April 25, 1967 R. H. PETERSON 3,316,341

ELECTRICAL MUSICAL INSTRUMENTS

Filed Nov. 29, 1963

3 Sheets-Sheet 1

Fig. 1.

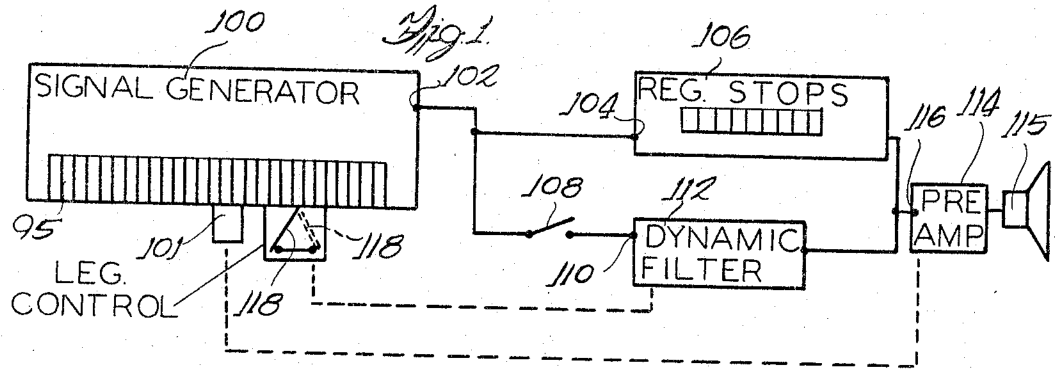

Fig. 2.

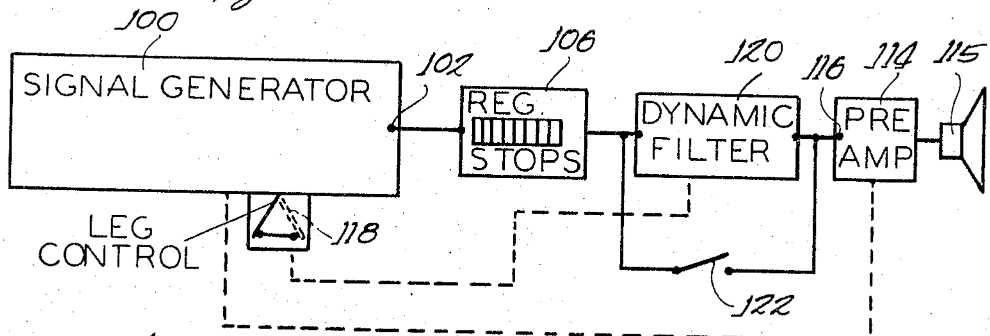

Fig. 3.

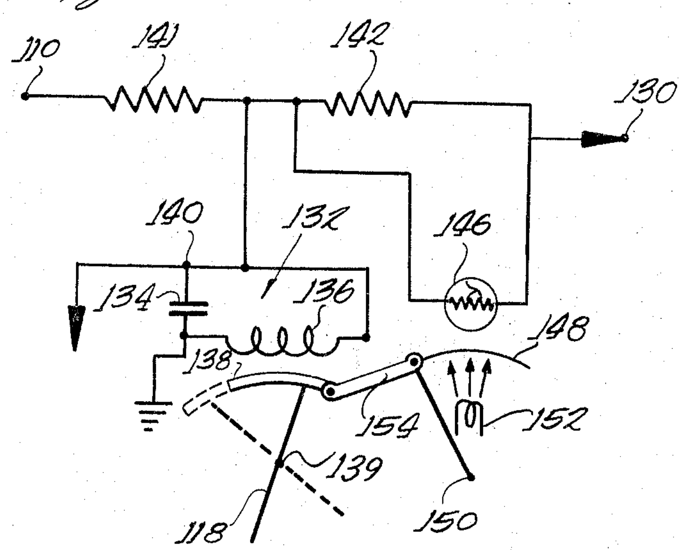

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Fig. 4.

