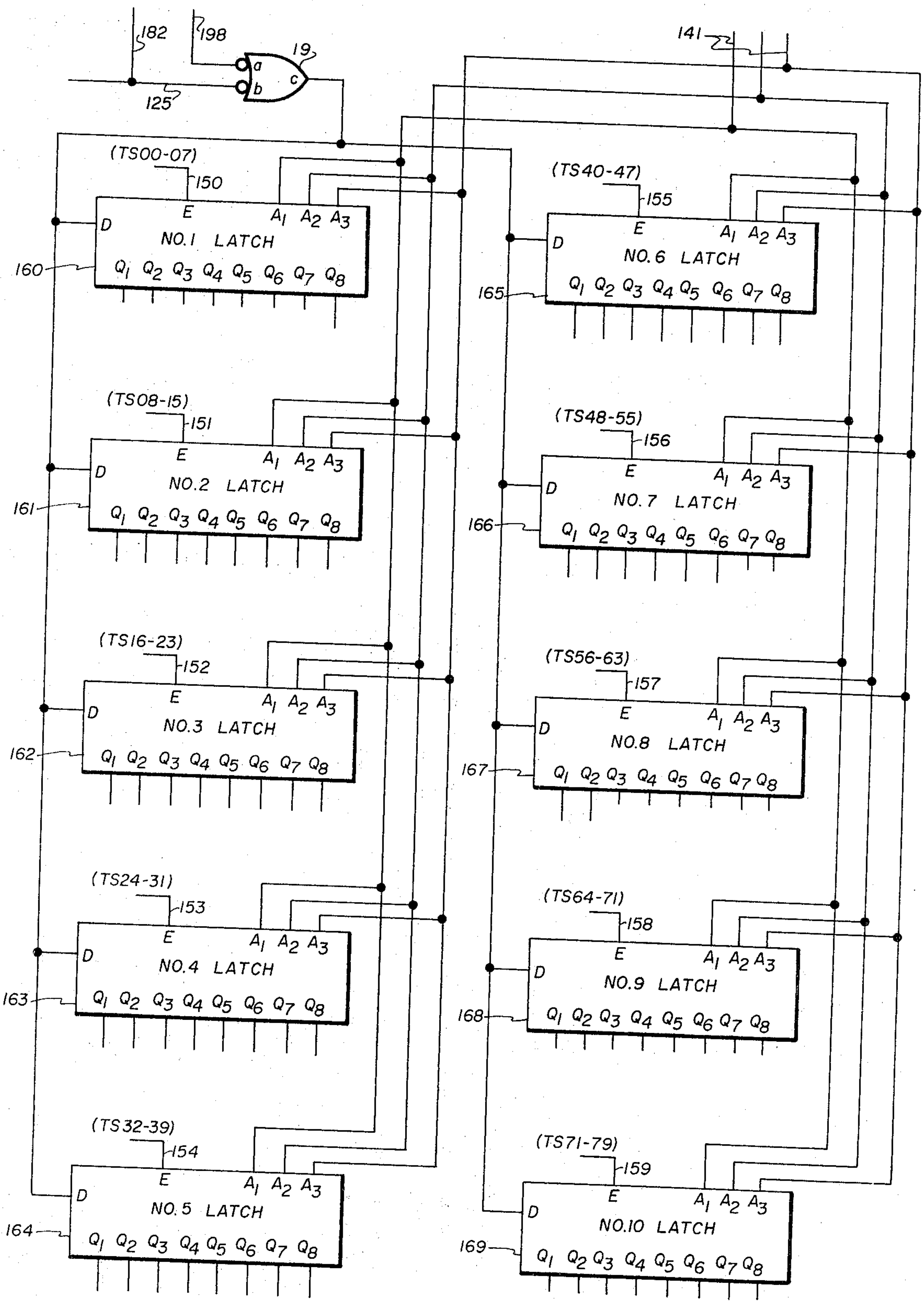

182
198
19
a
b
c
125
141
(TS00-07)
150
E
A1 A2 A3
D
NO.1 LATCH
160
Q1 Q2 Q3 Q4 Q5 Q6 Q7 Q8
(TS08-15)
151
NO.2 LATCH
161
(TS16-23)
152
NO.3 LATCH
162
(TS24-31)
153
NO.4 LATCH
163
(TS32-39)
154
NO.5 LATCH
164
(TS40-47)
155
NO.6 LATCH
165
(TS48-55)
156
NO.7 LATCH
166
(TS56-63)
157
NO.8 LATCH
167
(TS64-71)
158
NO.9 LATCH
168
(TS71-79)
159
NO.10 LATCH
169

FIG. 4

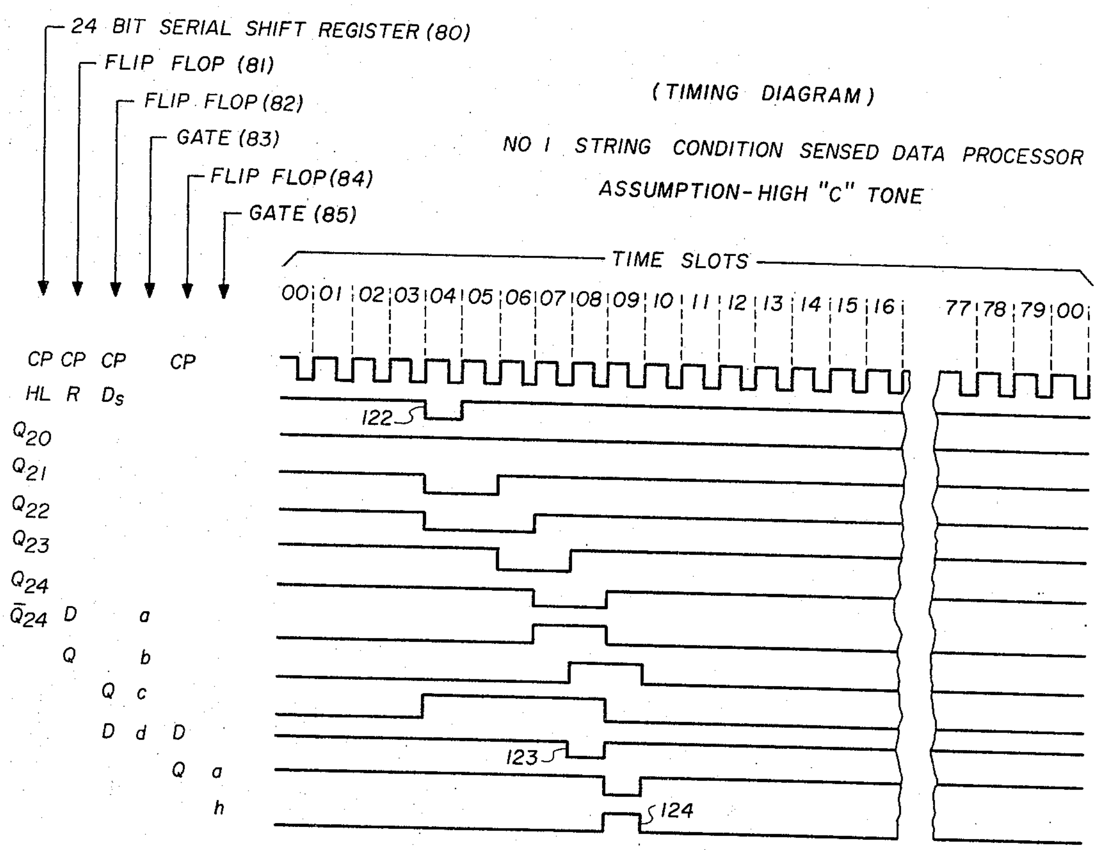

24 BIT SERIAL SHIFT REGISTER (80)
FLIP FLOP (81)
FLIP FLOP (82)
GATE (83)
FLIP FLOP (84)
GATE (85)
(TIMING DIAGRAM)
NO 1 STRING CONDITION SENSED DATA PROCESSOR
ASSUMPTION-HIGH "C" TONE
TIME SLOTS
00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 77 78 79 00
CP CP CP CP
HL R Ds
Q20
Q21
Q22
Q23
Q24
Q̄24 D a
Q b
Q c
D d D
Q a
h
122
123
124

FIG. 6

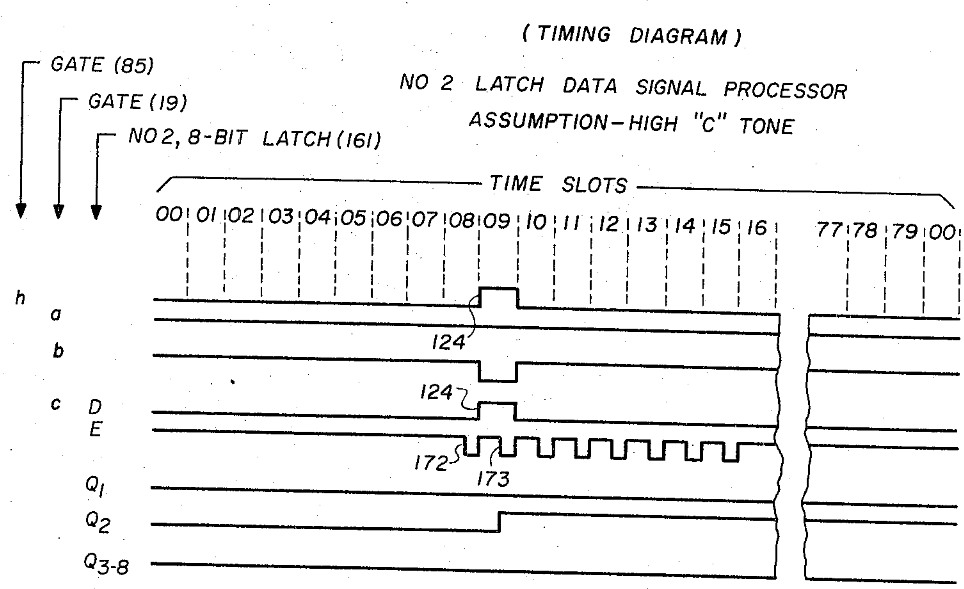

(TIMING DIAGRAM)
GATE (85)
GATE (19)
NO 2, 8-BIT LATCH (161)
NO 2 LATCH DATA SIGNAL PROCESSOR
ASSUMPTION-HIGH "C" TONE
TIME SLOTS
00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 77 78 79 00
h a
b
c D
E
Q1
Q2
Q3-8
124
124
172
173

