Nov. 10, 1970 U. A. MILDE 3,539,701

ELECTRICAL MUSICAL INSTRUMENT

Filed July 7, 1967 3 Sheets-Sheet 1

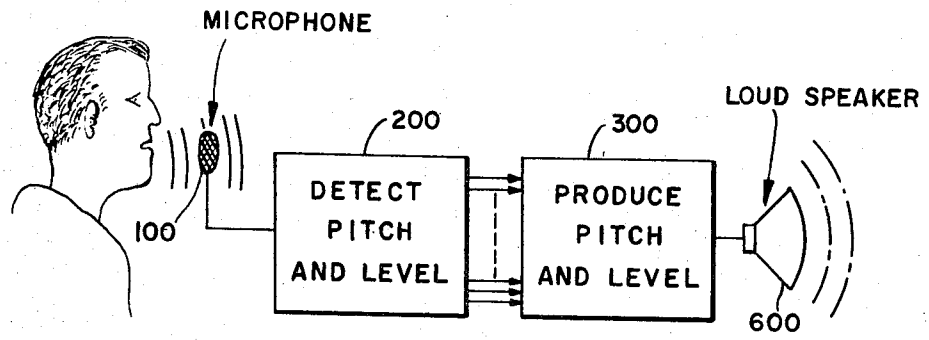



FIG. 1.

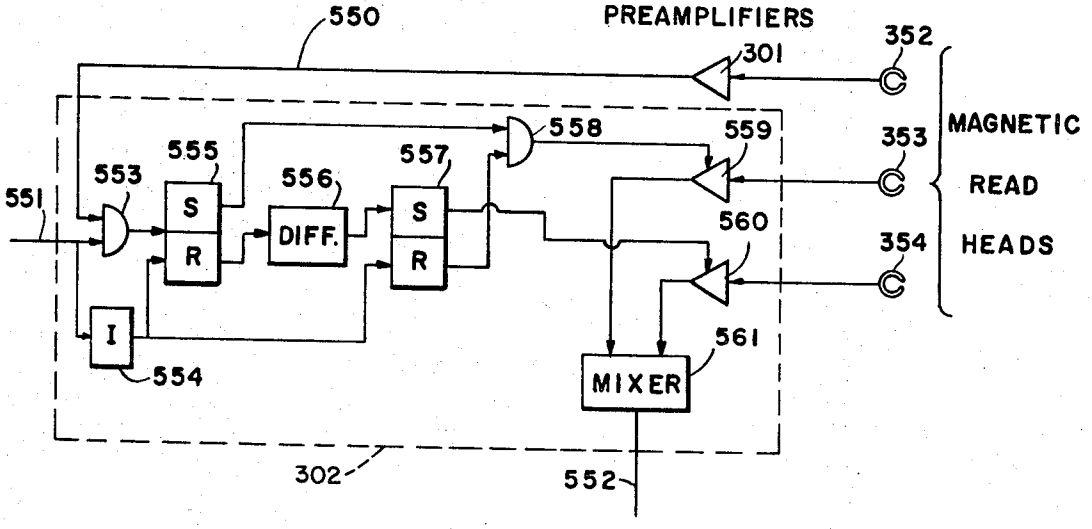
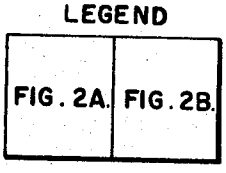



FIG. 3.

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ELECTRICAL MUSICAL INSTRUMENT

