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 781—786

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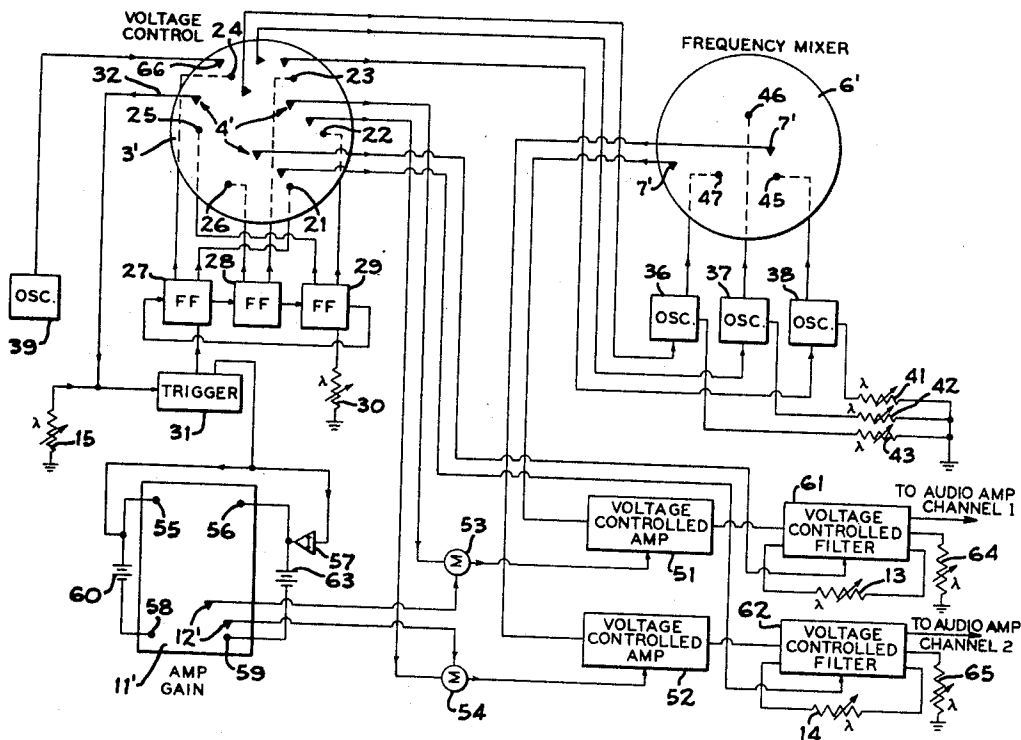
[54] **MOVABLE CONTACT CONTROL OF
 ELECTRONIC MUSIC MODULES**
 15 Claims, 5 Drawing Figs.