FIG. 7

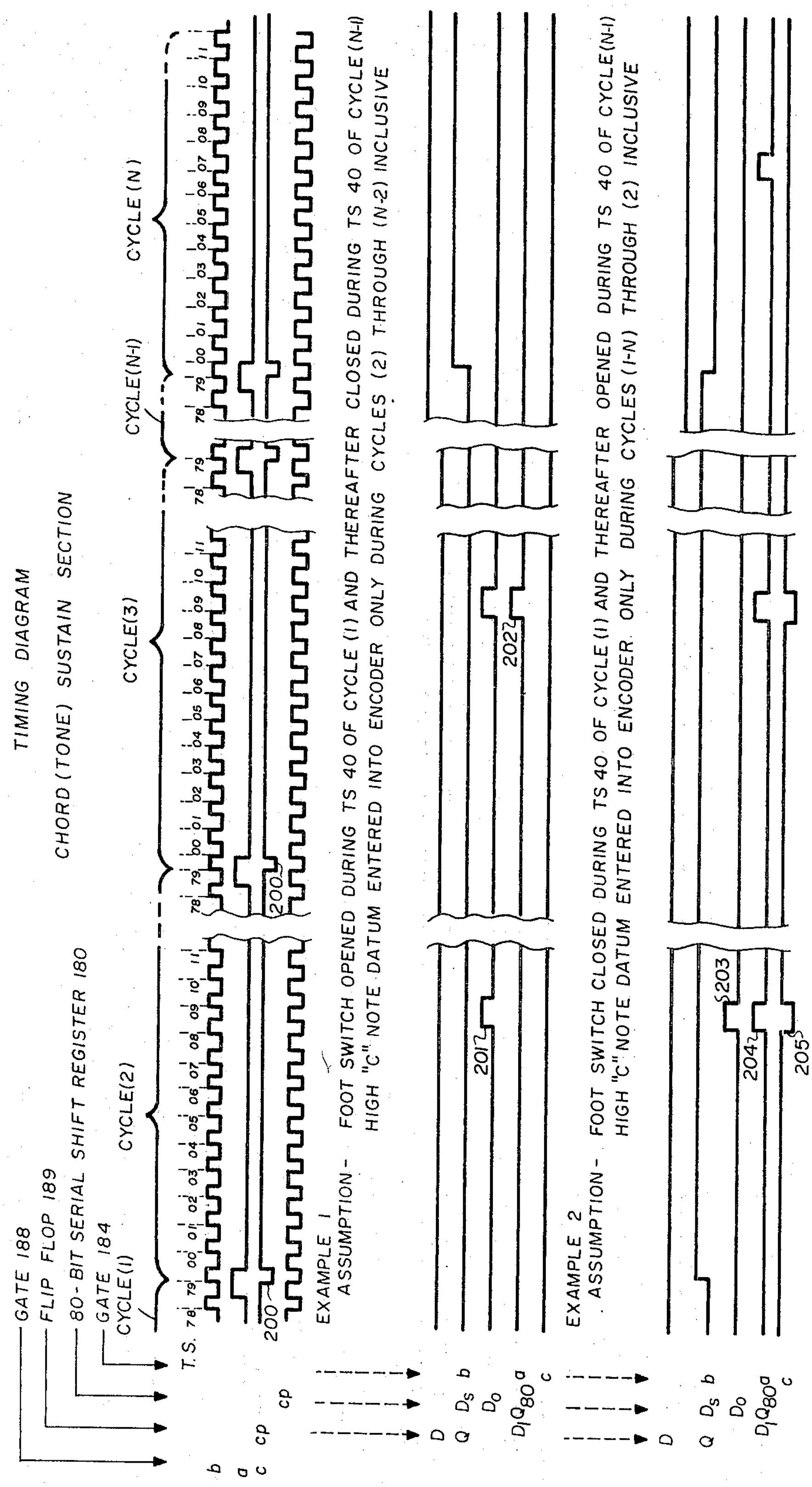
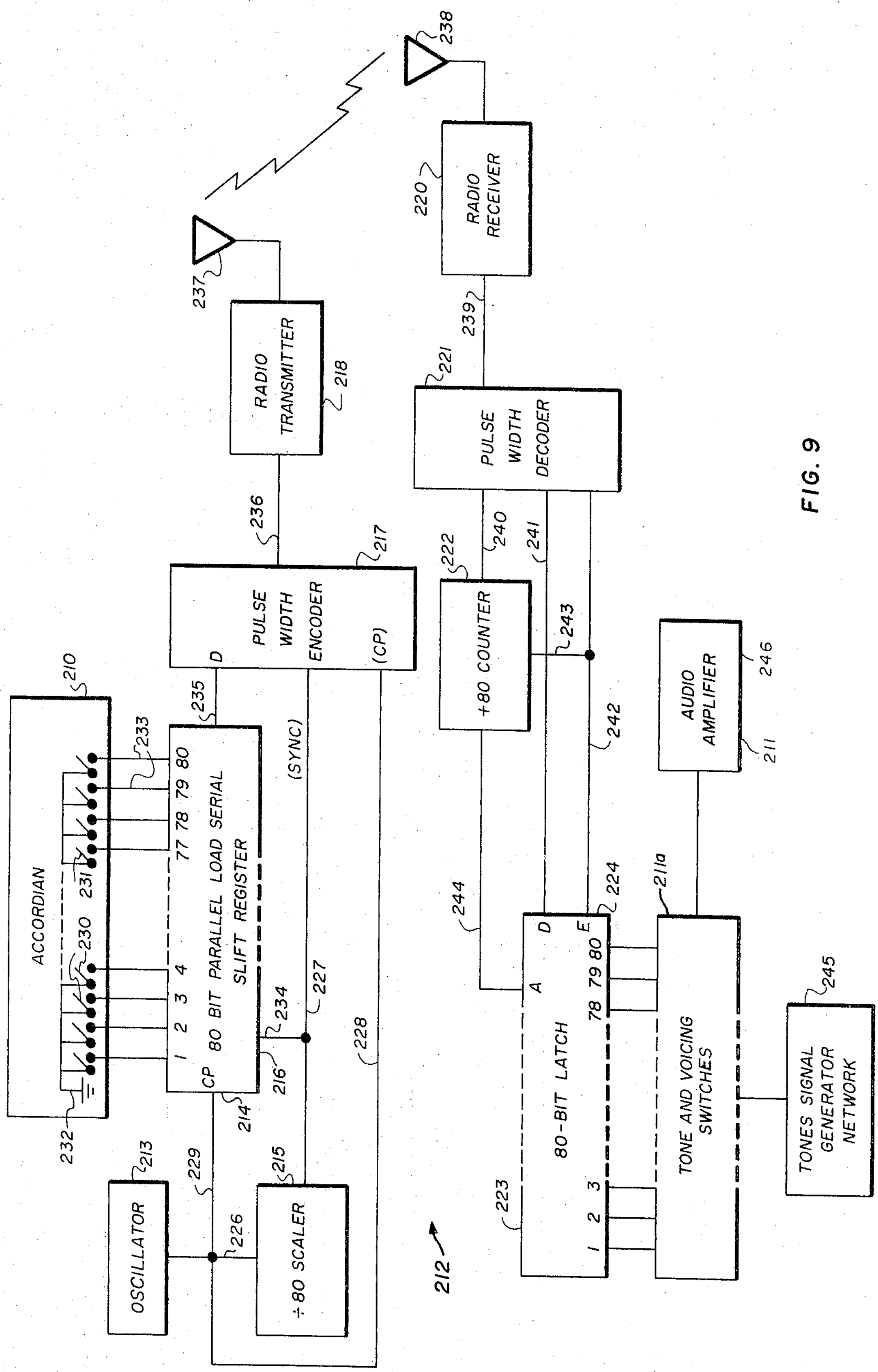

TIMING DIAGRAM
CHORD (TONE) SUSTAIN SECTION
GATE 188
FLIP FLOP 189
80-BIT SERIAL SHIFT REGISTER 180
GATE 184
CYCLE (1)
CYCLE (2)
CYCLE (3)
CYCLE (N-1)
CYCLE (N)
T.S.
200
EXAMPLE 1
ASSUMPTION - FOOT SWITCH OPENED DURING TS 40 OF CYCLE (1) AND THEREAFTER CLOSED DURING TS 40 OF CYCLE (N-1)
HIGH "C" NOTE DATUM ENTERED INTO ENCODER ONLY DURING CYCLES (2) THROUGH (N-2) INCLUSIVE
201
202
EXAMPLE 2
ASSUMPTION - FOOT SWITCH CLOSED DURING TS 40 OF CYCLE (1) AND THEREAFTER OPENED DURING TS 40 OF CYCLE (N-1)
HIGH "C" NOTE DATUM ENTERED INTO ENCODER ONLY DURING CYCLES (1-N) THROUGH (2) INCLUSIVE
203
204
205