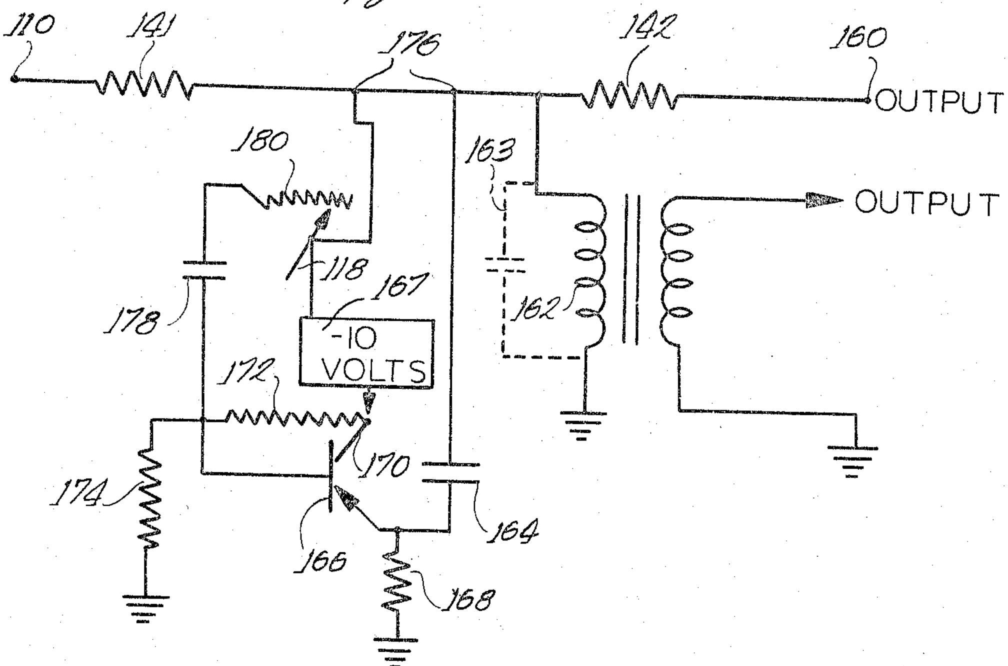

Fig. 5.

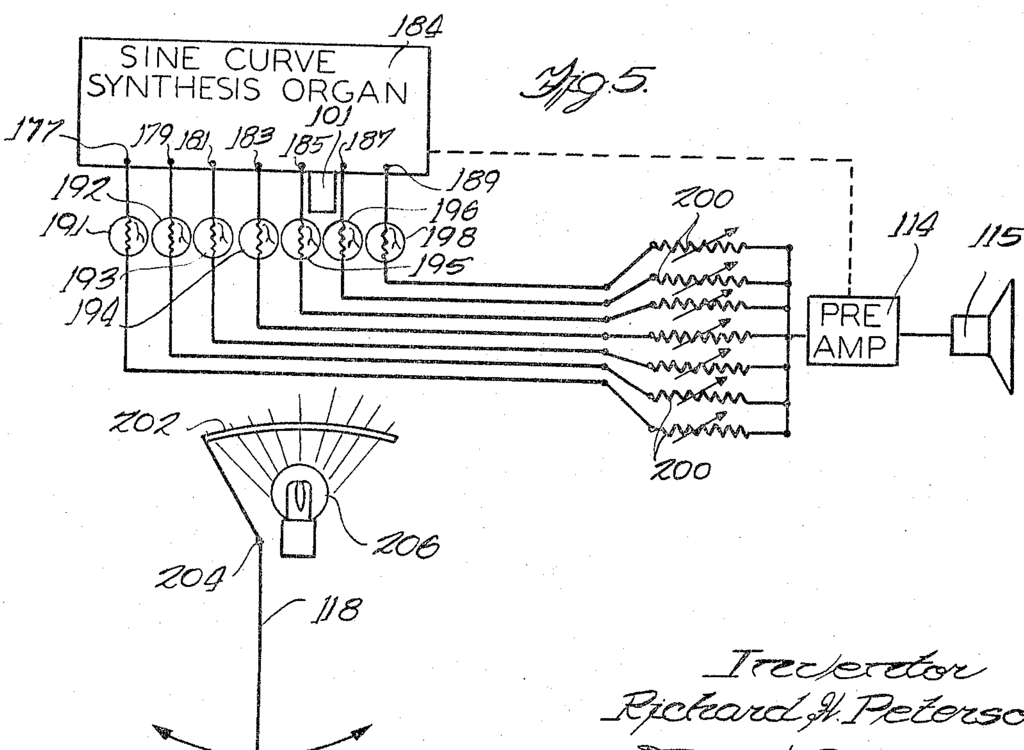

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Fig. 6.