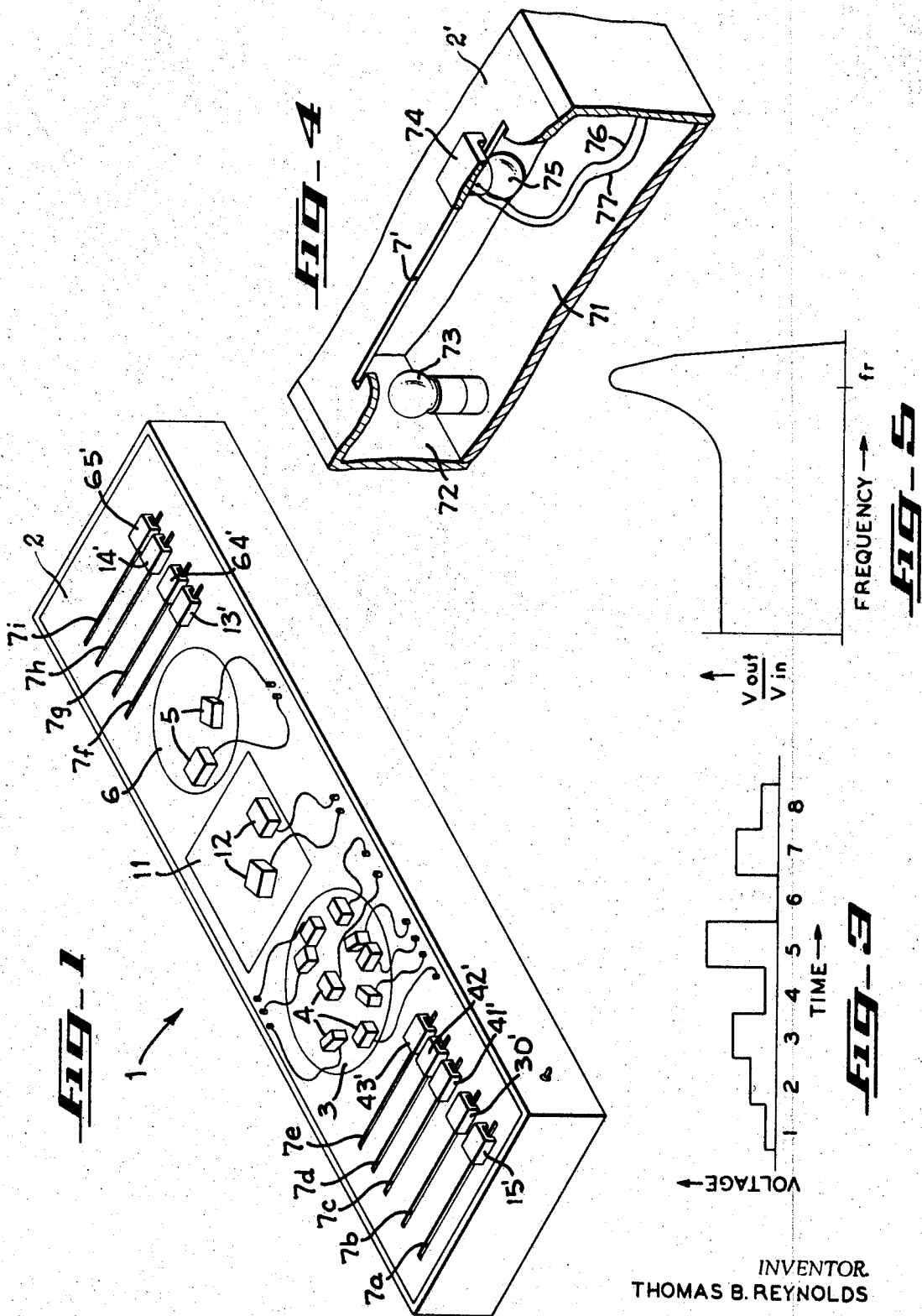
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[56] **References Cited**

Hugh LeCaine "Touch-Sensitive Organ Based on an Elec-

ABSTRACT: An electronic musical instrument including a first resistive surface to which a number of control signals are applied in physically spaced relation and from which variable oscillator control signals are picked up by movable contacts on the first resistive surface. Preferably, the oscillator signals are delivered to a second resistive surface so that additional movable contacts thereon can be shifted to vary the mixed oscillator signals.