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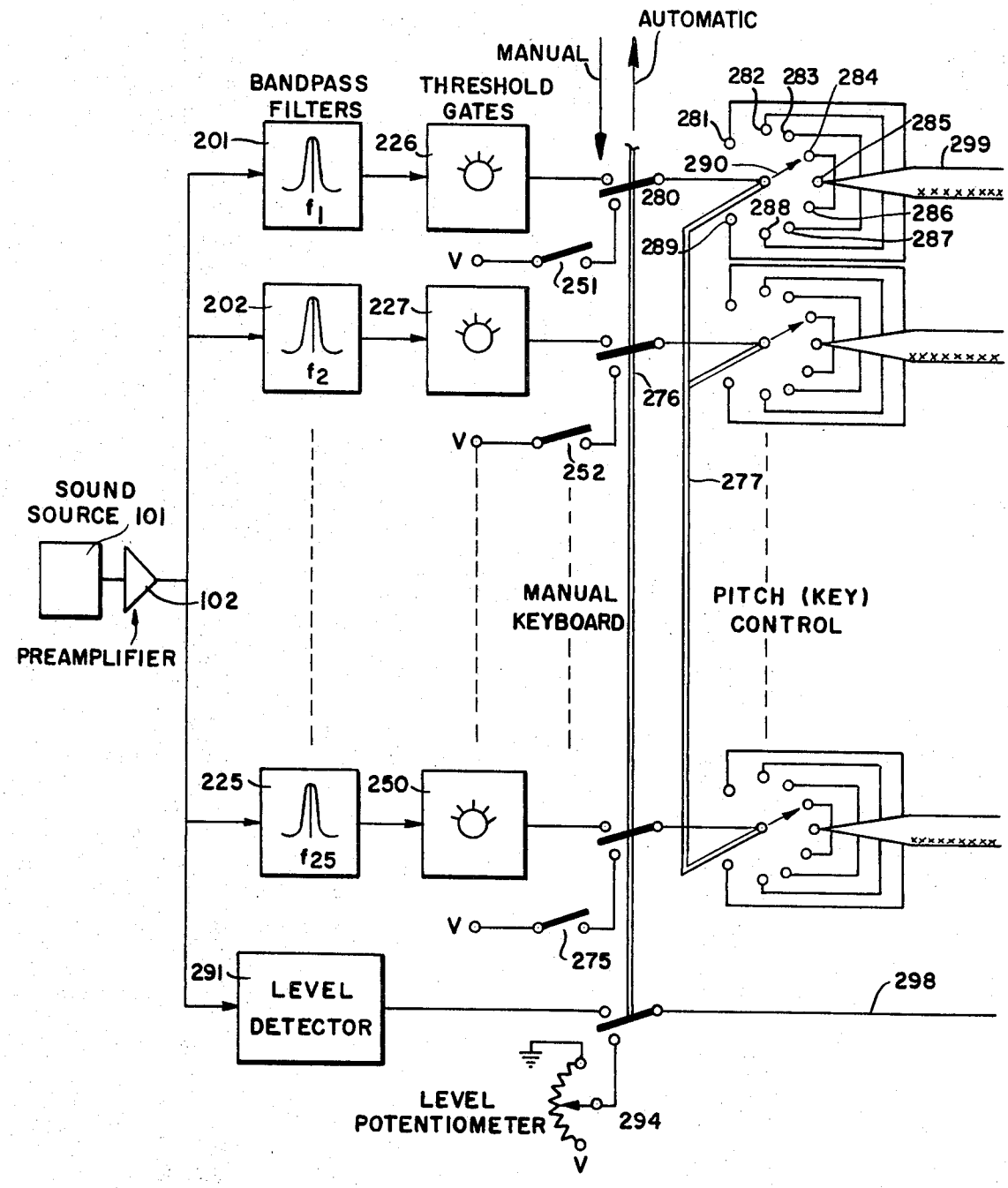


FIG. 2A.

