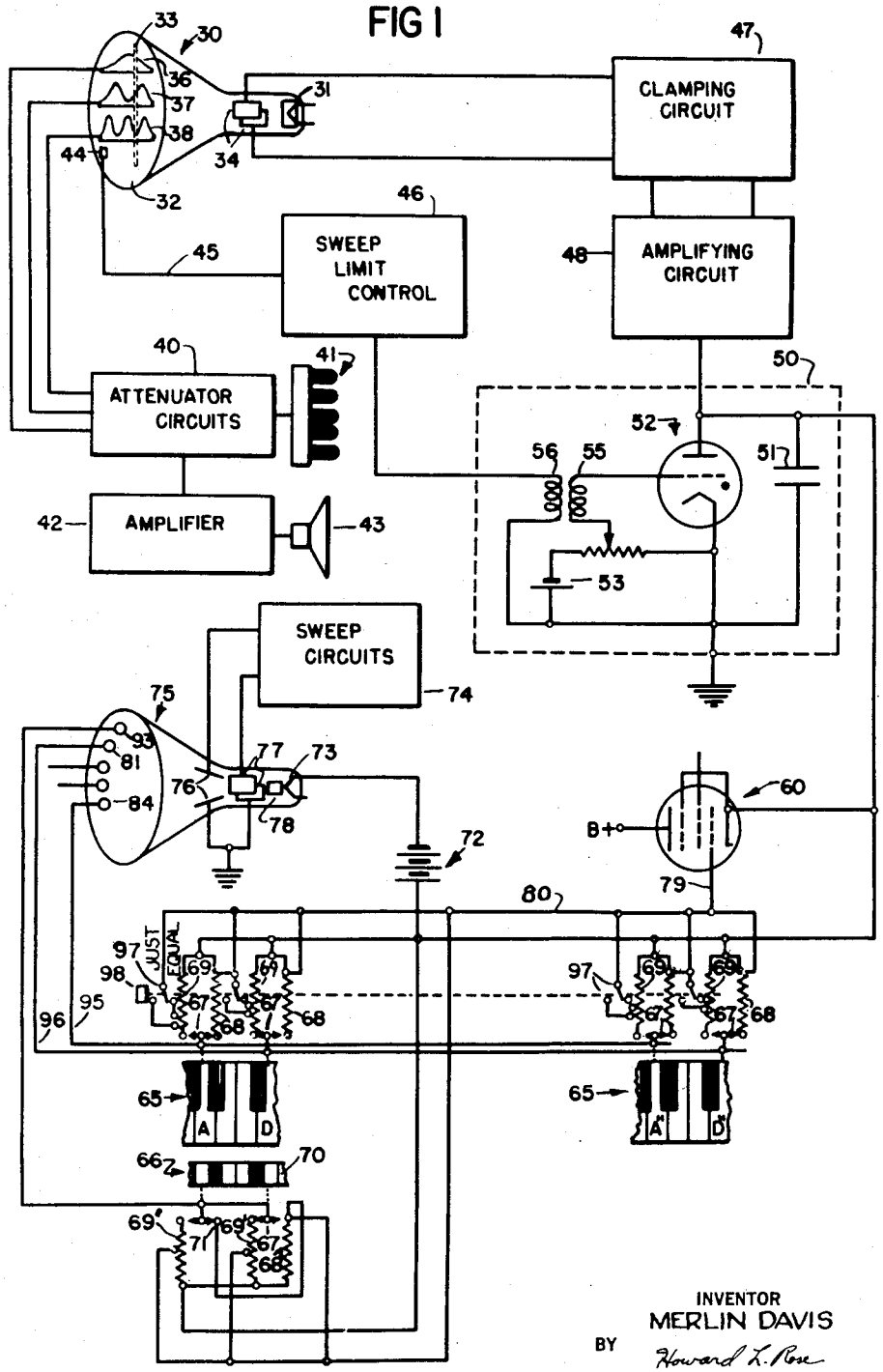
ELECTRONIC MUSICAL INSTRUMENTS

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FIG 1



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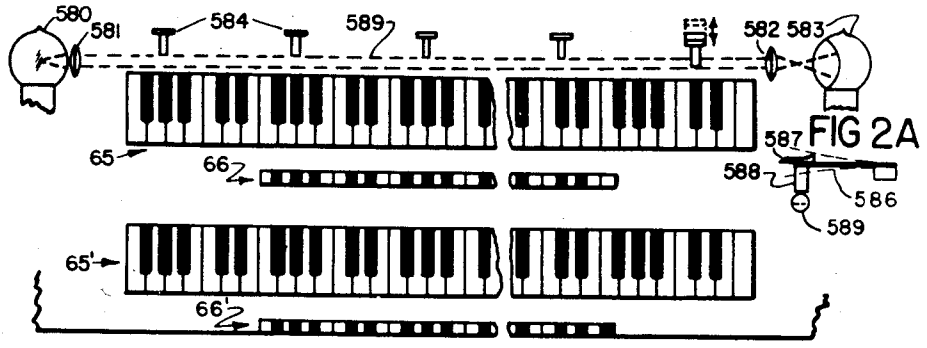