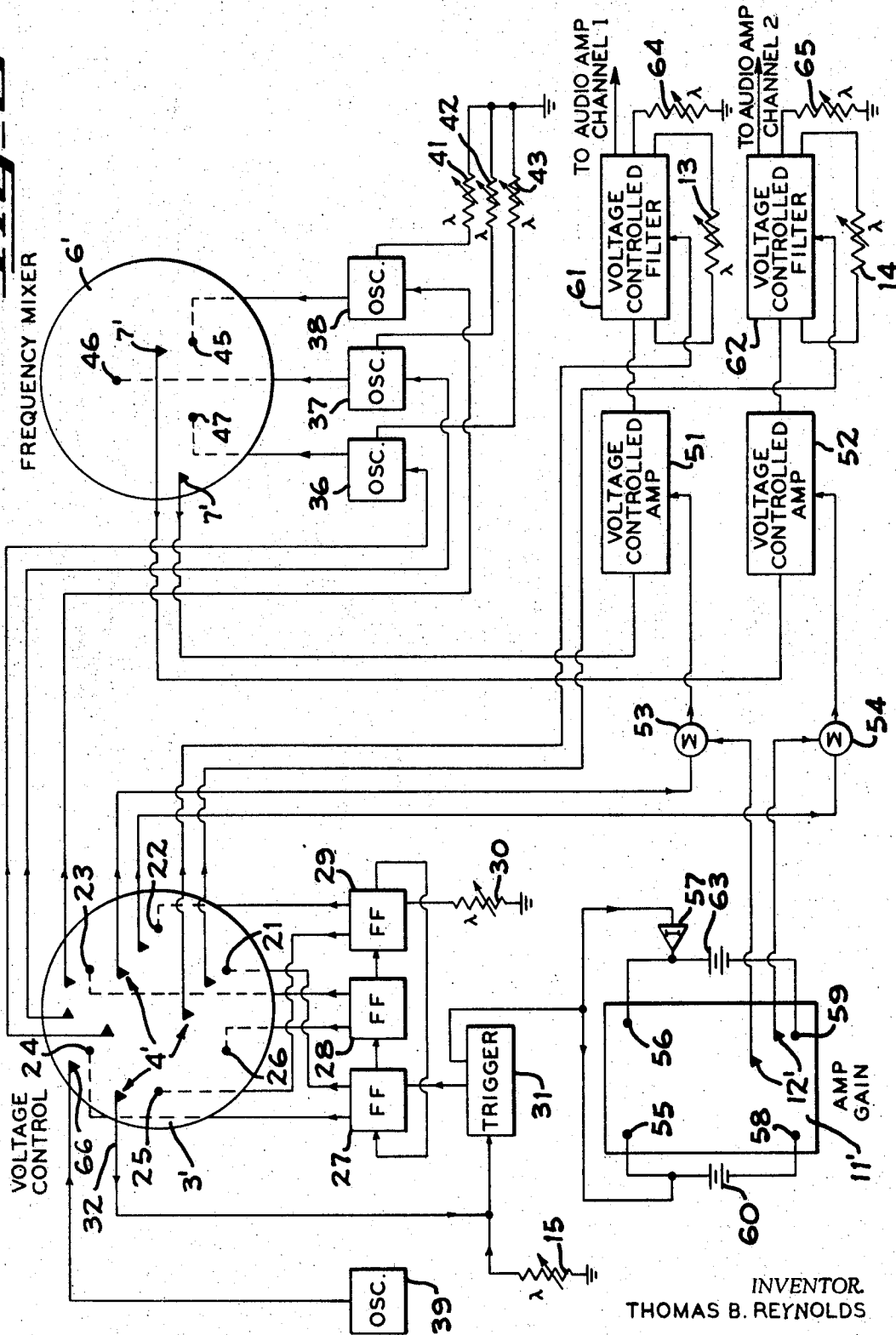




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FIG. 2



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MOVABLE CONTACT CONTROL OF ELECTRONIC MUSIC MODULES

BACKGROUND OF THE INVENTION

The invention relates to an electronic control apparatus and, more particularly, to an electronic musical instrument operated by such an electronic control apparatus.

Music from electronic circuits offers new vistas for creative composing. Instruments such as the recently developed "music synthesizers" of the large electronic music centers offer a wide range of interesting sounds to be explored. Most prior art electronic musical instruments are controlled by one dimensional input devices, such as keyboards, strings, potentiometers or their digital computer counterparts. By one-dimensional input is meant that one or more variable quantities can be controlled only in a monotonic manner. One-dimensional inputs tend to limit the variety of sound available as well as restricting the attention of the composer to fewer variable quantities. The result is that the composer's ability to rapidly change more than one variable quantity in a short time is somewhat limited.

SUMMARY OF THE INVENTION

An object of the invention is to provide an electronic control apparatus for deriving signals for control of signal controlled modules, as in electronic musical instruments.