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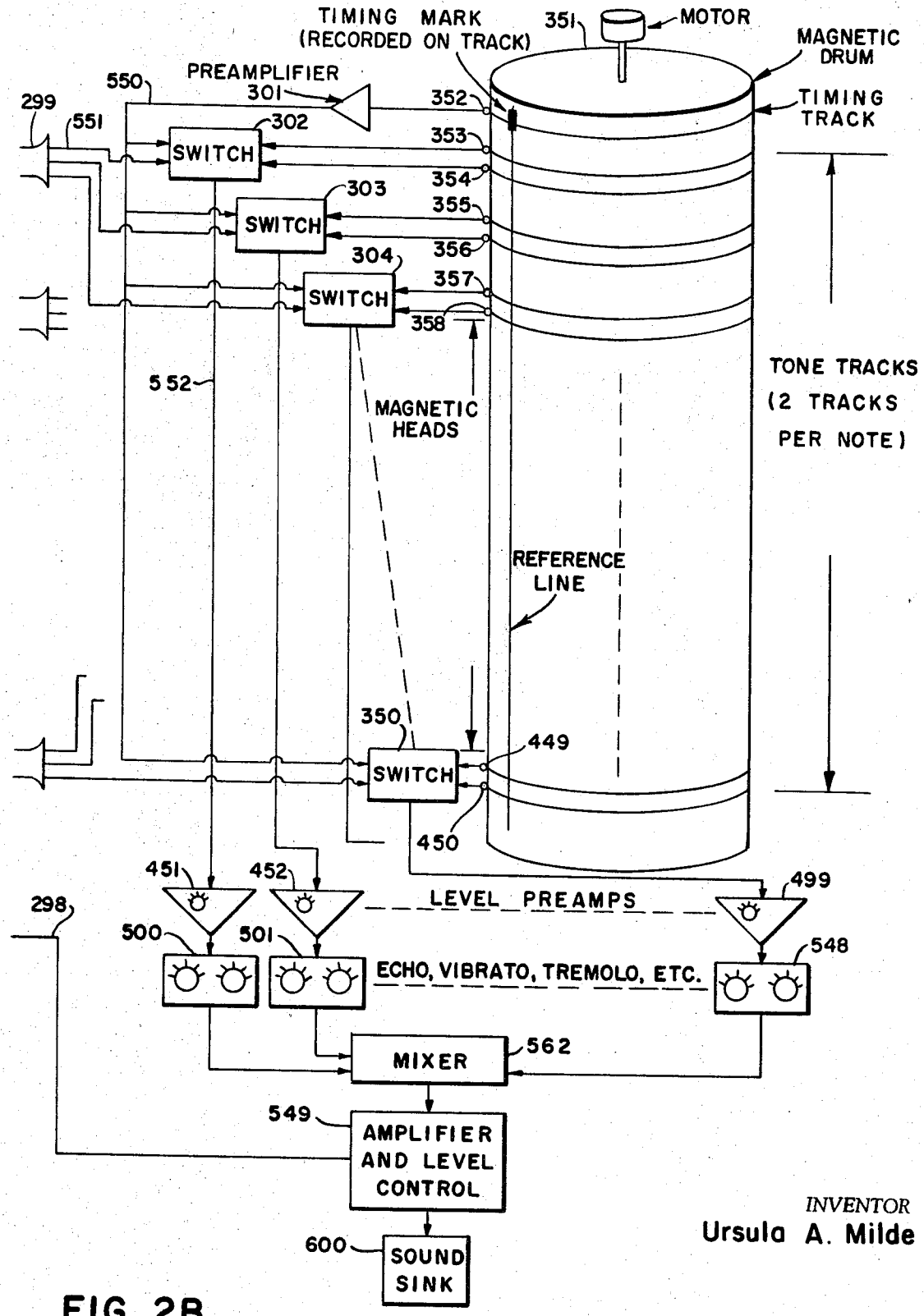


FIG. 2B.

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3,539,701

# ELECTRICAL MUSICAL INSTRUMENT

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Int. Cl. G10h 3/04
U.S. Cl. 84—1.28 16 Claims

## ABSTRACT OF THE DISCLOSURE

A method and apparatus for electrically generating musical sounds. The invention consists of a device for detecting the pitch and level of an input audio signal and a further device for generating the note of any recorded instrument of corresponding pitch and level. The detecting device consists of a plurality of parallelly connected bandpass filters which drive an identical number of adjustable threshold gates. The output of the threshold gates is used to select a note of particular pitch at the generator. The detecting device further consists of a level detector which controls the output level of the generator. The generator consists of a magnetic recording drum upon which are recorded two tracks for every note it is able to produce, one for the transient or attack characteristic of the note and the other for the steady state. The generator receives instructions as to the pitch of the note to be played, plays first the transient, then the steady state at a level prescribed by the level detector.

## BACKGROUND OF THE INVENTION

The present invention relates to a method and apparatus for generating musical sounds, more particularly, the sound of any desired instrument.