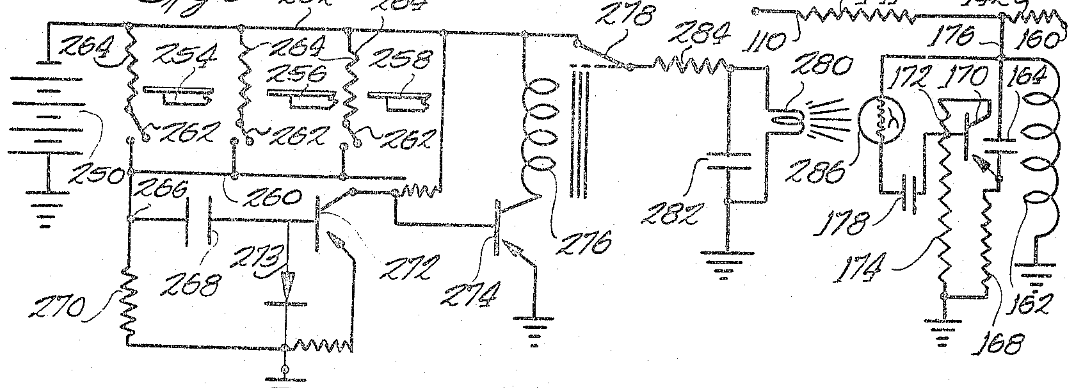


Fig. 7

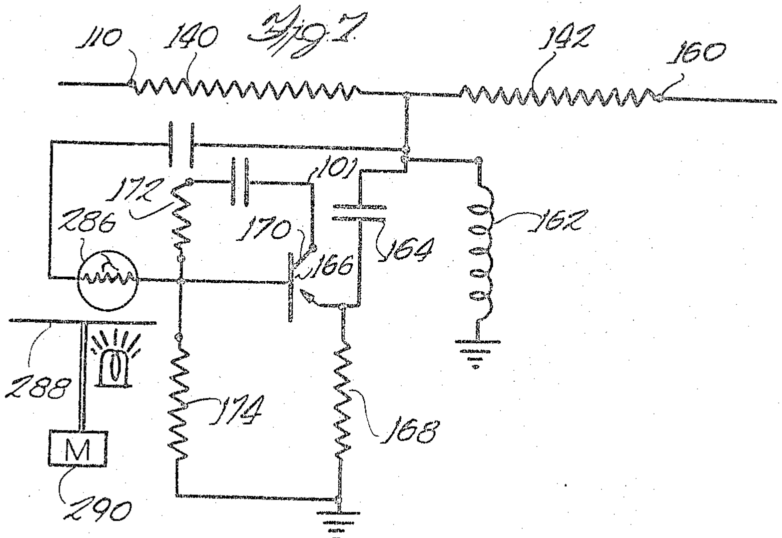
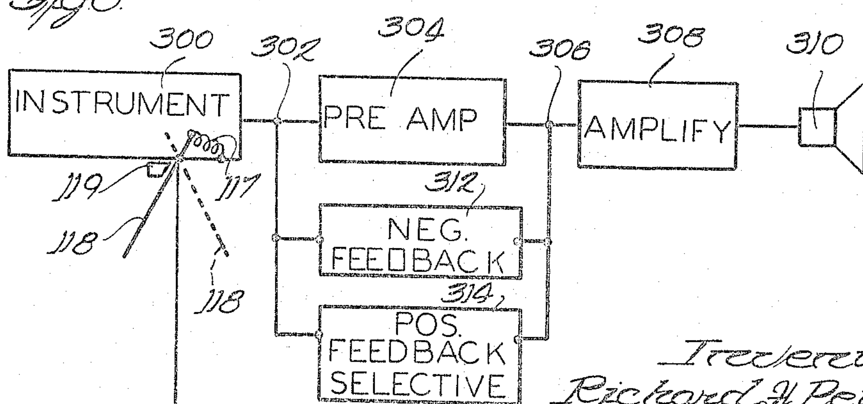


Fig. 8.