Another object of the invention is to provide an electronic musical instrument whose sound characteristics are more dynamically variable than previously available.

Another object of the invention is to provide input controls for an electronic musical instrument which may be operated by a relatively untrained composer.

A further object is to provide a musical instrument which expressively renders polyphonic and homophonic compositions in each of several output channels.

The present control apparatus operates controlled electronic modules, such as voltage controlled oscillators, by manipulation of contact members on energized resistive surfaces. A first resistive surface is energized by several control signals sequentially applied to one of several spaced terminals which form energy gradients on said resistive surface about the terminals. Contact members, i.e., conductive wires held in insulative supports, placed in proximity to selected terminals connected to the first surface pickup signals to be transmitted to the respective music module through an associated input lead to which a contact member is connected. The modules respond by adjustment of their controlled parameters in accord with new control signal levels. The total response of a particular module depends on the position of a contact member relative to each of the spaced terminals. Such response is carried away from each module by an output lead which may be connected as an input to another module or to an output transducer such as a loudspeaker.

Since signals applied to various terminals of the first surface are usually variable in time, the respective modules are adjusting their responses continuously for inherent variety. To provide additional interest the control signals applied to the terminals are pulsed in cyclic order so that electronic modules must respond to pulse on-off control as well as control signal variations.

The aforementioned control apparatus is especially useful in the control of electronic entertainment media such as electronic musical instruments of the type using a multiplicity of modular voltage controlled oscillators, amplifiers and filters. In the present invention each modular component derives input control signals from the first surface. Other control surfaces may be used to control output signal mixing and to mix the input control signals with other special purpose signals thereby providing multidimensional control.

In the present musical instrument a second control surface is energized by the outputs of a plurality of voltage controlled relaxation oscillators, rich in harmonics, receiving control signals from contact members on the first surface. The second

surface has fixed terminals to which the oscillator outputs are terminated in spaced relation to provide a basis for selecting polyphonic melodies. Contact members are movable on the second surface with respect to the terminals so that a mixture of frequencies or tones from the oscillators is picked up by the contact members. The variable tone mixture becomes the basic musical composition upon which the various other controlled modules operate. Voltage controlled oscillators and filters create an orchestral effect by manipulation of the input control signals.

Similarly other variable signal inputs may be controlled using resistive surfaces. Since each surface may simultaneously accommodate a plurality of independent signals, a contact member of an electronic music module may be selectively placed in a position proximate to the geometric area wherein the desired combination of signals is expected. Accordingly, the multidimensional control wherein several voltages may be simultaneously selected in desired proportion by a single motion of a contact member gives effect to the dynamic expressiveness of a composer exploring the new vistas available in electronic music.

Music played by the apparatus of the present invention may be characterized as having a variety of inherent basic musical ideas due to the time variable control voltages; rhythmic due to pulsing of the various control signals in cyclic order; dynamically expressive due to multidimensional control; rich and warm due to the high harmonic content; polyphonic due to a multiplicity of oscillators; melodically intriguing due to a superposition of control voltages and orchestral due to amplifiers and filters which modify the signal by boosting and diminishing various frequencies and amplitude in separate channels. The apparatus will be described with reference to the FIGS.

DESCRIPTION OF THE DRAWING

FIG. 1 is a perspective view of a packaged embodiment of the electronic musical instrument using the control apparatus of the present invention.

FIG. 2 is an electrical schematic of the apparatus shown in FIG. 1.

FIG. 3 is a graph showing 2ⁿ voltage states available from n flip-flops, each with two output voltages as shown in FIG. 2.

FIG. 4 is a detailed cutaway view of the manner of mounting a light sensitive resistor shown partially in FIG. 1.

FIG. 5 is a graph showing the frequency versus voltage ratio response for a voltage controlled filter with feedback applied indicated on the schematic of FIG. 2.