FIG 2A

FIG 2

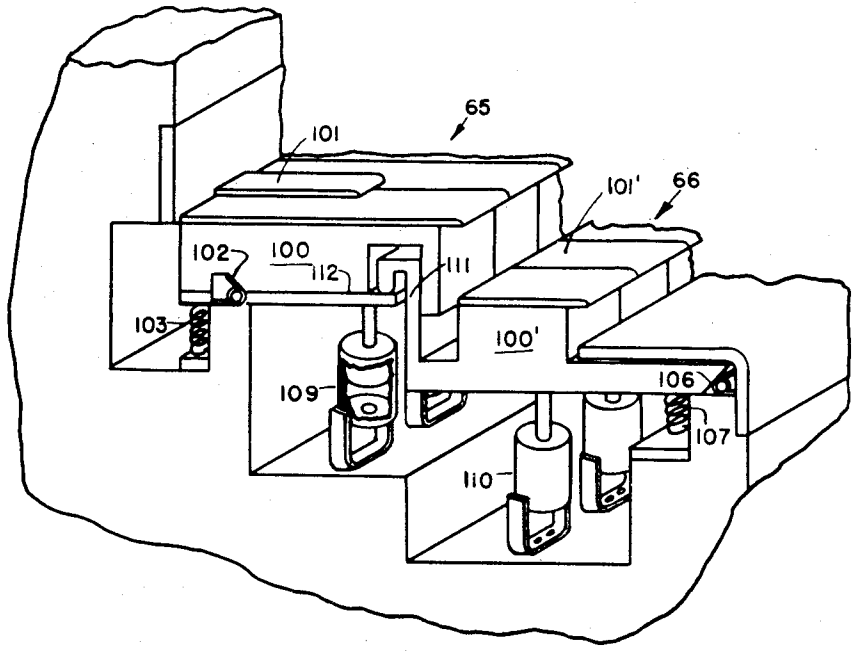


FIG 3

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FIG 4

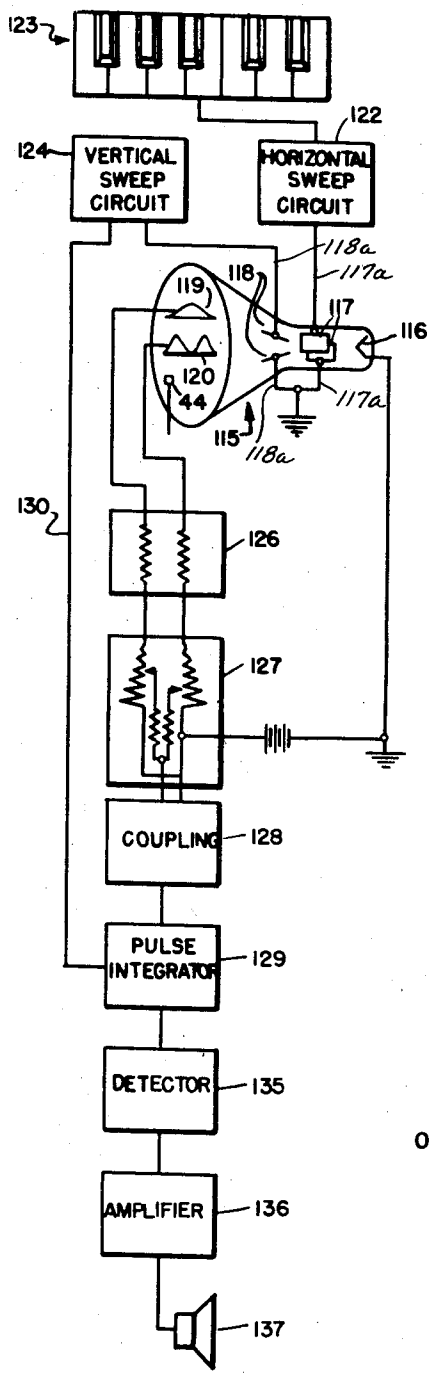


FIG 5a

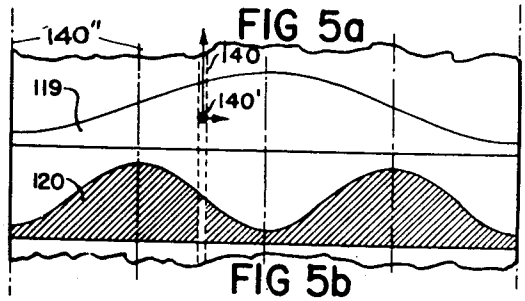


FIG 5b

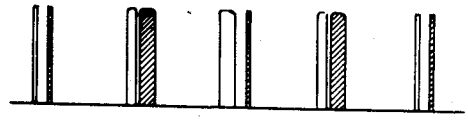