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ELECTRICAL MUSICAL INSTRUMENTS

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5 Claims. (Cl. 84—1.24)

My invention relates to electrical musical instruments, and particularly to novel means for producing desirable tonal effects, including certain effects not previously associated with such instruments. While primarily applicable to polyphonic musical instruments, certain features of the invention may also be applied to instruments of the monophonic or solo type.

It is convenient to identify the three common systems for producing audio-frequency signal of any particular desired wave shape, which wave shape determines the timbre of the sound wave into which said signal may be translated, as follows:

Harmonic synthesis is by superimposing a series of harmonically related signals. Wave distortion, or shaping, operates by starting with a sine curve and modifying its shape to introduce harmonics. U.S. Patent 2,649,006 discloses one typical example of this. "Formant" instruments start with a pulse wave shape, for example a sawtooth, and use various filters to attenuate or emphasize desired harmonic frequencies.

The invention is substantially equally applicable to all three systems. When suitably adapted to any one of the systems, it provides in each instance for dynamic control by the player of changes in the timbre or frequency or amplitude of the processed signal, or of any two or all three of these main characteristics.

The word "dynamic" is used to identify changes that are not step by step, but smooth and even and without abrupt discontinuities. Abrupt changes result readily from depressing different playing keys in an ordinary musical instrument, and also from the adjustive manipulation of the conventional stops. A good example of a "dynamic" control is the use of a mute by a trumpet player. By a continuous physical movement of the mute, he can change the resonance peaks of his instrument, and marked changes in tone quality may be introduced and eliminated at various time rates, but always smoothly and without any step by step discontinuities, and at the momentary fancy of the player. In electrical musical instruments, this has always been possible with the usual "swell" pedal, but only with respect to loudness of the entire instrument. Automatic tremulants of a substantial variety have also been successful. But changes in timbre as fully and freely and smoothly variable as in the muting of a horn, have not heretofore been available in electrical musical instruments, so far as I am aware.

The timbre modulations produced according to the invention include two distinct varieties. First, the deviation may correspond at each instant to the amount of the displacement of a dynamically movable control element activated by the player, so that the time envelope of the modulation is an instantaneous and simultaneous function of the player's physical movement. This variety may conveniently be identified as a modulation with a player-controlled envelope.

Second, the envelope may be automatically controlled, as a portamento or a recurring modulation, or a single regular or irregular modulation; but the occurrence of the automatic action may be conditioned on something done by the player. This variety can conveniently be identified as a modulation with automatic envelope control, and it may or may not be automatically repetitive.

Among the specific objects of the invention are:

(1) To provide a variable resonant reed stop for an electrical musical instrument;

(2) To provide means for electrical musical instruments for enabling the performer to duplicate certain effects ordinarily associated with an orchestra or with orchestral instruments;

(3) To provide means for the organist to introduce a novel type of expression into the music and thereby render a more truly artistic performance;

(4) To provide novel means for introducing dynamic variations in the tone quality of an electrical musical instrument;

(5) To provide means for quickly altering the tone quality of an electrical musical instrument over a wide range without employing the usual stops, combination action or the like.

Other objects and advantages of the invention will become apparent as the description proceeds.

In the accompaning drawings:

FIGURE 1 is a block diagram indicating the incorporation of the invention in an organ system of the formant type;

FIGURE 2 is a block diagram of an alternative arrangement for formant type instruments;

FIGURE 3 is a schematic circuit diagram indicating one type of filter control suitable for use in the invention;

FIGURE 4 is a schematic circuit diagram of a preferred dynamic filter circuit;

FIGURE 5 is a partial schematic diagram indicating the application of the invention to an organ of the harmonic synthesis type;

FIGURE 6 is a schematic circuit diagram for a triggered, automatically variable, dynamic filter;

FIGURE 7 is a circuit diagram of a dynamic variable filter arranged to produce reiterating effects automatically; and

FIGURE 8 is a block diagram of one way of combining the invention as an adjunct to an organ already in use.