FIG. 8


ACCORDIAN
80 BIT PARALLEL LOAD SERIAL SLIFT REGISTER
PULSE WIDTH ENCODER
RADIO TRANSMITTER
RADIO RECEIVER
PULSE WIDTH DECODER
+80 COUNTER
AUDIO AMPLIFIER
80-BIT LATCH
TONE AND VOICING SWITCHES
TONES SIGNAL GENERATOR NETWORK
OSCILLATOR
÷ 80 SCALER
(SYNC)
(CP)
CP
D
A
E
1 2 3 4
77 78 79 80
210
211
211a
212
213
214
215
216
217
218
220
221
222
223
224
226
227
228
229
230
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232
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245
246

FIG. 9

MUSICAL INSTRUMENT EMPLOYING TIME DIVISION MULTIPLEXING TECHNIQUES TO CONTROL A SECOND MUSICAL INSTRUMENT

BACKGROUND OF THE INVENTION

This invention relates to musical instruments, and more particularly to control systems for use in controlling the play of one instrument from the keyboard of another so that both instruments may be played in duet fashion by one person.

Systems for controlling the operation of the tone producing components of one musical instrument in accord with the musical tone selections being played manually on a second musical instrument are known. As the musical instrument that is being played manually is keyed to play a selected tone, a condition of the instrument develops which is characteristic of the playing of the tone and this condition can be sensed by appropriate means which can serve to complete a circuit that enables a tone producing component of the controlled instrument and which serves to produce a tone harmonically related to the tone selection being played on the first instrument. As an example, when the piano key associated with the middle "C" tone that is playable on a piano is depressed, this depressed condition can be sensed through the use of an appropriate switch which completes a circuit when the key is depressed. This circuit on being energized can serve to operate a solenoid which in turn actuates and depresses the middle "C" piano key of a second piano. As such, both pianos can be played by one person.

The concept of controlling the play of one musical instrument from the keyboard of another musical instrument is fairly well advanced in the art so that technology exists for the playing of pianos and organs, both pipe and electronic, as well as many other instruments from the keyboards of accordians, guitars and other musical instruments that are played manually.

The main problem that exists with the prior art control systems which are currently in use lies in the large number of electrical conduits or wires that are needed in order to interconnect the condition sensors of the manually played instrument and the tone enabling or actuating circuit components associated with the harmonically related musical tones that are playable on the controlled instrument. For example, the conventional accordian has 41 treble control keys, 12 bass control keys, and 12 chord control keys. If one proposes to control the operation of an electronic organ from the keyboard of the accordian and where the electronic organ has 12 voicing control circuits, the need exists for about 80 wires or electrical conduits in order to interconnect the two instruments so that harmonically related tones may be played on the two instruments in duet fashion. In conventional control systems the wires which interconnect the two musical instruments are usually cabled, and when the played instrument is portable, as for example in the case of an accordian or guitar, the cable hampers the movements of the player during stage-type performances. Additionally, the large number of wires that are used also creates a high probability of malfunctioning circuits, and consequently there is a need today for control systems which eliminate or at least minimize the number of wires which interconnect the two musical instruments.

STATEMENT OF THE INVENTION

The current invention contemplates a control system in which conditions associated with the playing of the musical tones on the manually played instrument are monitored and sensed. The sensed statuses of the conditions are periodically sampled and by the use of an encoder translated into a series of time multiplexed signals that are generated during each cycle or operating time frame for the encoder. Each tone that is playable on the instrument is assigned to a specific time slot in the operating time frame and when the sensed conditions indicate that the tone is being played a signal is generated during the time slot and transmitted to a decoder that is associated with the controlled musical instrument. The decoder is synchronized with the operation of the encoder and decodes the time multiplexed signals and enables the tones producing circuit of the controlled instrument so that the latter is controlled to play tones that are harmonically related to those being played manually by the player of the first instrument. Through the use of the encoding and decoding components of the control system the intelligence embodied in the time multiplexed signals can be transmitted by a single wire or conduit to the decoder or alternatively through the use of appropriately located radio signal transmission and receiving components can be transmitted between the two instruments as a component of a radio signal. The encoder and decoder of the control system are synchronized in their operation by appropriate control signals that are produced by a signal generator that in turn operates in dependency upon receipt of time spaced pulse signals such as produced by an oscillator or other appropriate means. These synchronizing control signals as well as the pulse signals may be transmitted between the encoding and decoding components of the control system by means of electrically conductive wires on the other hand, they may be transmitted through the use of radio signals, and together with the time multiplexed signals generated by the encoder may be formed into a composite signal by an appropriate pulse width encoder and transmitted together as a composite signal over a wire or by radio signal transmission means. This composite signal can then be decoded into its respective components which are then used for their intended purposes as will be subsequently seen.

Certain aspects of the invention have to do with a system for controlling the play of a musical instrument from the keyboard of a guitar or other stringed instrument. The control of an electronic organ from the keyboard of a guitar has been accomplished in the past by means described in various patents including Borell U.S. Pat. No. 3,465,086 and more recently in the Borell and Bonham application bearing Ser. No. 280,501 and which was filed Aug. 14, 1972 and is now U.S. Pat. No. 3,786,167. Each of the disclosures referred to show control systems in which the keyed string tones that are playable on the guitar strings are sensed on the basis of string contact with the fret involved in keying the string to play the selected keyed string tone. In the former patent, the string contact with the fret used in keying the string is used as a basis for controlling the tone producers of the electronic organ to play the organ tone harmonically related to the keyed string tone. The arrangement shown in the latter patent on the other hand relies on string contact when not only the fret against which the string is keyed but also with an adjacent fret in order to enable the appropriate tone producing component of the electronic organ. Certain aspects of the invention relate to controlling the audible tone production of an electronic organ from the keyboard of a guitar and wherein string contact with adjacent frets is detected in the circuits of the encoder and used as a basis for determing the play of the tone and for controlling the tone producers of the electronic organ as will become more apparent with the detailed description which follows.

Yet other aspects of the invention relate to a special effects circuit that permits the performing player of the guitar to initiate the play of a tone or chord on the organ from the keyboard of the guitar or other played instrument and to thereafter sustain the tone or chord playing condition after the harmonically related tones are no longer being played on the manually played instrument.

The novel features which are believed to be characteristic of this invention are set forth with particularity in the appended claims. The invention, itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in conjunction with the accompanying drawings, and in which:

FIG. **1** schematically illustrates a system embodying the concepts of the invention for controlling the operation of the tones producing means of an electronic organ in accord with the musical tone selections being played on the guitar;

FIG. **2** schematically depicts in greater detail circuit components of the time slot generator and time slot counter illustrated in FIG. **1** along with circuit components associated with the oscillator component shown therein;

FIG. **3** schematically depicts in greater detail the encoder string and switch condition processing section of the encoder shown in FIG. **1** and as seen in reference to the six strings of the guitar and the switches mounted on the guitar for controlling two of the voicing circuits of the organ section;

FIG. **4** schematically depicts in greater detail the components of the serial data signal processor section of the decoder shown in FIG. **1** and as seen in reference to a gate that is utilized in conjunction with the tone sustain control section of the control system shown in FIG. **1**;

FIG. **5** schematically depicts in greater detail the components of the tone sustain control section shown in FIG. **1**;

FIG. **6** is a timing diagram illustrating the operation of the data processor section of the encoder shown in FIG. **1**;

FIG. **7** is a timing diagram illustrating the operation of the data signal processor section of the decoder shown in FIG. **1**;

FIG. **8** is a timing diagram which shows the operation of the tone or chord sustain control section shown in FIG. **1**; and

FIG. **9** schematically illustrates a system for controlling an electronic organ from the keyboard of an accordian and wherein the signals are transmitted between the component of the control system which are associated with the organ and accordian respectively through the use of radio transmission and receiving means.

The embodiment of the invention which is generally illustrated in FIG. **1** is designed for controlling the operation of an electronic organ from the keyboard of a six string guitar that is equipped with frets which are bifurcated into segments that underlie the strings, and are, of course, used in playing the keyed string tones on the instrument. The instrument is also equipped with a means for sensing the play of the open string tone on each guitar string and reference is made to the aforementioned patents for the general arrangement of the bifurcated fret sections.

The system **10** for controlling the operation of the electronic organ in accord with the musical tone selection being played on the guitar includes an encoder **11** which has a time slot generator **12** and a string and switch condition sampling and data processor **13**. The guitar is equipped with a plurality of sensors **13***a*. Part of these sensors **13***a* are arranged to sense predetermined conditions that develop during the play of the musical tones on the guitar. Others serve to sense the closed status of certain voicing control switches. Processor **13** provides a means for sampling the sensed statuses of those predetermined conditions which develop during the play of the musical tones on the guitar to detect those tones actually being played and for generating an appropriate signal during the occurrence of those time slots to which the tones being played have been assigned. The various voicing control switches are also assigned to specific time slots in the operating time frames and processor **13** performs a similar sampling and signal general function with respect to the voicing control switches. The generator **12** and processor **13** are preferably suitably mounted in the body of the guitar.