In FIG. 1 the present electronic musical instrument 1 is shown with its principal control means on the top side of an enclosure 2. The control means includes a first resistive surface 3 upon which the first group of manually shiftable contact members 4 may be disposed. The contact members 4 pick up pulsating control signals on the resistive surface 3 for establishing rhythmic varied and intriguing musical ideas. A second surface 6 has a second group contact members 5 disposed thereon. The contact members 5 pick up a mixture of tone signals from resistive surface 6 for transmission to signal controlled modules thereby creating polyphony. Other controls include slots 7a, 7b, 7c, 7d, 7e, 7g, 7h, 7i in which the light sensitive resistors 15', 30', 41', 42', 43', 13', 64', 14', 65' may be moved with reference to light sources. The light sensitive resistors provide attenuation of the various signals within the musical instrument 1. A third surface 11 has a third group of contact members 12 disposed thereon. Contact members 12 pick up special control signals on surface 11 for controlling the gain of the musical instrument.

Each resistive surface is preferably made of graphite loaded epoxy resin which may be cast into various desired shapes. The surface is usually energized with voltages applied at terminals projecting through the underside of the surface. The voltage is distributed in gradients about each terminal, falling off with the resistive character of the surface. In general, at re-

gions nearest the terminals the maximum voltage applied to that terminal will be available. Between terminals, a composite voltage from various separately energized terminals is present so that the voltage combinations available over the entire surface are myriad.

The entire package is designed so that a relatively untrained person may play the present electronic musical instrument. A player or composer merely moves the contact members 4, 5, 12, and the light sensitive resistors 15', 30', 41', 42', 43', 13', 64', 14', 65' to play the instrument. The coordinated movement of the player's hands is the requisite which adds variety and interest to the composition played.

A more comprehensive view of the apparatus is available in FIG. 2 which shows the electrical connection of the various controls to their respective circuits. The controls described with reference to FIG. 1 will be explained in relation to their position in the electrical schematic. The first resistive surface 3' has a plurality of terminals 21, 22, 23, 24, 25, 26 permanently attached thereto and connected to a set of n flip-flops 27, 28, and 29 arranged as in a binary counter. The n flip-flops apply to a cyclic set of pulses to the resistive surface 3'. The pulses have varied amplitudes for a melodically intriguing and rhythmic effect. Each of the n flip-flops has a pair of outputs connected to two spaced terminals on the control surface 3'. For example, flip-flop 27 is connected to terminals 21 and 24. The flip-flops provide 2^n combinations of signal states available at their respective terminals. Each of the 2^n flip-flop combinations represents a particular voltage state applied to control surfaces 3. In FIG. 2, n equals 3, so that there are 8 voltage states which are sequentially applied by the counting flip-flops to the control surfaces 3. An example of eight different voltage states is illustrated in FIG. 3. When the counting cycle is complete after count 8, the flip-flops are automatically reset to recycle without perceptible delay since the 2^n counting states have all been exhausted. A means, 30, such as a switch or movable array of light sensitive resistors is provided to adjustably reduce the number of counting steps, when desired, to a value less than 2^n by the exclusion of one or more states. This is accomplished by shunting the counting states to be excluded.

The flip-flops are stepped into successive states by a trigger circuit 31 comprising a unijunction transistor oscillator. The trigger circuit 31 is voltage controlled with inputs from a potentiometer 15 and a feedback source 32 which will be described later. The light sensitive resistor 15 varies the rate at which trigger pulses are applied to flip-flops 27, 28, and 29 to control the tempo of the sounds to be derived. The feedback source 32, taken from the first control surface 3 and applied to trigger circuit 31 tends to control the pulse width by cutting off the trigger pulse envelope due to application of variable amounts of the output pulses from the flip-flops.

Disposed on the upper side of the surface 3 are a first group of contact members whereby voltages applied by the flip-flop 27, 28, and 29 may be picked up by the conductive contact members 4' for the transmission to associated modules for controlling the operation of said modules. The second control surface 6' has contact members 7' which are similarly used to pick up tone signals applied to the surface from a group of oscillators 36, 37 and 38 for transmission through the modules as the basic musical composition. The third control surface 11' has contact members 12' for adjusting the gain of the apparatus.