Referring first to FIGURES 1 and 2, the signal generator **100** has a terminal **102** for delivering the complete composite signal, including superposed signals from the variety of sources selected at the moment by the player by means of the keys **95**, which are representative of the keys of an organ or of one manual of a multi-manual organ. In FIGURE 1, this output enters two parallel channels. At the terminal **104**, it enters the regular stop equipment **106** for continuously delivering various timbres by the setting of the conventional stops by the player.

In addition, if the stop switch **108** is closed, the same signal is delivered at terminal **110** to a dynamic filter **112** to be described in detail hereinafter. The signals from the regular stop unit **106** and from the dynamic filter **112** are merged and the combined signal goes to the preamplifier **114** and the loud speaker **115**. The conventional swell pedal **101** controls the preamplifier **114**. The operator's dynamic control of the functioning of the filter **112** is by means of a control lever **118** projecting forward below the keyboard on the console in a position to lie close beside the right knee of the player. The leg control lever **118** is held resiliently in the full line position, but yields readily to be pushed over by the player's knee approximately to the position indicated in the same figure in dotted lines, and the extent of the modification of the signal received by the dynamic filter will vary as a direct, but not necessarily a linear, function of the extent of displacement of the lever.

In FIGURE 2, I have indicated the same generator **100** and regular stop **106**; but the dynamic filter **120** is connected in series between the stops **106** and the preamplifier **114**. This part of the system of FIGURE 2 performs substantially the identical function of the dynamic filter **112** but because it processes signal that has already been acted on by the regular stops **106**, its detail design may be slightly altered for best results. In the system of FIGURE 2, the operator can still play with the regular stops only by closing the by-pass switch **122** so that the signal proceeds from the regular stops to the preamplifier without passing through the filter **120**.

One type of dynamic filter adapted for use in the combination of FIGURES 1 and 2 is the resonant or band pass type filter indicated in FIGURE 3. Signal of any frequency appearing across input terminal **110** and ground will arrive at the output terminal **130** with the degree of attenuation a function of frequency. At the resonant frequency of the tuned circuit **132**, comprising the capacitor **134** and the inductor **136**, the attenuation will be relatively slight, and at frequencies much above or below this resonant frequency the attenuation is greatly increased.

Means are provided for varying the resonant frequency of the tuned circuit **132**. I have indicated a magnetic core **138** moveable with respect to the position of coil **136** to vary the value of the inductance. This may be rotated about a pivot **139** by the knee lever **118** projecting out beside the player. The full line position obtains when the lever **118** is not displaced by the operator's knee; and movement may proceed to the dotted line position, where the frequency of resonance has been changed greatly.

It will be obvious that signal may be taken either from terminal **130** or from terminal **140** on the tuned circuit **132**.

The sharpness of the resonance peak is a function of the circuit design, including the impedances of the input and output circuits, series resistors **141** and **142**, and the components comprising the resonant circuit **132**.

As a practical matter, it has been found that because of the relatively large amount of energy represented by the lower frequency components of a composite organ signal, the actual volume of signal delivered to the output terminal **130** diminishes as the resonant frequency of the tuned circuit is increased. Means are provided for compensating for this undesirable reduction in signal and loudness as the control is moved to or in the direction of higher frequencies. One suitable compensating means is a light-sensitive resistor **146** connected in shunt around resistor **142**. A variable density shutter **148** is pivoted on an axis at **150** and moves back and forth between the light source **152** and the light-sensitive resistor **146**. A drag link **154** connects the shutter **148** mechanically with the core **138** of the tuned circuit; and as the core moves to the left, the shutter **148** delivers increasing illumination to the light-sensitive resistor **146**. The resulting decreased resistance increases the energy transmitted through the filter.