FIG 5c

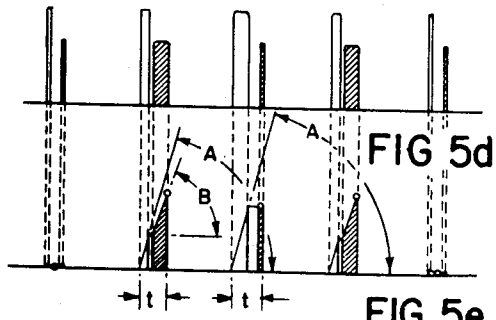


FIG 5d

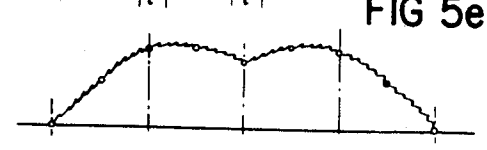
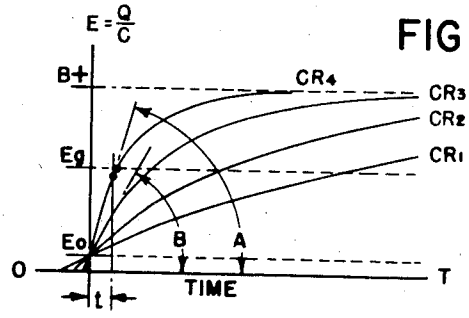


FIG 5e

FIG 5f



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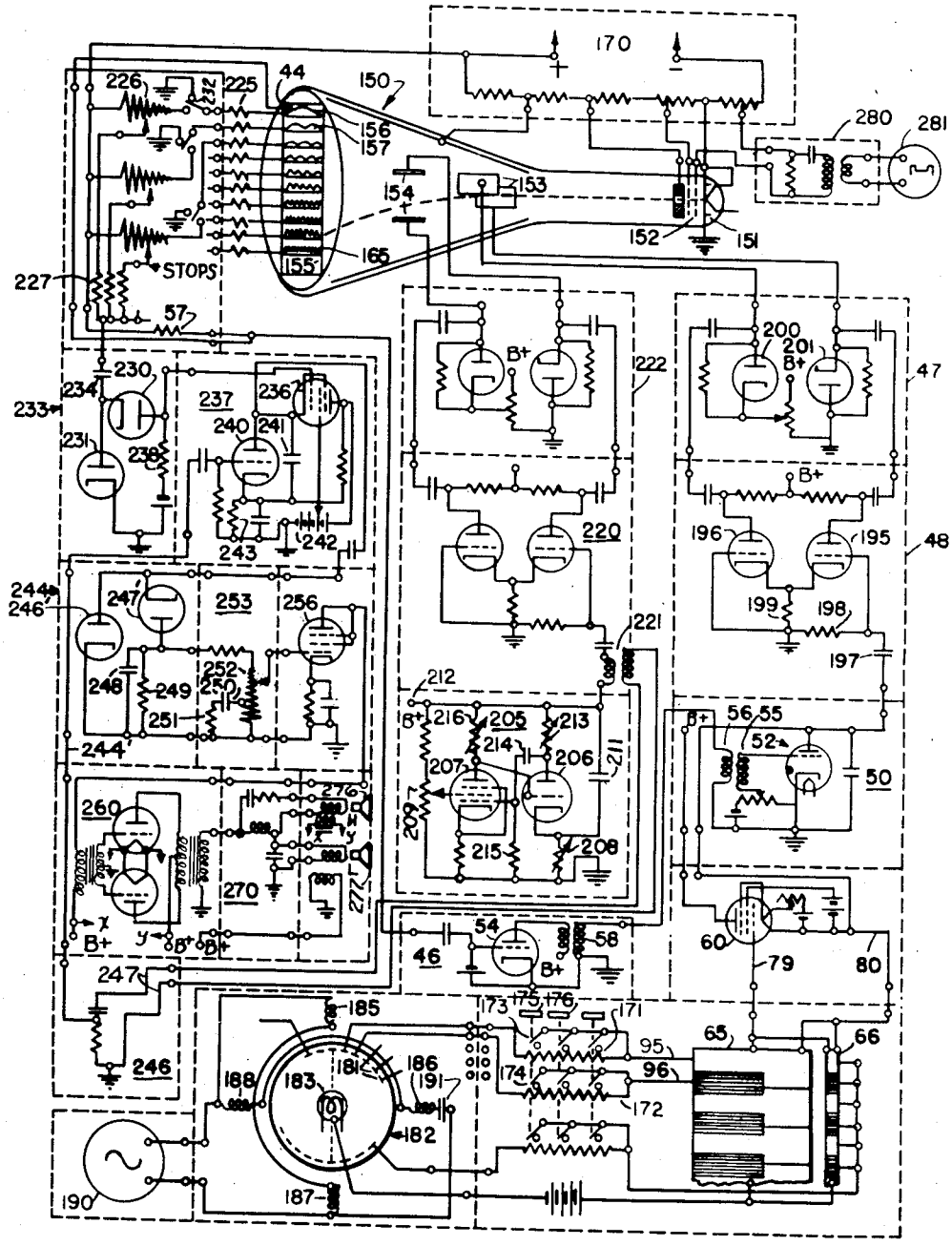