Many devices have been invented in past which simulate the sounds of the standard musical instruments, notably that of the pipe organ. A few have used the technique of recording the audio signal of every note of the musical scale on a magnetic drum or disc, and, at the desired moment of play, reading the note into an amplifier and, in turn, a loudspeaker. This latter system has the advantage that it may literally reproduce the sounds of the best instruments in the world. If the generation of a violin sound is desired, for example, a Stradivarius instrument might be used in the original drum or disc recording.

This system as described has never been practical for the reason that only the steady state sound of any instrument could be recorded. An important characteristic of the tone of any musical instrument is the sound it makes when the tone is begun. This characteristic, called the "attack," is a transient which varies from instrument to instrument, from note to note. It is an extremely complicated addition of harmonics with time varying amplitudes, which, for all practical purposes, defies direct generation.

The present invention additionally relates to a method and apparatus for playing a device which generates musical sounds, more particularly for receiving musical sounds of one instrument, detecting level and pitch, and controlling the production of sounds, by the generator, of another musical instrument.

There has long been a need, in the musical circles, for a device which would enable the player of one instrument to play another. Musicians have learned to play a plurality of instruments in the past, but have invariably found that best proficiency came with specialization. Various mechanical devices have been invented to bring similarity between the "operation" of instruments, however, none



have used the actual sound of one instrument to choose the notes of another.

## SUMMARY OF THE INVENTION

It is an object of the present invention to provide a musical signal generator of the recording type which also reproduces the attack characteristic of the instrument recorded.

It is a further object of the present invention to provide method and apparatus for the generation of musical sounds of one instrument in accordance with the notes played on another.

These and other objects which will hereafter become apparent are achieved by a device consisting of a number of bandpass filters each adjusted to pass only the frequencies in the immediate vicinity of one note of the well tempered scale, a corresponding number of threshold level detectors each connected to a bandpass filter for determining when a note has been played, and a magnetic recording drum, having two tracks per note, one track capable of reproducing the attack characteristic, the other, the steady state of any musical instrument, operatively connected to the threshold detectors so that first the attack and then the steady state of any note is generated in response to a signal therefrom. The device is thus capable of "hearing" what note is sung or played by the musician, converting this information into signals denoting the pitch and level of the sound heard, and reproducing the sound of any desired instrument, in accordance with these signals, at the same pitch and level.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram showing the overall system which forms the basis of the instant invention.

FIG. 2A is a schematic diagram showing the pitch and level detector of the preferred embodiment of the instant invention.

FIG. 2B is a schematic diagram showing the musical signal generator according to the preferred embodiment of the present invention.

FIG. 3 is a schematic diagram showing one type of magnetic head control switch that may be used with the signal generator of the present invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 of the drawings is a block representation of the apparatus and method that forms the basis of the invention: apparatus and method wherein musical sounds of one instrument may be converted to the musical sounds of another. Sound waves of any pitch, level and quality impinge on microphone **100** where they are converted to corresponding electrical oscillations. The pitch of the fundamental note, as well as the level or intensity of the tone is isolated in electronic device **200** and the information transmitted to a musical tone generator **300**. The generator **300** is capable of producing the electrical signal facsimile of the musical note of any given musical instrument, with the possible exception of the human voice, at an intensity corresponding to that detected by the device **200**. This electrical signal is then passed to a loudspeaker **600**.

It will be appreciated that the system shown in FIG. 1 is neither limited to a single pitch and level detector nor a single producer. One detector may be used, for example to feed a number of electronic tone producers each generating the sounds of a different musical instrument. Likewise a single tone producer generating, say, the sounds of an organ, may be fed by various detectors adjusted to detect the pitch and level of various other instruments to provide a number of organ "voices" or simultaneous lines of music.

A complex system is readily contemplated whereby any number of detectors may be switched into service to control any desired number of tone generators. As will be explained in more detail below, the tone generators need not necessarily produce sound at the pitch emitted by the source instrument but might be further switchable to permit the production of music in any desired key.

FIG. 2A depicts the preferred embodiment for detecting pitch and level. Electrical oscillations in the audio range originate at the sound source **101** which may be a microphone; a magnetic tape, magnetic drum, phonograph or motion picture reproducing head; a ratio or television audio output or any similar device. These oscillations may be amplified if necessary by introducing a preamplifier **102** into the circuit.