Many desirable tonal effects are possible with a dynamic filter according to FIGURE 3, but as a practical matter, it has been found difficult to provide a variable inductor of reasonably constant Q over the very wide range of inductance that has been found to be desirable. Saturable reactors can be used, but the difficulty in obtaining the desired range of inductance in that way without distortion involves complex control apparatus and is not generally desirable.

The resonant or band-pass circuit indicated in FIGURE 4 is tunable over a range of several octaves with relatively constant Q.

As in the circuit of FIGURE 3, the input is supplied across terminal **110** and ground and the output across ground and terminal **160**. Again, the attenuation of signals through the filter is minimum at the resonant frequency of the tuned circuit, which in this case consists of the inductor **162** and the capacitor **164**. Instead of being returned directly to ground, capacitor **164** is connected to the emitter of the transistor **166** which is a common collector transistor amplifier having the load resistor **168**. The collector **170** of transistor **166** is connected to a suitable source **167** of supply potential, such as minus ten volts. Resistors **172** and **174** provide bias in the usual manner. Resistor **168**, connected between the emitter and ground, is of a relatively low value and is ordinarily sufficiently low so that it has a negligible effect upon the circulating current in the resonant circuit **162** and **164**. Thus it is seen that with no input signal applied to the base of transistor **166** the filter circuit shown in FIGURE 4 operates in an identical manner to that of the filter in FIGURE 3, with the resonant frequency determined by the values of inductor **162** and capacitor **164**. However, if the signal appearing at **176** is applied to the base of transistor **166** through the coupling capacitor **178** and through the resistor **180** (when short circuited) a voltage will now appear at the emitter of transistor **166** that is substantially the same as the voltage appearing at terminal **176**. This is because the common collector-amplifier circuit has a gain of approximately unity and produces an output signal across the load resistor **168** that is in phase with the input signal. Since the capacitor **164** now has an identical voltage at both of its terminals, substantially no current can flow through capacitor **164**. As a result, this capacitor has been effectively removed from the resonant circuit and the resonant frequency of the tuned circuit is now determined primarily by the inductance of inductor **162** and by the distributed capacitance across its winding. The highest frequency to which the resonant circuit **162** and **164** can be tuned is determined by the distributed capacitance of the coil **162**, conventionally indicated in FIGURE 4 in dotted lines at **163**. Capacitor **164** usually has a value of the order of fifty times the capacitance **163**, which allows a range of resonant frequencies of more than five octaves.

Now by connecting the control element **118** to the variable resistance element **180** it is possible to render the capacitor **164** effective in the resonant circuit to any desired degree by simply adjusting the position of the lever **118**. It is interesting to note that in this circuit, the change in the resonant frequency of the tuned circuit is accomplished without substantially affecting the Q of the resonant circuit.

Referring now to FIGURE 5, similar effects may be obtained in organs of the harmonic synthesis type. Organs of this type use tone generators that ordinarily provide pure sinusoidal wave forms and the various organ tone colors are obtained by combining sine wave signals that are simultaneously derived from a plurality of harmonically related signal sources. The electric organ system **184** of the tone synthesis type has a plurality of output terminals **177, 179, 181, 183, 185, 187,** and **189** adapted to deliver the fundamental, and second, third, fourth, fifth, sixth, and eighth harmonics. It should be understood that in such a system whenever a given key is depressed on the organ keyboard, the plurality of harmonically related signals will all appear respectively at the aforementioned output terminals. When a plurality of keys are depressed, terminal **177** has a composite signal including the fundamentals of all the notes being played; terminal **179** has the octaves, terminal **181** the third harmonics and so on.

Each harmonic component signal is delivered to a circuit having a light-sensitive resistor in series with an adjustable resistor, which latter can be adjusted by the operator in advance of playing, to determine the selected relative amplitude of each harmonic component. Light-sensitive resistor **191** receives the fundamental, and resistors **192, 193, 194, 195, 196,** and **198** the higher harmonics. Conventional means are provided by means of which the player can adjust the relative amplitudes of the different harmonics. These are diagrammatically indicated in FIGURE 5 as variable resistors **200**.