System **10** also includes an oscillator **14** which in the illustrated embodiment is preferably mounted in the area of the electronic organ along with a time slot counter **15** and a time multiplexed signal processor **16** of the decoder component **17** of the system. As an optional feature, the depicted system has a chord or tone sustain section **18** and a gating circuit **19** which, as will be subsequently seen, may be used to sustain operation of organ tone producers that have been enabled by the detected play of a musical tone selection on the guitar for a controllable period which outlasts the play of the musical tone selection on the guitar.

System **10** is based upon the transmission of a series of time multiplexed signals during each cycle or operating time frame of the encoder and upon the transmission of the cyclic output **20** of the encoder **11** to the time multiplexed signal processor **16** of the decoder **17**. As will be subsequently seen, each tone playble on the guitar, as well as each organ voicing control switch that is manipulatable from the guitar is assigned to a specific time slot during the time frames.

When the play of a musical tone is detected from the sampled conditions, the encoder responds during the time slot assignment of the tone detected to generate an appropriate signal that is indicative of the play. A similar signal is generated in the appropriate time slot when a voicing control switch is detected in use from the sampled conditions. In the embodiment illustrated, the output **20** of the encoder comprises a series of time multiplexed signals that are generated by a gate **85** in response to control signals which are generated in separate sections of processor **13**. Each of these sections is either associated with one of the guitar strings or with a bank of voicing control switches.

In the embodiment illustrated, the oscillator **14** serves to generate time spaced clock pulse output signals **21** which are routed to both the time slot generator **12** and time slot counter **15**, as seen in FIG. **1**. Generator **12** operates in dependency upon receipt of the clock pulse signals **21**, and, as will be subsequently seen, serves to generate a separate control signal for each of the seven sampling and data processing sections of the encoder processor **13**. Six of these sections are devoted to sampling conditions and processing electronic data that relates to the play of the musical tones on the strings, whereas the remaining section of processor **13** is devoted to sampling conditions and processing data that relates to the use of the voicing control switches. The control signals for initiating the sampling procedures in each of the sections are generally designated at **22** in FIG. **1**. Each section of processor **13** also operates in dependency upon receipt of the clock pulse output signal **21** as will be subsequently evident. In addition to control signals **22**, generator **12** also generates a control signal **23** during each time frame and which is routed to the time slot counter **15** and also to the tone sustain control section **18** for synchronizing the operation of the decoder and sustain control section with that of the encoder operation.

The time multiplexed signal processor **16** of the decoder **17** utilized in the illustrated embodiment has a plurality of 8-bit latches and the encoder output **20** is routed, as seen in FIG. **1**, through gate **19** to each of the latches of section **16**. Each bit section of each latch is either assigned to a spare time slot in the time frame or is assigned to a time slot associated with one of the control switches or musical tones playable on the guitar. Those latch sections assigned to the guitar tones and control switches **26*a*** have outputs connected to the appropriate electronic switches of the organ for routing the harmonically related tone signals from the organ tones producer network **26** to the audio amplifier **27** of the organ.

The time multiplexed signals generated during each time frame are also routed to the tone sustain control section **18** of the control system, as seen in FIG. **1**. This section is controllable by the guitar player to store electronic data reflecting the multiplexed signals received during a time frame and thereafter, during succeeding time frames, to generate pulse signals **28** during the time slot assignments of the guitar tones and switches assigned to the time slot occurrences of the multiplexed signals received during the preceding time frame. These signals **28**, during the operation of the sustain control section, are combined in gate **19** with the signals in the encoder output **20** to provide a composite output **29** in the form of a series of time multiplexed signals that are fed to the decoder.

Reference is now made to FIG. **2** and wherein the time slot generator **12** is seen as including a decade counter **30**, a decade counter **31** and a sixteen stage decoder **32** that operates under the control of the counters **30** and **31**. Counter **30** has a binary output and is wired to serve as a divide by five scaler. The clock pulse input terminal (CP) of counter **30** is connected by lead **33** to the output terminal of oscillator **14**. The clock pulse signals from the oscillator are subjected to inversions in inverters **34, 35, 36** and **37** which are series connected in the lead for providing drive power and are fed as indicated in FIG. **2** to counter **30**. The third stage binary output (Q_3) of counter **30** is tapped by lead **38** and delivered via inverter **39** to the clock pulse input terminal (CP) of counter **31**. The output of inverter **39** is in turn tapped by lead **40** and is delivered to the parallel enable input terminal (E) as the enabling signal to the decoder stage which is then being addressed by the four stage output signals of counter **31**.

Decade counter **31** is wired to count under the control of the third stage pulse output of counter **30** to 15 and to thereafter reset during the sixteenth count. The signals from the binary output terminals (Q_1), (Q_2), (Q_3) and (Q_4) of the four flip-flop stages of counter **31** are delivered to the input terminals (A_1), (A_2), (A_3) and (A_4) of the decoder address circuit. The arrangement is such that the stages of decoder **32** are addressed successively for periods corresponding to the time duration of five pulses from oscillator **14** and during the fifth pulse output from the third stage of counter **30** are enabled to provide the signals **22** that control the cyclic operation of the condition sampling and data processing sections of processor **13** and also to provide the sync signal **23** for synchronizing the decoder section with the encoding section of the control system. Thus the outputs of the first six stages of decoder **32** are tapped by leads **41, 42, 43, 44, 45** and **46** and delivered as the control signals for the string condition sampling and data processing sections **51, 52, 53,** 54, 55 and **56** (FIG. 3) while the eleventh stage output of the decoder is tapped by lead **47** and delivered to the switch condition sampling and data processing section **57** of processor **13**. The output of the sixteenth stage of decoder **32** is tapped by lead **48** and delivered via inverters **58, 59, 60** and **61** as the control signal to the "a" input of a gate component **138** of the time slot counter **15**. The arrangement and operation of the time slot generator **12** is such as to provide 80 discrete time slots during the operating cycle of the encoder and decoder for reasons which will be subsequently apparent.

Reference is now made to FIG. **3** and wherein each of the string condition sampling and data processing sections **51** through **56** inclusive is shown as associated with a respective one of the guitar strings **62** through **67** inclusive. Sections **51** through **56** are connected in the data processing circuit of encoder **11** in parallel with each other and in parallel with the switch condition sampling and data processing section **57**. The outputs generated by these sections are delivered as control signals to gate **85** and serve to control the generation of the multiplexed signals by gate **85** during the appropriate time slots.

Each guitar string in the embodiment illustrated has a bank of sensors that provide a means for sensing conditions that are developed by the play of the musical tone selections on the string. These sensing banks are designated at **71** through **76** inclusive and each bank of sensors is monitored and the sensed condition sampled by a shift register component of the data processing section associated with the string as will be more apparent subsequently.

The string condition sensing arrangement used in the illustrated embodiment is founded, insofar as it relates to keyed string tones that are playable on the strings, on a switching action that transpires when the guitar string is pressed against the keyboard at the selected keying position and into string keying contact with the fret associated with the tone playable on the string at the selected position. Thus, the conventional six string guitar has 22 positions at which the strings are keyed and each position is provided with a fret which underlies the strings. In the illustrated embodiment, the fret at each string keying position on the keyboard is segmented to provide a segment which underlies each of the strings and each segment is made of electrically conductive material that is electrically isolated from the other fret segments that are mounted on the keyboard. The arrangement provides a plurality of fret segments which underlie each guitar string and which are spaced apart on the keyboard and located at the respective positions for keying the string against the keyboard.

As explained in the aforementioned copending patent application, one of the difficulties that has confronted efforts to develop keyed string tone switching arrangements founded on electrical contact between a string and the fret segment is the fact that the string may momentarily contact one or more frets in the process of being keyed at a selected position. Furthermore, at the selected position the string simultaneously contacts not only the fret segment which keys the string at the selected keyboard position but it also contacts the fret segment at the adjacent keyboard position that is associated with the next lower pitched keyed string tone that is playable on the guitar string. As will be subsequently seen the string data processing section in accord with the illustrated embodiment is designed to monitor the sensor bank associated with the string and to periodically on a timed basis sample the sensed conditions and detect those conditions which are indicative of a tone selection being played on the string.

Insofar as the keyed string tones are concerned, their play is detected by storing an electronic information bit for each fret in contact with the string at the time the sample is taken. These information bits are then screened during the operating cycle of the section to detect the stored information bits which represent simultaneous string contact with adjacent frets at the time of the sample. When such simultaneous contact is detected, the section operates to generate a control signal during the time slot assignment of the keyed string tone being played on the string. A serial shift register is used to sample and store the information bits pertaining to the sensed string contacts with the frets and the register is controlled to generate an output in response to each fret that is contacted and to do this in a time slot that has a predetermined time offset from the time slot assignment of the musical tone selection which would be playable on the string by keying the string into contact with the fret. To compensate for the lack of string contact with a fret segment when the open tone is being played on the string, a metal or other electrically conductive "touch" plate is mounted under each string at the first position for keying the string so that the electronic data indicative of the play of the keyed string tone associated with the first keyboard position on the guitar is based on string contact with the touch plate as well as with the fret segment against which the string is keyed at the first keyboard position of the guitar.

Insofar as the string condition sensing arrangement used in the illustrated embodiment relates to sensing the open string tones that are playable on the guitar strings, it involves the use of any suitable sensor which can detect the open string tone movement either through direct physical contact with the string or indirectly as by sensing sound waves or magnetic field changes attributable to open string tone movement of the string. In the instant case a conventional magnetic pickup principle is used to detect open tone string movement that interrupts a magnetic field. The output of the pickup is amplified and suitably modified to provide an "0" condition when the open string tone is being detected and otherwise to provide a "1" condition when such movement is absent for reasons which will be evident subsequently.