The electrical oscillations are then fed to a number of bandpass filters **201** to **225** of conventional design arranged in parallel. These filters are each tuned to a note in the welltempered scale with a "Q" sufficient to distinguish notes a "half-tone" apart. Since the welltempered scale consists of thirteen notes in an octave, each, as is well known, defined by a particular frequency, a pitch detector with the normal musical instrument and singing voice range of two octaves must comprise twenty-five such filters. If the musical sounds to be detected are to occur in the lower musical registers it might be necessary to insert a frequency doubler in the circuit after the preamplifier and to set all bandpass filters to a frequency an octave higher. This technique will overcome the practical difficulties of obtaining the necessary "Q" where the difference of a half-tone is but a few cycles per second.

The output of each bandpass filter is connected to the input of a separate adjustable threshold gate. Twenty-five threshold gates **226–250** have been indicated for this purpose in the diagram. The object of the threshold gates, which are of conventional design, is to produce a voltage at the output if the input voltage exceeds a given value. If the input voltage is less than the "threshold" the output is either at ground or at least at some other potential. It is common in the art to call the former output a "1," the latter a "0"; this nomenclature will hereinafter be used. The threshold gate is commonly called a "Schmitt trigger."

The circle in the center of blocks in FIG. 2A, as well as FIG. 2B, from which emanate the short hash marks is intended to indicate that the device represented by the block is subject to the manual adjustment of some parameter. The threshold voltage of the threshold gates must here be adjustable so as to cause a "1" only when the fundamental of any note has passed through the bandpass filter. Harmonics as well as unwanted background may, in this simple manner, be excluded from detection. Since the amplitude range of any given note varies from instrument to instrument, and of any given instrument even from note to note, the use of the detector to distinguish notes of more than one instrument necessitates the availability of manual adjustment.

The outputs "1" or "0" of the parallel threshold gates may be directly connected to the musical signal generator shown in FIG. 2B and discussed in detail below. In this case they would each be simply connected to a separate magnetic head control switch; if there be 25 threshold gates, to 25 control switches.Two further features are shown in FIG. 2A, however, which may be inserted intermediate between the threshold gates and the control switches. The first permits the manual operation of the signal generator by keyboard, and the second the selection of musical key.

Since the musical signal generator is capable of producing the sounds of practically any musical instrument, it permits the musician to conveniently "play" all instruments without laboriously learning their technique. If the musician can operate a keyboard, as for example, a piano keyboard, he can "operate" the musical instrument which the musical signal generator is designed to imitate. Single-



pole, single-throw switches **251–275** biased with a mechanical spring or some other device to hold them normally open, serve, when manually depressed, to provide a "1" signal to the magnetic head control switch of the musical signal generator. When open they provide a "0." These switches are physically in the form of push buttons, piano keys, or any other configuration which is easy to "play."

One terminal or circuit point of the switches **251–275** is connected to a source of voltage V, which potentially represents a "1." The other terminal or circuit point is connected through switch **276** to the magnetic head control switch of the musical signal generator. Multiple pole, double throw switch **276** permits setting the apparatus to "automatic," whereby the pitch and level detector are connected into the circuit, or to "manual." In the manual setting terminal switches **251** to **275** as well as a level potentiometer are connected to the musical signal generator. It will be appreciated that the "1" signal, which is to be generated by closing the switches **251–275**, can be represented by any other potential as well, including a negative potential or even ground.

The output of either the pitch detector (automatic setting) or the manual keyboard (manual setting) may then either be connected directly to the magnetic head control switch of the musical signal generator or to a key control switch **277**, as shown in FIG. 2A. The key control switch is simply a multiple pole (one per input note channel) multiple throw (one per output note key) switch which connects all input note channels to a number of possible magnetic head control switches. This switch enables the operator to "play" the input in one key, say C major, and produce signals and, of course, by loudspeaker, sounds in any other. If the keyboard is used, this feature would permit an operator to always play in his most accustomed key while choosing any other. If the pitch and level detector is used to detect, for example, voice sounds from a microphone, the singer need only sing in his most comfortable register.