Each oscillator is a voltage controlled unijunction transistor oscillator generating generally triangular or sawtooth waves. This waveshape is known for its high harmonic content, thereby adding an abundance of tone color to the music. The aforesaid oscillators are in the audio frequency range extending from approximately 5 Hz. to 10 Hz. For schematics of unijunction transistor oscillators of a type similar to that used herein reference is made to the General Electric Transistor Manual, 7th edition, 1964, page 318. Each oscillator 36, 37 and 38 receives controlled voltages from two sources. A first source for each oscillator is a light sensitive resistor 41, 42 and

43 which faces a light source. The light sensitive resistors 41, 42 and 43 provide a linear frequency control source, whereas the contact members 4' provide a multidimensional control whereby alternatively high and low cyclic control voltages may be selectively applied to the oscillators 36, 37, and 38.

Although all variable resistances described herein may be standard potentiometers, light sensitive resistors disposed relative to light sources are preferred. The manner of variation of the light sensitive resistors described herein may be shaped arbitrarily by geometrical control of the spatial distribution of luminous flux. For example, multiple light sources, point sources, shadow masking, translucent materials will all give different resistive contours to light sensitive resistors. This type of resistive shaping is difficult, if not impossible, to achieve with conventional contact-type resistive potentiometers.

Light sensitive resistors 41, 42, and 43 are mounted through slots 7, extending radially from light sources at one end of slots 7. Movement of the light sensitive resistors along their respective slots to and from the light sources provides an input especially useful for frequency control since the variable resistance of light sensitive resistors 41, 42 and 43 controls the frequency of oscillators 36, 37, and 38. The manner of mounting light sensitive resistors is illustrated in more detail in FIG. 4.

In FIG. 4 a series of passageways 71 are designed in a closed container such as the enclosure 2' similar to channels and slots 7a-7i in the enclosure 2 of FIG. 1. At one end 72 of passageway 71 a light source 73 is positioned. A slot 7' designed through the enclosure 2' enables a slidable member 74 to guide a light sensitive resistor 75 back and forth along the slot. The light sensitive resistor has a first lead 76 to carry away an output signal, and a second lead 77 connected to ground. In operation the light source 73 is usually left on so that movement of the slidable member 74 increases and decreases the variable resistance of the light sensitive resistor 75.

Used in this manner the response of many light sensitive resistors is generally exponential. The linear motion provided to light sensitive resistors in slots 7' has an aesthetic appeal since changed linear distance intervals along the slots approximate corresponding changes in frequency as heard in the human ear, i.e., a doubled distance produces an audibly apparent doubled frequency.

With reference to FIG. 2, terminals are permanently fixed to the resistive control surface 6' corresponding in number to the number of oscillators. The output of each oscillator 37, 38, 39 is connected to a respective spaced terminal so that the oscillations produced by each of the oscillators is present on control surface 6'. Accordingly, contact members 7' may be moved in geometric relation to the fixed terminals 45, 46 and 47 to pick up desired combinations of oscillations available on the control surface. The signals thus picked up become the basic tones which are operated upon by the remaining voltage controlled modules.

Voltage controlled amplifiers 51 and 52 provide the desired amplitude modulation for the basic signals. The amplifiers derive inputs from two sources which are summed in respective summing means 53 and 54. Each summing means is a linear adder such as a resistor or an operational amplifier. The two sources of control voltages to the summing means are inputs from the resistive control surface 3' and from a third control surface 11' corresponding to surfaces 3 and 11 in FIG. 1.

The control surface 11' has inputs applied to paired and opposed terminals 55, 56, 58, and 59. For example, if the surface is a square or a rectangle, the terminals may be pairs of adjacent corners. The first voltage, applied to terminal 55, is a voltage derived from the trigger circuit 31. A second voltage, applied to terminal 56 is also derived from trigger circuit 31 but has its phase inverted by inverter 57.