A light shutter **202**, of variable density, lies in front of the light-sensitive resistors, pivoted at **204** and rotatable by the knee lever **118**. In the usual configuration, sufficient light reaches all the resistors **191**, etc. so that some signal will be transmitted, but one or two or three adjacent resistors receive greater illumination and those harmonics are emphasized to determine the timbre of the note produced. Light from the source **206** will reach the resistors **191** etc. in the proportions desired and determined by the shutter characteristics, and movement of the knee lever **118** will produce the desired shift in the emphasized harmonics as the lever is displaced.

The dynamic change can also be produced with an automatically determined time envelope whenever a predetermined time-change cycle is desired, instead of a variation that is dictated by the player's momentary fancy. For instance, a conspicuous timbre change at the inception of each note is a popular feature in certain types of music.

In FIGURE 6, I have indicated a source **250** of negative potential connected to bus **252**. Three of the playing keys are indicated at **254**, **256**, and **258**. Each key is connected to a trigger bus **260**, by a switch **262**, with a resistor **264** between the buses **252** and **260**. Closure of any one key will deliver potential to the terminal **266** of capacitor **268**, equal to the fraction of B-potential, represented by the resistance of resistor **270** between terminal **266** and ground, divided by the sum of the values of resistors **264** and **270**.

When a key is depressed, the change in potential delivers a transitory pulse through trigger capacitor **268** to the base of the trigger transistor **272**, which is normally non-conductive and is rendered momentarily conductive by the pulse.

Normally conductive relay transistor **274** is direct coupled to trigger transistor **272**, which renders it non-conductive momentarily. The relay coil **276** operates to hold switch **278** normally open, but the contact closes when the coil **276** is de-energized.

The momentary current supply through contact **278** charges capacitor **282** and also lights the control lamp **280**, with a timing determined by the RC timing circuit including capacitor **282** and resistor **284**. After contact **278** has opened again, the energy in the capacitor **282** continues the illumination of the light over a decay period determined by the stored energy and the impedance of the lamp **280** itself.

The lamp **280** illuminates the light-sensitive resistor **286**, which thus receives illumination of varying intensity, with a time function consisting of a relatively abrupt, timed rise; and an immediate, much slower, timed decay of the logarithmic decrement type.

Means according to the formant control of FIGURE 4 are provided for causing the initial sound to have a predetermined timbre, and to shift to a different timbre at the rate determined by the logarithmic decrement curve of the decay of the lamp **280**. The lamp **280** performs the function of the knee lever **118** of FIGURE 4, and the light-sensitive resistor **286** corresponds to resistor **180**.

Means are provided for terminating this condition in time to let the system respond to the depression of a subsequent key. The charging of capacitor **268** completes itself very quickly, and the pulse that renders transistor **272** conductive ends, and relay transistor **274** becomes conductive again and contact **278** opens. Diode **273** provides a discharge path in series with resistor **270** for rapidly discharging capacitor **268**, when the voltage at **266** drops in response to the opening of any key switch **262**.

If, now, a second key is depressed while the first key is still held down a second resistor **264** is included in parallel with the first. It will be obvious that if the impedance of one resistor **264** is many times greater than that of resistor **270**, each additional key closure, up to a substantial number, will cause approximately the same potential change on capacitor **268**, and the transistor **272** can be adjusted to respond to that change, so that any number of keys can be depressed seriatim, at least up to the number of available fingers possessed by the player, and each differently timed closure will trigger the automatic formant action.

The formant circuit of FIGURE 6 is also useful for developing repeated change from one tone output to another and back again at frequencies higher than can be generated by manual movements, or when manual movement would be tiresome or interfere with other activities by the player. In FIGURE 7 the same light-sensitive resistor **286** receives its illumination through a rotating screen **288** of variable optical density, driven by a motor **290**, and the timbre change can follow any desired timed envelope function at any desired frequencies, commonly from about one-half to about sixty cycles per second. At certain appropriate frequencies, this can be made to duplicate the frequencies of activation of the strings of a plucked stringed instrument or a xylophone.

In addition, between about 20 and about 60 cycles per second, modulation of timbre or frequency or amplitude produces a gutteral effect closely resembling the acoustic effect produced in brass and other instruments by expert jazz musicians.