Reference will be made herein to "0" and "1" levels or conditions, and it should be understood as having reference to relative voltage levels where the "0" level or condition is lower than the "1" level or condition.

As seen in FIG. **3**, each of the guitar strings **62** through **67** inclusive is grounded to an "0" condition and is strung between a conventional bridge and guitar nut that are respectively designated at **68** and **69.**

The string condition sampling and data processing sections **51** and **52** for the number one and number two strings of the guitar are identical and the string condition sampling and data processing sections **53, 54, 55** and **56** for strings **64** through **67** inclusive are also identical to each other and differ in makeup from sections **51** and **52** only in that they lack a flip-flop that is used to delay the output signal from the sections one time slot for reasons of the tone offset between strings two and three. Thus on the chromatic scale strings one and two are offset by five tones. String numbers two and three on the other hand are offset by four tones while the offset between strings three and four, four and five, and five and six is five tones on the chromatic scale. Since the strings data processing sections of processor **13** are controlled by pulse control signals from decoder **32** that are offset a matter of five time slots in each case, the additional flip-flop in sections **51** and **52** as will be subsequently seen serves to compensate for the four tone offset between strings two and three in the embodiment illustrated.

The composition and operation of the string condition sampling and data processing sections **51** and **52** that are associated with strings **62** and **63** will be evident from a consideration of the components of section **51.** Section **51** includes a 24-bit parallel load shift register **80** in which electronic data pertaining to the sensed string conditions are loaded during each time frame, and a pair of flip-flops **81** and **82** which together with a gate **83** serve to screen the electronic data stored during the timing cycle to detect those sensed conditions which are indicative of a tone selection being played on the string. When such is detected gate **83** provides an appropriate output signal. This signal is then delayed for one time slot in flip-flop **84** and fed as a control signal during the occurrence of the time slot assignment of the detected tone to a seven input gate **85** which in turn responds to receipt of the signal to generate a time multiplexed signal component in the output of the encoder.

In the illustrated embodiment the time spaced pulse output signal from oscillator **14** is tapped by lead **86** and fed to a bus **87** that serves sections **51** through **57.** This signal is in turn tapped by lead **88** and fed to the clock pulse input of flip-flop **84** and by leads **89, 90** and **91** is also tapped and fed to the clock pulse inputs of register **80,** and flip-flops **81** and **82.** Section **51** while operating in dependency upon receipt of the clock pulse signal generated by the oscillator is controlled in its cyclic operation by the first stage output signal that is generated in decoder **32.** Thus the pulse output in the fourth time slot of the cycle is delivered by lead **41** as a control signal to the direct set input (DS) for flip-flop **82** and is tapped by leads **92** and **93** and delivered to the load input (L) of register **80** and to the reset input (R) of flip-flop **81.**

Each flip-flop of the **24**-bit register **80** has a direct load input, and the input of the first stage flip-flop of the register is connected by lead **94** to receive the output of the open tone sensor **95** of the sensor bank **71.** The input of the second stage of the register is connected by lead **96** to the "touch" plate **97** at the first string keying position on the keyboard, the leads **94** and **96** are electrically interconnected through a diode **98.** The direct load inputs for stages three through 24 inclusive are electrically connected by leads generally designated at **99** to the respective fret segments that underlie the number one string at the first through twenty-second string keying positions respectively.

In the embodiment illustrated the compliment or $\bar{Q}$ output of the twenty-fourth stage of register **80** is delivered by lead **100** to the data input terminal of flip-flop **81.** This signal is also tapped by lead **101** and delivered to the "*a*" input terminal of the three input "and" gate **83.** The "Q" output of flip-flop **81** is delivered by lead **102** to the "*b*" input of gate **83** and the "Q" output of flip-flop **82** is delivered by lead **103** to the "*c*" input terminal of gate **83.** The output "*d*" of gate **83** is delivered by lead **104** to the data input terminal of flip-flop **84** and by lead **105** this output signal is tapped and delivered to the data input of flip-flop **82.** The "Q111" output of flip-flop **84** is delivered by lead **106** to the "*a*" input terminal of the seven position "or" gate **85.**

The string condition sampling and data processor sections **52** for the number two string **63** is identical in composition and operation to that of processor section **51** except that the section operates under the control of the pulse signal from the second stage of decoder **32** and which is fed to the section **52** by lead **42.** The sensor banks **72** is also identical to that used with the other strings and the output from section **52** is fed by lead **107** to the "*b*" input terminal of gate **85.**

The composition of the data processor sections **53,** 54, 55 and **56** that are associated with strings **64, 65,** 66 and **67** is illustrated by reference to section **53** and wherein it will be seen that each of these sections has a 24-bit register **80***a*, and a pair of flip-flops **81***a* and **82***a* which together with gate **83***a* are wired to perform the data screening and detecting function for the electronic data stored in the 24-bit serial shift register **80***a* in a manner similar to that performed by the corresponding components of section **51.** Sections **53, 54, 55** and **56** operate under the control of the time spaced signals delivered to the sections by leads **43, 44, 45** and **46** respectively and the outputs of the sections are delivered as control signals by leads **108, 109, 110** and **111** to the "*c*", "*d*", "*e*" and "*f*" inputs of gate **85** as shown in FIG. **3.**

The switch condition processing section **57** also comprises a 24-bit serial shift register **112** which like the shift registers of the string data processing sections operates in dependency upon receipt of a time spaced pulse output signal from the oscillator. The operation of this section is initiated during each timing cycle by the pulse output of the eleventh stage of decoder **32** and which by lead **47** is delivered to the load input of register **112.** As will be subsequently seen, a "1" condition is maintained at the direct load input terminals of the 24 stages of register **112** as with the other shift registers associated with the other sections. In this case the direct load inputs **22** and **23** are connected to ground by leads **113** and **114** through switches **115** and **116.** These switches **115** and **116** are associated with separate voicing control circuits in the electronic organ and during the cyclic operation of the section will cause the delivery of a control signal to the "*g*" input terminal of gate **85** as by lead **117** during the appropriate time slot assignments for the switches detected in use.

As shown in Table I each tone playable on the guitar strings is assigned to a specific time slot with the highest note playable on the guitar being the "D" tone played by keying the number one string at the twenty-second position being assigned to the seventh time slot whereas the lowest tone, being the open string tone playable on the number six string, is assigned to the fifty-third time slot. This reflects an orderly assignment of the musical tones of progressively changing pitch to successively occurring time slots during a time frame. Each voicing control switch is also assigned to a specific time slot as seen in Table I. Table I also shows the input assignments for the 24-bit shift registers associated with the string and switch data processing sections.

The operation of the number one string condition sampling and data processing section **51** and the operation of the sensor bank **71** associated therewith is illustrated by reference to the timing diagram shown in FIG. **6** and wherein it is assumed that the number one guitar string **62** is depressed at the twentieth keyboard position **119** to play the high "C" note on the string. The direct load inputs of the 24 stages of register **80** are normally at a "1" condition, and when string **62** is thus depressed, it contacts and is keyed against fret segment **120** to establish the mode of vibration of the string. The string also contacts the fret segment **121** that underlies the string at the next lower number string keying position and which is associated with the next lower pitch tone playable on the string, namely the high "B" tone. String **62** like the other strings of the guitar is grounded, and the contact with the fret segments **120** and **121** at the twentieth keyboard position imposes an "O" condition on the input terminals to the twenty-first and twenty-second stages of register **80.** With this assumed condition existing at the commencement of the timing cycle, the timing cycle insofar as it relates to section **51** is initiated by receipt of the pulse signal **122** during the fourth time slot from the first stage of decoder **32.** This control signal **122** overrides the shifting action of the clock pulse input to register **80** and loads the twenty-first and twenty-second stages of the register with an "O" condition while the other stages of the register remain at the "1" condition. The "O" conditions loaded in the twenty-first and twenty-second stages constitute electronic information bits which reflect string contacts with frets **120** and **121** at the time of the sample and remain during the fifth time slot. The control signal **122** by application to the reset input terminal (R) of flip-flop **81** establishes an "0" condition at the "*b*" input terminal of gate **83** and also serves to set flip-flop **82** to a "1" condition which is imposed upon the "*c*" input of gate **83** and thereby conditions the gate. The "O" conditions in register stages **21** and

22 shift to the following stages during each clock pulse during the sixth and seventh time slots, and as the "O" condition in stage 23 shifts to stage 24 at the commencement of the seventh time slot the "1" condition of the Q̄ output of stage 24 is imposed upon the "*a*" input terminal of gate 83 and also on the data input of flip-flop 81. The "1" condition at the "*a*" input of gate 83 remains during the eighth time slot by virtue of the shift of the "O" condition from the twenty-third stage to the twenty-fourth stage of the register during the eighth time slot. The "1" condition at the data input (D) of flip-flop 81 during the seventh time slot is loaded into the flip-flop at the commencement of the eighth time slot, and this opens gate 83 and provides an "O" pulse output 123 from the output terminal (d) of gate 83 during the eighth time slot. This pulse output during the eighth time slot is delivered to the data input (D) of flip-flop 82 and this drives the flip-flop 82 to the "O" condition at the commencement of the ninth time slot and thereby closes the gate during the remainder of the timing cycle. The pulse output 123 during the eighth time slot shifts to flip-flop 84 during the ninth time slot that has been assigned to the "C" note and the output "Q" of this flip-flop 84 is imposed upon the "a" input of gate 85 to generate a signal in the output of gate 85 and in the time slot assigned to the high "C" note or tone playable on the string. The output of gate 85 is transmitted by electrically conductive lead 125 through inverter 126 to the decoder section of the control system as will be subsequently seen.