A third voltage is applied to terminal 58 below terminal 55. This voltage is the same as that applied to terminal 55 but with a DC bias added to it from battery 60. A fourth voltage ap-

plied to terminal 59 below terminal 56 but with another DC bias added to it from battery 63. Two movable contact members 12' are disposed to select the desired combinations of voltages to be applied to both summing devices 53 and 54. Accordingly, voltage controlled amplifiers 51 and 52 are controlled with respect to the general gain characteristics by their spacing between terminal pairs 55, 56 and pairs 58, 59 whereas the attack and decay of the wave shapes is controlled from the surface 11' using sawtooth waves between terminal pairs 55, 58 and terminal pairs 56, 59, from trigger circuit 31.

Each voltage control amplifier 51, 52 is connected to a voltage controlled filter 61 and 62 respectively. Each filter has a passband set by inputs from the control surface 3' and the light sensitive resistors 64 and 65. The passband is adjustable from very low cutoff frequencies to very high frequencies. As an additional feature, each filter includes a variable feedback light sensitive resistor 13 and 14, respectively, whereby the filters may be made resonant at particular frequencies. The effect of increased feedback is to boost the amplification of signals at the resonant frequencies as in FIG. 5. The curve in the FIG. is the passband of the filter. Note the amplification available at the resonant frequency f_r .

The voltage controlled amplifiers and filters 51, 61, and 52, 62 are paired so that two channels of audio may be provided for stereophonic effect. The voltage controlled oscillators amplifiers and filters are the well-known type commonly used in electronic musical instruments. For example, see the article in "Electronics World" Feb. 1967, by Robert A. Moog at page 45. The main feature of a voltage controlled filter is balanced network of transistors preferably with matched component parameters available in integrated circuit packaging.

Previously it was mentioned that the contact members disposed on the surface 3' pickup signals applied from the flip-flop 27, 28, and 29. There is one exception. A single contact member 66 is provided to superimpose low frequency sine wave oscillations at about 8 Hz. on control surface 3'. This provides a vibrato effect to the music whenever applied.

In operation, the electronic musical instrument of the present invention is played in the following preferred manner. All contact members 4' and 7' are cleared from the surfaces 3' and 6'. Light sensitive resistor 15 is set to the desired trigger rate thereby defining the tempo. Since flip-flop 27, 28 and 29 are pulsing the surface 3' with a sequence of signals as in FIG. 3, the contact 32 is set to pick up the desired amount of trigger feedback for tempo modulation or syncopation. The contact members for the oscillators are then set on surface 3' at desired positions and the light sensitive resistors 41, 42, 43 are put in view of light sources. The oscillators are adjusted in frequency by movement of the light sensitive resistors 41, 42 and 43 by movement of the oscillator-associated contact members.

The contact members 7' are placed on surface 6' to pick up the desired combination of tones or frequencies to be amplified and filtered. Contact members controlling the response of their respective amplifiers and filters are normally set on surface 3'.

At this point a cyclic melody is issuing from each channel. The contact members for one channel are first adjusted for a bass response. This is accomplished by adjusting a feedback light sensitive resistor on one channel, say 13, to boost bass frequencies in filter 61. The "beat" of the music is then set in the bass by placing the contact arm associated with filter 61 nearest the terminals of the various flip-flop which are producing appropriate "beat" pulses, for example, midway between terminals producing the first and fourth signal states so as to set up 4/4 time or an approximation thereof.

The voltage controlled amplifier 51 is then set to amplify a preferred portion of the cyclic pulsing by appropriate placement of a connected contact member on surface 3'. If the contact member of amplifier 51 is adjacent to the contact member of filter 61 the "beat" tends to be emphatic.

The melody may be set up in the same manner in the other channel. Usually the melody will not emphasize one portion of

the pulsing cycle. Accordingly feedback from potentiometer 14 is cut back. The remaining adjustments are similar to those of the bass.