The switch **277** comprises a number of input circuits **290** which each may be selectively connected to a number of output circuits **281** to **289**. The output circuits pass through a cable **299** to the musical signal generator where each is connected to a magnetic head switch. The output circuits can thus be connected with any desired magnetic head switch to give the desired key; the simplest and most obvious format would be a connection of the input notes so as to selectively generate notes up to, say 4 half notes below, and 4 half notes above the note played as well as the note itself.

The sound source generated signal is also connected to a level detector **291** which produces a D.C. voltage output in proportion to the A.C. voltage input. Any known technique such as integration may be used to obtain this result. The D.C. output is passed through switch **276** on line **298** to the musical signal generator where it is used to control the level of the output as described in detail below.

In the event that the operator wishes to control the output level manually, either switch **276** or a separately provided switch may be used to disconnect the level detector and connect a potentiometer **294**. This potentiometer permits setting the D.C. voltage on line **298**, at will, anywhere from zero to "V" as shown in FIG. 2A. The signal generation mechanism thus normally operates to produce higher musical volume the greater the voltage.

FIG. 2B, showing the preferred embodiment of the musical signal generator, will now be described. This device employs a magnetic drum **351** of conventional design having two tracks for every note to be produced. The steady state tone of a musical instrument is recorded completely around one track at a constant level so that the drum may turn more than one complete revolution without any consequent break in the signal. This requirement necessitates more than the mere recording of a note

on one circumference of the drum; the tail of a single circumference must be placed in phase with the head of the recorded signal so that no audible change in the tone occurs at the joinder of head and tail. The phase may be adjusted by slightly increasing or decreasing the frequency of the entire recorded signal, a process best carried out by adjusting the speed of the recording from which the drum recording is made.

The second track for each note recorder on the magnetic drum carries the starting transient or "attack" characteristic of the musical instrument represented. This characteristic is recorded in one circumference of the drum beginning in the case of every note at a certain reference line drawn in the axial direction along the face of the drum. Since the time length of the attack characteristic varies from instrument to instrument and even with one instrument from note to note it will be necessary either to adjust the circumference of the drum or the speed of the drum's rotation so that the attack transients are completely damped for all the notes in exactly one revolution.

The magnetic drum shown in the diagram is provided with forty-nine dual tone tracks, twelve per octave for four octaves and an additional one making the highest note four octaves above the lowest. The drum has a single additional timing track on which, precisely where the track crosses the reference line, is recorded a timing mark or blip. Ninety-nine magnetic recording heads **352** to **450** are arranged in an axial line, one per track, to read the tracks described above. The tone track heads are connected directly to the magnetic head control switches **302–350**, of which there are also forty-nine, one per dual tone track, or in other words, one for every two heads. The timing track magnetic head **352** is connected through a preamplifier **301** to each of the magnetic head control switches. The magnetic heads **352–450**, the preamplifier **301** and the control switches **302–350** constitute means, according to this embodiment of the present invention, for reading first the attack transient and then the steady state characteristic of a desired musical note or notes from the plurality of recorded notes.

The reference line described above need not, of course, be a physical line drawn on the magnetic drum. Its purpose is merely to insure that the start of the attack characteristics are all aligned with the timing mark as recorded on their respective tracks. It may be helpful during drum recording to actually have a visible line; however, this depends on the manufacturing processes used.

The magnetic head control switches **302** to **350** will be further described below in connection with FIG. 3 and the discussion of operation of the musical signal generator. Suffice it now to say that the output of each is the composite of the transient and the steady state recorded signals; that is, a single musical note. Each control switch is connected to its own level preamplifier **451** to **499** wherein the signal is amplified an adjustable amount. Not shown but useful is an adjustable note "end" control connected in each channel and to the pitch and level detector which anticipates the end of the note and drops the volume gradually, not abruptly as would be the case with the presently shown apparatus.