The sensor bank 71 provides a means for monitoring the play of musical tones on the number one string and section 51 serves to cyclically detect the play of a tone selection and to thereafter generate a signal appropriately indicative of the selection and in the time slot assignment of the played section.

A consideration of the timing diagram shown in FIG. 6 will show that each information bit that is stored at the time of the sample in response to a sensed string contact with a fret appears as the Q̄ output of the twenty-forth stage during a time slot which is offset by three time slots from the time slot assigned to the musical tone obtained by keying the string into string keying contact with the detected fret.

Flip-flops 81 and 82 in conjunction with gate 83 serve to process electronic data stored by register 80 at the commencement of the cycle to detect the sensed conditions which indicate the play of a selection on the string. Thus at the time of the response to the control signal 122 gate 83 is primed to respond to simultaneous "1" condition outputs from the twenty-fourth stage of register 80 and from flip-flop 81. Such response, however, only occurs when a "1" condition is generated at the Q̄ output of the twenty-fourth stage during each of successively occurring time slots.

When string 62 is keyed at the first keying keyboard position it simultaneously contacts the "touch" plate 97 and the fret segment 127 that serves to key the string and determine the vibrational mode for the "F" tone assigned to the twenty-eighth time slot. When this happens the direct load input terminals of the second and third stages of the register are grounded to load "O" conditions into the second and third stages of register 80. Diode 98 serves to isolate the first stage input from the "O" condition established through string contact with touch plate 97 as will be apparent to those skilled in the art. After the "O" conditions have been loaded in the second and third stages of register 80 during the fourth time slot, the shifting action and data processing is comparable to that previously described except that the output control signal from flip-flop 84 occurs during the twenty-eighth time slot assigned to the "F" tone or note obtainable by keying the string at the first keyboard position. When the open string tone is played on string 62, sensor 95 establishes a ground or "O" condition at the input terminal of the first stage of the register, and by virtue of the diode 98, this condition is also established at the direct load input of the second stage flip-flop of the register. Thereafter the operation of the circuit components of the string sampling and data processing section 51 is similar to that previously spelled out except that the pulse output indicative of the playing of the open string tone appears in the "Q" output of flip-flop 84 during the twenty-ninth time slot assigned to the tone.

Section 52 as previously indicated operates in the same manner as section 51 except that the control signal delivered by lead 42 appears in the ninth time slot to commence the cyclic operation of the section. Sections 53 through 56 also operate in the manner of section 51 except for the control signals and the fact that the gate outputs are delivered directly to the "or" gate 85 without the need for the time delay associated with the use of flip-flop 84 in section 51. The operation of the switch condition sampling and data process section 57 is believed apparent from the described operation of register 80. Briefly however, when voicing control switch 116 is closed an "O" condition is imposed upon the input to the twenty-third stage of register 112. The load input of register 112 is connected to the eleventh stage output of decoder 32 by lead 47 so that the conditions of the switches are sampled in response to receipt of the pulse output of the decoder stage during the fifty-fourth time slot. As such, the "O" condition in the twenty-third stage of register 112 shifts with each succeeding clock pulse input and appears as an output signal in lead 117 during the time slot assigned to the switch. Gate 85 as previously indicated generates a series of time multiplexed signals and wherein each signal is generated in response to a control signal received from one of the sampling and data processing sections 51 through 57.

The time slot counter 15 of decoder 17 includes a four stage binary counter 130 that is wired to function as a divide by eight scaler. It has a total count output (TC) that is delivered by lead 131 to the data input terminal (D) of a decade counter component 132 of the counter 15. Counter 15 also includes a 10 stage addressable decoder 133 that operates under the control of counter 132.

The time space clock pulses from oscillator 14 are tapped at the output of inverter 34 and delivered via inverter 134 in lead 135 to the clock pulse input terminal (CP) of binary counter 130. The total count output signal of binary counter 130 is tapped by lead 136 and delivered through inverter 137 to the "*b*" input terminal of an "or" gate 138. The sync signal during the seventy-ninth time slot is delivered by lead 48 to the "*a*" input of gate 138 as seen in FIG. 2. The output of gate 138 is passed via lead 139 through inverter 140 to the parallel enable input terminal (PE) of the four stage binary counter 130 and the signal is also tapped by lead 139*a* and delivered to the parallel enable input terminal (PE) of decade counter 132, so that the operation of counter **15** is referenced to the sync pulse delivered from the time slot generator section of the encoder **11.** The output terminals (Q_1), (Q_2) and (Q_3) of the first three stages of counter **130** are tapped by leads generally designated at **141** and are delivered to each of the address circuits of the 8-bit latches that are used in the time multiplexed signal processor **16.** As will be subsequently seen, these binary outputs are used to successively address the stages of each latch.

The clock pulse output signal of oscillator **14** is tapped by lead **142** and delivered to the clock pulse input terminal (CP) of decade counter **132** and the output terminals (Q_1), (Q_2), (Q_3) and (Q_4) of the four stages of counter **132** are tapped by lead **143** and delivered to the address circuit input terminals (A_1), (A_2), (A_3) and (A_4) of decoder **133.** Decade counter **132** also has a total count output terminal (TC) and this is connected by lead **144** for reasons which will be subsequently explained.

Decoder **133** has ten stages that are successively addressed by the binary outputs of counter **132** and the clock pulse from oscillator **14** is delivered by lead **145** to the parallel enable input circuit of the ten stage decoder **133.** The operation of the time slot counter is such that each stage of decoder **133** is addressed for a period of eight clock pulses by the outputs from decade counter **132** and is enabled when being addressed by each of the clock pulses that are delivered to the decoder from oscillator **14.** As such, each decoder stage has an output that comprises a train of eight pulses during the period in which it is enabled and these pulse output signals from the 10 stages are delivered by leads **150** through **159** inclusive to the respective latches of processor **16.**

The pulse signals in the encoder output **20** from the "or" gate component **85** of the encoder section are inverted in inverter **126** and by lead **125** passed to the "*b*" input terminal of the "or" gate **19** that serves the chord sustain section **18** of the control system **10.**

The time multiplexed signal processor **16** comprises, in the embodiment illustrated, ten, 8-bit addressable latches that are designated at **160** through **169** inclusive. Each latch has a data input terminal (D) and the time multiplexed signals in the output **20** from the "or" gate **19** is delivered to the data input terminal (D) of each latch as seen in FIG. **4.** The address circuits of each latch are connected to the output leads **141** of the binary counter **130,** as also seen in FIG. **4.** As the binary counter **130** counts with each clock pulse fed to it from the oscillator **14,** the stages of each latch are sequentially addressed with the first stage of each latch being initially addressed simultaneously, the second stage of each latch being addressed in the next time slot and so on so that each latch is addressed once with every eight clock pulses. Each latch however, is connected to a different stage of decoder **133,** and consequently each latch stage only receives an enabling pulse once during each timing cycle. The outputs of each latch are normally at an "O" level and when enabled will assume the output condition of the data input so that if the signal **29** has a "1" level during the time slot when the stage is enabled, then the output of the stage will assume the "1" level until such time as the "**O**" condition appears in the signal **29** during the assigned time slot of a subsequent time frame. The time slot and tone or switch assignments for the outputs of the latches are set forth in Table II and FIG. **7** exemplifies the operation of the processor **16** when the high "C" tone is being played on one of the guitar strings. Under such circumstances the output of gate **85** bears a pulse signal **124** during the ninth time slot and which is indicative of the play of the "C" note on one of the strings of the guitar at the commencement of the time frame. Signal **124** is inverted by inverter **126** and again by "or" gate **19** and appears as a "**1**" level pulse signal **124** in the data input (D) of each of the latches. During time slots 8 through 15 the number two latch **161** is fed a train of pulses **172** and the address circuits address the second stage of each of the latches during the ninth time slot so that the (Q_2) output of the number two latch **161** is enabled by the receipt of a pulse **173** during the time slot when a "1" level pulse signal appears in the datum input. This enables the second stage (Q_2) output by providing a "1" level condition which controls and enables the tone producers of the electronic organ to produce an audible "C" tone that is harmonically related to the corresponding tone being played on the guitar.

The chord or tone sustain section **18** of control system **10** is designed to enable the guitar player to initiate the playing of a chord or tone on the guitar and to thereafter sustain the playing of the same chord or tone on the organ after the guitar player has ceased playing the tone selection or selections on the guitar.

Section **18** as seen in FIG. **5** includes an 80-bit serial shift register which has a data select input terminal (DS) and which is wired as a loop register with the output terminal (Q_{80}) of the eightieth stage being connected by lead **181** to one of the data input terminals (D_1) of the first stage of the register. The output **20** of the encoder is fed to the "*b*" input of gate **19** and is tapped by lead **182** and delivered via inverter **183** to the other data input terminal (D_0) of the first stage of the register. The sustain section also has a two input "and" gate **184** and the output signal of register **180** is tapped by lead **185** and delivered to the "*a*" input of gate **184.** The clock pulse input of register **180** is provided by a lead **186** that taps the output signal from inverter **134** and delivers the signal to the clock pulse input terminal (CP) of shift register **180.**

The sustain section has a circuit that controls the signal fed to the register in the operation of gate **184.** This circuit includes an "and" gate **188,** a flip-flop **189** and a switch **190** which is normally opened and which may be manually controlled by the guitar player to control the operation of the sustain section. The switch is preferably a foot switch.