The overall gain of both bass and melody channels is adjusted with control surface 11'. Movement of contact arms 12' between terminal pairs 55, 56 and 58, 59 adjusts the overall gain of the apparatus while movement between terminal pairs 55, 56 and 58, 59 adjusts the shape or attack and decay of pulses entering the amplifiers and filters.

When it is desirable to "soften" the music, low frequency oscillations may be applied by contact arm 63 positioned on surface 3'. A sine wave oscillator 39 supplies the superposed modulation at about 8 Hz.

Although the present control surfaces have been described with reference to an operation of the presently described electronic musical instrument, it is clear that other modular electronic equipment may be similarly operated.

I claim:

1. Electrical control apparatus comprising:

a multiplicity of controllable electronic modules each having a control input for picking up input control signals; a first resistive surface having movable contacts disposable thereon for conductive communication with said surface, said contacts connected to said control inputs for providing each control module with input control signals; and means for energizing said first surface with a multiplicity of first control signals terminated in spaced relation on said first resistive surface thereby forming a signal gradient on said surface so that communication of said movable contacts with said first resistive surface imparts a proportion of signals to said modules for control thereof depending on the spacing of said movable contacts relative to each of the terminated signals for variable control of said modules.

2. The apparatus of claim 1 wherein said controllable electronic modules include electronic oscillators having movable output contact members for conducting the oscillator output to desired locations.

3. The apparatus of claim 1 wherein said controllable electronic modules include filters and amplifiers.

4. The apparatus of claim 2 further defined by:

a second surface upon which the outputs of said electronic oscillators are terminated in spaced relation: controlled output means having movable control members for picking up output signals; and whereby positioning of said output control members on said second surface imparts to said output means a mixture of oscillations from said terminated electronic oscillators.

5. The apparatus of claim 1 wherein said control signals are sequentially applied by trigger circuit activated flip-flops connected as in a cyclic counting circuit.

6. The apparatus of claim 5 wherein said flip-flops have a variable output pulse width.

7. The apparatus of claim 6 wherein the pulse width of said flip-flops is controlled by an input control signal from said surfaces.

8. The apparatus of claim 3 wherein a third surface is provided with second control signals of an oscillatory type applied thereto whereby a movable output control member of said amplifiers and filters derives a second control signal therefrom for summing with said first control signal thereby providing a pulse attack and decay characteristic for said amplifiers and filters.

9. An improved electronic musical instrument of the type having signal controlled music modules including oscillators, amplifiers and filters wherein the improvement comprises a resistive control surface having control signals applied thereto and movable contacts in conductive communication therewith, said movable contacts connected to said music modules for control thereof when said movable contacts are in conductive communication with said control surface.

10. An electronic musical instrument comprising:

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signal controlled music modules having input and output leads, said modules including variable frequency oscillators for generating vibrations, filters and amplifiers for processing said vibrations;

a first resistive surface;

control signal means terminated on said first resistive surface for applying control signals thereto;

contact members connected to input leads of each of said music modules for picking up control signals, said contact members movably disposed on said first resistive surface; and

output means connected to said output leads of said electronic music modules for producing electrical vibrations in response to energization of said music modules by said control signals.

1. The apparatus of claim 10 further defined by a second resistive surface on which the output leads of said oscillators and the input leads of said filters and amplifiers are disposed whereby said second surface is energized by said oscillators so

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that movement of said leads varies the emphasis of one or more oscillators with respect to said filters and amplifiers.

12. The apparatus of claim 11 further defined by a third resistive surface energized by a time varying signal, said surface having input leads of said amplifiers disposed thereon whereby said third surface partially controls the gain of said amplifiers.

13. The apparatus of claim 10 further defined by a variable resistor across which a signal is applied for summation with the control signal picked up by a contact member of said variable frequency oscillators whereby the frequency of said oscillators may be controlled by said variable resistor and by movement of said contact members.

14. The apparatus of claim 13 further defined wherein said variable resistor is a light sensitive resistor disposed in movable radial relation relative to a light source.

15. The apparatus of claim 14 wherein said light sensitive resistor is adapted to move radially relative to said light source in a linear slot facing said light source.

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