To the level preamplifiers or note end control devices may be attached other commonly known devices **500** to **548**, such as the echo, vibrato or tremolo generators. These devices should be individually manually adjustable in all the significant parameters; namely period, amplitude, attack and damping transients, etc., or attached to some device which detects these parameters in the input to the pitch and level detector for automatic control of same. The various channels are finally combined in a mixer **562**, and fed through a final amplifier **549** which includes the level control. This amplifier **549** responds to the voltage on line **298** to produce an output signal of corresponding amplitude. This control function is most easily accomplished by using the voltage from line **298** to bias the first stage of amplification. The lower the bias the lower the output signal from that particular stage.

The final signal emerging from the amplifier **549** is fed to a sound sink, which can be a loudspeaker, magnetic tape or phonograph recording head, motion picture sound recording head or the like.

Turning now to FIG. 3, which illustrates one type of magnetic head control switch that may be used with the present invention, it is necessary to briefly state the modus operandi of the musical signal generator. The two recording heads for any note constantly read the transient as well as steady state tone tracks and pass these to the magnetic head control switches. As soon as the control switch receives a "1" input from the pitch detector described in connection with FIG. 2A:

(a) it waits until it receives the next timing signal from timing track head **352** and preamplifier **301**;
(b) upon receipt of the first timing signal it connects the transient recording head, through a preamplifier, to the output;
(c) upon receipt of the second timing signal (denoting one complete revolution of the drum), it disconnects the transient recording head and connects the steady state recording head, through a preamplifier, to the output;
(d) it maintains the final connection mentioned above, the receipt of further timing signals notwithstanding, until the input from the pitch detector returns to "0." While the input is "0," of course, both recording heads remain disconnected from the output.

It is therefore seen that first the transient, then the steady state is read from the recording of any given note. There is a short waiting period between the "playing" of a note and the production of same until the magnetic heads next cross the reference line but, as the length of the attack characteristic is short, usually in the neighborhood of $\frac{1}{10}$ second, this period will not be noticeable. It is interesting to note in this regard that these instruments with the longest attack characteristic are just those instruments that must be played the slowest and for which, therefore, the waiting period will be less noticeable. Compare, for example, the bass (slow, long characteristic) and the violin (fast, short characteristic).

FIG. 3 depicts two flip-flops **555** and **557**, capable of being triggered by positive going pulses, AND gates **553** and **558**, inverter **554**, differentiator **556**, mixer **561** and controllable preamplifiers **559** and **560**. The input **551** from the pitch detector, normally "0" but in the "1" state when a note is to be played, passes through AND gate **553** upon coincidence with a timing signal on line **550** from magnetic head **352** and preamplifier **301**. Since the flip-flop **555** was held in its reset state "R" by the positive signal from inverter **554**, it will change to the set state "S" on the occurrence of the "1" and the first timing mark. The AND gate **558** will then pass the set output signal to preamplifier **559** to enable the transient signal from magnetic head **353** to pass through mixer **561** to the output line **552**. The other input to AND gate **558** will be "1" since flip-flop **557** has been constrained to start in the reset state by a signal from inverter **554**. The preamplifiers **559** and **560** operate as signal gates, permitting the recording signal to pass from the magnetic heads **353** and **354** to mixer **561** if and only if a "1" appears on the respective enable inputs.

When the second timing mark is read the signal is passed through AND gate **553** to reset flip-flop **555**. The set output signal ceases and the recorded signal from head **353** is halted at preamplifier **559**. The presence of a sudden increase in voltage at the reset output of flip-flop **555**, however, causes the differentiator **556** to produce an output pulse setting flip-flop **557** and enabling the recorded signal from the steady state magnetic head **354**. This signal is also passed through the mixer **561** to the output line **552**.

Flip-flop **557** will remain in the set position until the input on line **551** changes from a "1" to a "0." The inverter **554** will then reset both flip-flops and hold them there until the note, which the particular magnetic head control switch controls, is played again. It will be noted that flip-flop **555** oscillates between the set and reset conditions while the note is played but is only functional in the control switch while flip-flop **557** remains reset.

Although this invention has been described with reference to a specific illustrative embodiment thereof, it will be understood that various modifications, elaborations and alterations will occur to those skilled in the art which do not depart from the essential spirit of the invention.