The "*a*" input of "and" gate **188** is connected by lead **144** to the total count output of decade counter **132** of section **15.** The "*b*" input of gate **188** is connected by a lead **187** that taps the pulse output signal from inverter **34.** This arrangement provides a "1" level pulse during the seventy-ninth time slot of each timing cycle and which opens the gate **188** and by lead **191** applies a pulse at the clock pulse input (CP) of flip-flop **189.** The data input terminal (D) of flip-flop **189** is connected by lead **192** through inverter **193** and resistor **194** to a positive potential, and lead **192** is tapped by a lead **195** that through switch **190** is connected to ground. The "Q" output of flip-flop **189** as seen in the drawings, is fed by lead **196** to the "*b*" input terminal of gate **184** and this lead is tapped in the embodiment via lead **197** that delivers the "Q" output of flip-flop **189** to the data select terminal (DS) of register **180.**

When switch **190** is opened, an "O" condition is applied to the data input of flip-flop **189** and with each clock pulse that occurs during the seventy-ninth time slot, the "O" condition is stored in the flip-flop **189** for the period of the next timing cycle. As a result, an "O" condition is applied to gate **184** and which maintains the gate in a closed condition for the cycle. Similarly this applies an "O" condition to the data select terminal (DS) of register **180** and this selects the signal delivered to the (DO) input terminal as the data fed to the register **180.** Hence the time multiplexed signals being delivered to gate **19** are applied after inversion in inverter **183** to the first stage input of the register and the electronic data stored in the register during the previous timing cycle is blocked from passage to the processor by the closed condition of gate **184.**

When the foot switch **190** is closed however, the input to inverter **193** is grounded and a "1" level condition is established at the data input terminal (D) of flip-flop **189.** This "1" level condition is then stored in the flip-flop **189** by the next clock pulse which in time corresponds to the sync pulse, and a "1" level condition is established at the data select terminal (DS) of register **180** as well as at the "*b*" input terminal of gate **184.** This primes gate **184** and causes selection of the (D_1) input terminal of the register so that the electronic information bits stored in the register during the previous time frame are caused to loop back through the register and by virtue of the lead tap **185** are delivered to gate **184.** Gate **184** accordingly is enabled during each time slot where the output of the register **180** has an "1" level pulse and this of course is passed via lead **198** to the "*a*" input of "or" gate **19** and where it enables the gate to generate a signal during the time slot. The operation of the sustain section is exemplified by reference to FIG. **8** and wherein it will be seen that flip-flop **189** receives but one pulse **200** during each time frame.

In "Example One" it is assumed that the foot switch is initially opened during the fortieth time slot of cycle (**1**) and thereafter closed during the fortieth time slot of cycle (N-**1**) while the high "C" tone signal is entered into the encoder during each of the cycles (**2**) through (N-**2**). Under such circumstances the "1" level pulse **201** in the output **20** of the encoder during cycle (**2**) appears as a "1" level output pulse signal **202** that is blocked from passage from the sustain section by the "O" level condition at the "*b*" input of gate **184.**

In "Example Two" it is assumed that the foot switch is closed during the fortieth time slot of cycle (**1**) and thereafter opened during the fortieth time slot of cycle (N-**1**) while the high "C" note signal is entered into the encoder during cycles (**1**-N) through (**2**) inclusive. Under such circumstances the foot switch imposes a "1" level condition at the "*d*" input of flip-flop **189** while the switch is closed and upon receipt of the clock pulse output signal **200** from gate **188** the "Q" output of flip-flop **189** imposes a "1" level priming condition on the "*b*" input of gate **184** and, through the data select terminal selects the data at the (D_1) input as the data input to the first stage of register **180.** As such, the pulse signal **203** during cycle (**2**) is blocked from entry into the register **180** by the condition at the data select input terminal but the signal that was entered into the register during the ninth time slot of cycle (**1**) appears as a pulse **204** in the corresponding time slot of cycle (**2**). By virtue of the primed condition of gate **184,** this pulse **204** appears as an inverted pulse **205** in the output of gate **184** and enables gate **19** to thereafter, during each cycle while the gate is opened, to provide a pulse signal indicative of the playing of the high "C" tone on the guitar during the time slot associated with this note. This, of course, results in a sustained playing of the high "C" note on the organ until such time as the foot switch is again opened and the clock pulse during the next seventy-ninth time slot of a timing cycle causes the gate to close.

In the embodiment illustrated in FIGS. **1** through **8** the decoder and encoder sections of the control system are shown as connected by three electrically conductive leads or wires, one for transmitting the sync signal, a second wire for transmitting the time multiplexed signals, and a third wire for transmitting the oscillator output signal. This type arrangement minimizes the probability of electrical failures due to the use of a large number of wires and avoids the need for a bulky cable-type interconnection between the two musical instruments. If one wants to avoid the use of all wire connections between instruments playable in duet fashion, the signals can be transmitted between the instruments by radio signals and FIG. **9** illustrates a system which may be employed for playing an electronic organ in duet fashion with an accordian.

In this instance the accordian which is generally depicted at **210** is assumed to have 41 treble key switches, 12 bass key switches, 12 chord key switches and to be further equipped with 12 voicing control switches. The system for controlling the electronic organ **211** is designated at **212** and is founded on the production of a series of time multiplexed output signals during successive time frames that have 80 time slots. Sixty-five of these time slots are assigned to the treble, bass and chord key switches associated with the tones and chords playable on the accordian and twelve time slots are assigned to the voicing control switches associated with the voicing circuits of the electronic organ. One time slot is assigned for a sync signal and the other two time slots are spares.

The control system includes an oscillator **213** and encoder **214** that has a divide by eighty scaler **215** and an 80-bit parallel load serial shift register **216.** It also includes a pulse width enccoder **217** and a radio transmitter **218.** The oscillator **213,** encoder **214,** pulse width encoder **217** and transmitter **218** are associated with and mounted on the accordian **210.** The control system also includes a radio receiver **220,** a pulse width decoder **221,** a divide by 80 counter **222** and an 80-bit latch **223.** The counter **222** and latch **223** serve as a decoder **224** for the series of time multiplexed output signals produced in the encoder section of the control system.

In the operation of the system oscillator **213** serves to generate a time spaced clock pulse output signal **226** that is delivered to the scaler **215** to provide a sync signal **227** that divides the clock pulse signal into a series of 80 time slots. The clock pulse signal is tapped as by lead **228** and delivered to the pulse width encoder **217** and is also tapped as by lead **229** and fed to the clock pulse input (CP) of register **216** in the illustrated embodiment.

Accordian **210** is equipped with a plurality of switches **230** that are associated with the treble, bass and chord keying switches of the accordian and is also equipped with a plurality of switches **231** that are used to control the voicing circuits of the organ. Each of the switches **230** is mechanically coupled to one of the treble, bass or chord keying switches and is closed by operation of the keying switch while switches **231** are manually manipulatable to a closed position to enable the voicing circuits associated with them. As seen in FIG. **9**, the pole pieces of switches **230** and **231** are connected to ground **232** while the switch contacts are connected to the input terminals of the respective stages of register **216** as by leads **233**.

In the normal operation of the accordian **210** one or more of the switches **230** is closed as a tone selection is being played on the accordian and the status of the switches is sampled at the commencement of each cycle in response to a control signal derived by a wire tape **234** in the sync output circuit of scaler **215**. When the sync signal is received by register **216** the stages of the register are loaded and an "**O**" condition is established in those flip-flop stages which are connected to a closed switch component. Thereafter under the influence of the clock pulse signal, electronic data or information bit are shifted from one stage to the next with each clock pulse signal and an output **235** is produced each time frame with time multiplexed signals being generated in those time slots assigned to the respective switches that had a closed condition at the time of the register response. In the embodiment illustrated, the time multiplexed signals in the output **235**, the sync pulse **227** and the clock pulse signals **228** are encoded in a pulse width encoder **217** and a composite signal **236** is delivered to radio transmitter **218** which via antenna **237** transmits the encoded signals as modulated on a radio wave to the antenna **238** associated with the organ. The radio signal is then delivered to the radio receiver **220** and the composite pulse width signal after demodulation from the carrier and is transmitted by lead **239** to a pulse width decoder **221** which separates the composite signal into its component parts. The sync signal is delivered by lead **240** to a divide by 80 counter while the time multiplexed signals are delivered by lead **241** to the data input of the 80-bit latch. The clock pulse signal component is delivered by lead **242** to the parallel enable input (E) of the 80-bit latch **223** and is tapped by lead **243** and also delivered to counter **222**. Counter **222** generates a binary output **244** that is fed to the address circuit inputs (A) of the 80-bit latch **223**. Each stage of latch **223** has an output that is connected by a lead to the appropriate tone or voicing control switch of the organ **211** tone and voicing switches **211**a so that when the output is energized the switch closes to deliver the harmonically related tone from the tone signal generator network **245** to the audio amplifier **246** of the organ when the switch is one of the tone control switches. When the stage of the latch is associated with one of the voicing control circuits of course the output of the network **245** is modified by the special effects circuitry associated with the tones being delivered to the amplifier **246**.

In the normal operation of the latch the address outputs **244** of counter **222** serve to sequentially address the stages of the latch **223** and the pulse in the clock pulse signal serves to enable the address stage which like the latch stages in the prior embodiment will assume an output condition corresponding to the signal being delivered to the latch at the time the stage is enabled and will retain the condition so long as the data component appears in the time slot associated with the latch stage during subsequent cycles.