In FIGURE 8, I have indicated an organ **300**, a preamplifier **304**, an amplifier **308**, and a loudspeaker **310**. Around the preamplifier **304** is a negative feedback circuit **312**. A second positive feedback circuit **314** feeds back a signal, the phase of which is a function of frequency; and in a certain frequency range, there is positive feedback which results in emphasizing the harmonics within that range. The frequency-sensitive selective feedback **314** is controlled by the knee lever **118**, or equivalent control means. This combination lends itself to use in connection with existing instruments because preamplifiers with negative feedback to reduce noise and distortion are common.

It is emphasized that the resonant frequency of the formant filters does not alter the effective pitch of the entire signal. It only varies the relative amplitudes of the harmonic components of the received complex signal, so that the wave shape, or timbre, of the delivered signal is changed without noticeable change in frequency.

Others may readily adapt the invention for use under various conditions of service by employing one or more of the novel features disclosed or equivalents thereof.

For instance, the preferred control lever **118** (see FIGURE 8) is gently and yieldably held in the full-line position by any conventional means such as gravity or a light spring, indicated at **117**; and its position of rest may be defined by a stop **119**. It will be obvious that an equivalent control member can also be arranged to lie against one side of the player's body at the waist or adjacent the axilla, to please the whim of the player or to facilitate playing by someone with a physical handicap. Any of these control members can obviously be arranged to be positively moved in both directions by the player, but a gentle spring pressure toward the stopped position of rest indicated in the drawings is preferred for ordinary usage.

It happens that, on conventional organ consoles, the left foot plays most of the pedal notes and can play them all, leaving the right foot to ride the swell pedal. This anchors the right foot sufficiently to facilitate an accurate and comfortable swinging of the right knee through a distance of two or three inches and the muscular action involved is easily mastered, without disturbing the muscular control of the swell pedal. Another part of the player's person available for this control is the toe of the right foot, which can be swung laterally an inch or so and activate a control member, or carry the swell pedal **101** around with it by rotation about a vertical axis, with the swell pedal pushing the lever.

As at present advised with respect to the apparent scope of my invention, I desire to claim the following subject matter:

1. In an electrical musical instrument, in combination: a signal source; a signal circuit connected to said source to receive the signal therefrom; means for altering said

signal circuit to alter the timbre of the signal delivered from said signal circuit; automatic trigger control means for rendering said altering means operative through varying degrees in a predetermined time cycle; and player-controlled means for activating said source and said trigger means.

2. A combination according to claim **1** in which said signal circuit includes a formant circuit comprising an inductive component and a capacitive component; said formant circuit having a resonant frequency depending on the values of said components; said altering means changing the effective value of one of said components.

3. In an electrical musical instrument, in combination: a signal circuit; a source of audio-frequency signal connected to said signal circuit; a formant circuit operatively associated with said signal circuit for altering the harmonic content of the signal in said circuit; said formant circuit comprising an inductive element and a capacitive element, each having terminals identified as first and second; said first terminals being connected to each other and to said signal circuit; an impedance connected between said second terminals; means for impressing at the second terminal of one of said elements a voltage synchronous with said audio-frequency signal for varying the effectiveness of said element, and player-controlled means for varying said synchronous voltage.

4. In an electrical musical instrument, in combination: a signal circuit; a source of audio-frequency signal connected to said signal circuit; a formant circuit operatively associated with said signal circuit for altering the harmonic content of the signal in said circuit; said formant

circuit comprising an inductive element and a capacitive element, a connection for delivering signal from said signal circuit to one first terminal of one of said elements; means for delivering to the other, second terminal of said last-mentioned elements, a signal synchronous with the sgnal received by its first terminal; and player-actuated means for varying the amplitude of said second signal.

5. In an electronic musical instrument, in combination: a plurality of signal sources adapted to deliver signals of predetermined frequencies related to each other in the ratios of small integers; a separate channel circuit for each source; a collector bus bar connected to all said channel circuits to receive signal from them; a light-sensitive resistor in each channel circuit for attenuating the signal in that channel as a function of illumination; a light source adapted to deliver illumination to all said resistors; and player-controlled means for simultaneously varying the relative illumination of a plurality of said resistors.

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