What is claimed is:

**1.** An electrical musical instrument comprising, in combination:

(a) first input means for producing at least one signal determinative of the pitch of a musical note to be played;

(b) recording means having both the attack and the steady state characteristics of a plurality of musical notes recorded thereon;

(c) reading means, connected to said first input means, for reading from said recording means first the attack, then the steady state characteristic, of said note to be played upon receipt of said signal from said first input means.

**2.** The electrical musical instrument defined in claim **1**, wherein said first input means comprises a source of electrical signals representative of musical sound and means, connected to said signal source, for producing said at least one signal determinative of the pitch of the musical notes of said musical sound.

**3.** The electrical musical instrument defined in claim **2**, wherein said signal producing means comprises a plurality of frequency filters connected to said signal source.

**4.** The electrical musical instrument defined in claim **3**, wherein said frequency filters are connected in parallel and said signal producing means further includes a plurality of threshold gates, connected to said frequency filters, for producing an output only if the output of a frequency filter exceeds given level.

**5.** The electrical musical instrument defined in claim **1** wherein said first input means comprises a voltage source, a plurality of circuit points and a plurality of switches each of which connects said voltage source to one of said circuit points.

**6.** The electrical musical instrument defined in claim **1** wherein said recording means is a rotating drum having a plurality of recording tracks wherein on one of said tracks is recorded at least one timing mark; on half the rest of said tracks are recorded the attack characteristics of said plurality of musical notes, one characteristic recorded on each one of said tracks; and on the other half of said rest of said tracks are recorded the steady state characteristics of said plurality of musical notes, one characteristic recorded on each one of said tracks.

**7.** The electrical musical instrument defined in claim **6**, wherein said recording means is a magnetic recording means.

**8.** The electrical musical instrument defined in claim **6**, wherein said reading means includes a plurality of read heads, each of said heads being arranged to read one of said recording tracks, and wherein said reading means further includes means responsive to said first input means for connecting selected ones of said read heads to an output.

**9.** The electrical musical instrument defined in claim **8**, wherein said connecting means is connected to a read head arranged to read said track having said timing mark recorded thereon, and wherein said connecting means is operative, responsive to said first input means,



(1) to connect to said output, in response to a first reading of said timing mark, the read head arranged to read the attack characteristic of said note to be played;

(2) to connect to said output, in response to a further reading of said timing mark, the read head arranged to read the steady state characteristic of said note to be played; and

(3) to disconnect from said output, responsive to said first input means, the read head arranged to read the steady state characteristic of said note to be played.

**10.** The electrical musical instrument defined in claim **1**, further comprising amplifier means connected to said reading means.

**11.** The electrical musical instrument defined in claim **10**, further comprising loudspeaker means connected to said amplifier means.

**12.** The electrical musical instrument defined in claim **1**, further comprising second input means for producing a signal determinative of the level of said note to be played, and output means, connected to said reading means and to said second input means, for producing an output signal representative of said note to be played, the level of which is dependent on the signal received from said second input means.

**13.** The electrical musical instrument defined in claim **12** wherein said second input means comprises a voltage source, a circuit point and a variable voltage divider connecting said source to said circuit point.

**14.** The electrical musical instrument defined in claim **12**, wherein said second input means comprises a source of electrical signals representative of musical sound and a level detector, connected thereto, for producing an output which depends upon the level of said musical sound.

**15.** The electrical musical instrument defined in claim **14**, wherein said electrical signal source produces a signal which is an analog representation of said musical sound and said level detector produces an output which depends upon the average level of said signal produced by said signal source.

**16.** Apparatus comprising, in combination:

(a) a signal source, said signal being representative of at least one first musical note;

(b) means connected to said source, for detecting the pitch of said at least one first note; and

(c) means, connected to said pitch detecting means, for producing at least one second musical note, the pitch of which is dependent on the pitch of at least one of said at least one first note, said producing means including a record medium having a plurality of tracks, said tracks having the attack characteristic and the steady state characteristic representative of a plurality of musical notes recorded thereon, and said producing means further including reading means for reading first the attack characteristic and then the steady state characteristic of at least one selected recorded musical note in response to said detecting means, said at least one selected note being said at least one second musical note.


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U.S. Cl. X.R.

84—1.26