While only certain preferred embodiments of this invention have been shown and described by way of illustration, many modifications will occur to those skilled in the art and it is, therefore, desired that it be understood that it is intended herein to cover all such modifications as fall within the true spirit and scope of this invention.

Table I

T/S	Guitar Tone and Voicing Switch T/S Assignments	(Storage Register Stage Input Assignments) No. 1 String Register Stage	No. 2 String Register Stage	No. 3 String Register Stage	No. 4 String Register Stage	No. 5 String Register Stage	No. 6 String Register Stage	Switch Register Stage
00	(SP)							
01	(SP)							
02	(SP)							
03	(SP)							
04	(SP)							
05	(SP)							
06	(SP)							
07	D#	24						
08	C	23						
09	C	22						
10	B#	21						
11	A	20						
12	A#	19	24					
13	G	18	23					
14	G#	17	22					
15	F	16	21					
16	F	15	20	24				
17	E#	14	19	23				
18	D	13	18	22				
19	D#	12	17	21				
20	C	11	16	20				
21	C	10	15	19	24			
22	B#	9	14	18	23			
23	A	8	13	17	22			
24	A#	7	12	16	21			
25	G	6	11	15	20			
26	G#	5	10	14	19	24		

Table I – Continued

27	F	4	9	13	18	23	
28	F	3	8	12	17	22	
29	E	2–1	7	11	16	21	
30	D#		6	10	15	20	
31	D		5	9	14	19	24
32	C#		4	8	13	18	23
33	C		3	7	12	17	22
34	B		2–1	6	11	16	21
35	A#			5	10	15	20
36	A		4	9	14	19	
37	G#		3	8	13	18	
38	G		2–1	7	12	17	
39	F#			6	11	16	
40	F			5	10	15	
41	E			4	9	14	
42	D#			3	8	13	
43	D			2–1	7	12	
44	C#				6	11	
45	C				5	10	
46	B				4	9	
47	A#				3	8	
48	A				2–1	7	
49	G#					6	
50	G					5	
51	F#					4	
52	F					3	
53	E**					2–1	
54	(SP)						
55	(SP)						
56	(SW)						23
57	(SW)						22
58	(SP)						
59	(SP)						
60	(SP)						
61	(SP)						
62	(SP)						
63	(SP)						
64	(SP)						
65	(SP)						
66	(SP)						
67	(SP)						
68	(SP)						
69	(SP)						
70	(SP)						
71	(SP)						
72	(SP)						
73	(SP)						
74	(SP)						
75	(SP)						
76	(SP)						
77	(SP)						
78	(SP)						
79	(SY)						

(SP) = Spare
(SW) = Switch
(SY) = Sync
*Highest Tone
**Lowest Tone

Table II

T/S	Organ Tone and Voicing Switch T/S Assignments	(Latch Output Tone and Switch Assignments) No. 1 Latch	No. 2 Latch	No. 3 Latch	No. 4 Latch	No. 5 Latch	No. 6 Latch	No. 7 Latch	No. 8 Latch	No. 9 Latch	No. 10 Latch
00	(SP)										
01	(SP)										
02	(SP)										
03	(SP)										
04	(SP)										
05	(SP)										
06	(SP)										
07	D	Q_8									
08	C#		Q_1								
09	C		Q_2								
10	B		Q_3								
11	A#		Q_4								
12	A		Q_5								
13	G#		Q_6								

Table II – Continued

14	G	Q_7						
15	F#	Q_8						
16	F		Q_1					
17	E		Q_2					
18	D#		Q_3					
19	D		Q_4					
20	C#		Q_5					
21	C		Q_6					
22	B		Q_7					
23	A#		Q_8					
24	A			Q_1				
25	G#			Q_2				
26	G			Q_3				
27	F#			Q_4				
28	F			Q_5				
29	E			Q_6				
30	D#			Q_7				
31	D			Q_8				
32	C#				Q_1			
33	C				Q_2			
34	B				Q_3			
35	A#				Q_4			
36	A				Q_5			
37	G#				Q_6			
38	G				Q_7			
39	F#				Q_8			
40	F					Q_1		
41	E					Q_2		
42	D#					Q_3		
43	D					Q_4		
44	C#					Q_5		
45	C					Q_6		
46	B					Q_7		
47	A#					Q_8		
48	A						Q_1	
49	G#						Q_2	
50	G						Q_3	
51	F#						Q_4	
52	F						Q_5	
53	E						Q_6	
54	(SP)							
55	(SP)							
56	(SW)							Q_1
57	(SW)							Q_2
58	(SP)							
59	(SP)							
60	(SP)							
61	(SP)							
62	(SP)							
63	(SP)							
64	(SP)							
65	(SP)							
66	(SP)							
67	(SP)							
68	(SP)							
69	(SP)							
70	(SP)							
71	(SP)							
72	(SP)							
73	(SP)							
74	(SP)							
75	(SP)							
76	(SP)							
77	(SP)							
78	(SP)							
79	(SY)							

(SP) = Spare
(SW) = Switch
(SY) = Sync

What is claimed as new and what is desired to secure by Letters Patent of the United States is:

1. In a combination comprising a guitar having strings with musical tones that are manually and selectably playable thereon, a second musical instrument having means for producing audible tones which are harmonically related to said musical tones, and a system for controlling the operation of the tones producing means in accord with the selected play of said musical tones on said strings, the improved control system comprising encoding means for detecting the play of said musical tones on said strings during each of successively occurring time frames and for generating a series of time multiplexed signals during each of said time frames, each of said time frames having a plurality of time slots, each of said musical tones being assigned to a respective one of said time slots, and each of said signals being generated in response to the detected play of a respective one of said musical tones on a string of the guitar and during the occurrence of the time slot assignment of said one tone; decoding means for decoding the time multiplexed signals and controlling the audible tones producing means to produce audible tones harmonically related to the musical tones assigned to the time slot occurrences of said time multiplexed signals, means for transmitting said time multiplexed signals

from said encoding means to said decoding means, and manually controllable means for sustaining the production of audible tones during subsequent time frames which are harmonically related to the musical tones assigned to the time slot occurrences of the multiplexed signals generated during a time frame preceding said subsequent time frames.

2. The improved control system in accord with claim **1** where the sustaining means comprises storage means connected to receive the time multiplexed signals generated during said preceding time frame and manually controllable to thereafter generate an output signal during said subsequent time frames and during each occurrence of the time slot assignments of the musical tones assigned to the time slot occurrences of the multiplexed signals received by the storage means during said preceding time frame, and where said transmitting means comprises means operating during each of the subsequent time frames to combine the time multiplexed and output signals generated during the time frame into a series of time multiplexed signals that are transmitted to said decoding means.

3. In a combination which comprises a guitar having strings with musical tones that are manually and selectably playable thereon, a second musical instrument having means for producing audible tones which are harmonically related to said musical tones, and a system for controlling the operation of the audible tones producing means in accord with the selected play of said musical tones on said strings, the improved control system comprising encoding means for detecting the play of said musical tones on said strings during each of successively occurring time frames and for generating a series of time multiplexed signals during each of said time frames, each of said time frames having a plurality of time slots, each of said musical tones being assigned to a respective one of said time slots and in an order reflecting as assignment of tones of progressively changing pitch to successively occurring time slots, and each of said multiplexed signals being generated in response to the detected play of a respective one of said musical tones and during the occurrence of the time slot assignment of said one tone, decoding means for decoding the time multiplexed signals and controlling the audible tones producing means to produce audible tones harmonically related to the musical tones assigned to the time slot occurrences of said time multiplexed signals, and means for transmitting said time multiplexed signals from said encoding means to said decoding means, said encoding means comprising means for generating a first control signal during each time frame, a section for detecting the selected play on one of said strings of the musical tone selections that are playable thereon, and means for generating said multiplexed signals and controlled by receipt of a second control signal to generate a multiplexed signal during the occurrence of the time slot assignment of a musical tone selection detected by the section as being played on said one string, said guitar having frets which are spaced apart and underlie said strings, said one string having keyed string tones which are playable thereon, each of said keyed string tones being playable on said one string by keying said one string into string keying contact with a respective one of said frets, said section having storage means operating in response to receipt of said first control signal to detect each fret in contact with said one string at the time of such response and to generate an output in response to the detected contact with the fret and in a time slot having a predetermined time offset from the time slot assignment of the musical tone selection playable by string keying contact with the fret, said one string being arranged when keyed into contact with said one fret to also contact another fret which is adjacent said one fret, and said section having means operating in dependency upon receipt of an output generated by the storage means during each of the successively occuring time slots for generating said second control signal.

4. The improved control system in accord with claim **3** comprising manually controllable means for sustaining the production of audible tones, during subsequent time frames, which are harmonically related to the musical tones assigned to the time slot occurrences of the multiplexed signals generated during a time frame preceding said subsequent time frames.

5. The improved control system in accord with claim **4** where the sustaining means comprises second storage means connected to receive the time multiplexed signals generated during said preceding time frame and manually controllable to thereafter generate an output signal during said subsequent time frames and during each occurrence of the time slot assignments of the musical tones assigned to the time slot occurrences of the multiplexed signals received by the second storage means during said preceding time frame, and where said transmitting means comprises means operating during each of the subsequent time frames to combine the time multiplexed and output signals generated during the time frame into a series of time multiplexed signals that are transmitted to said decoding means.

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