FIG 6

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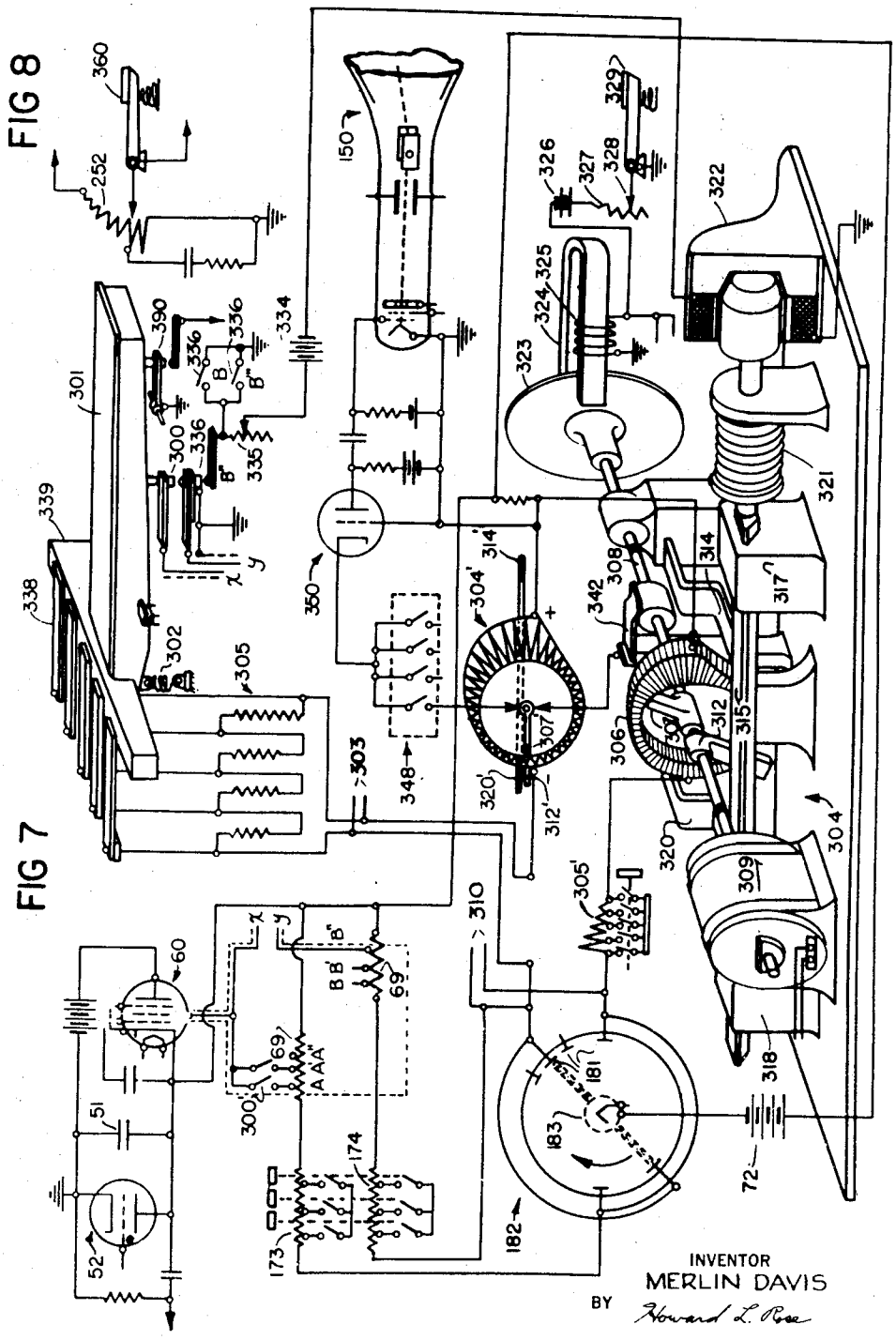
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FIG 8

FIG 7



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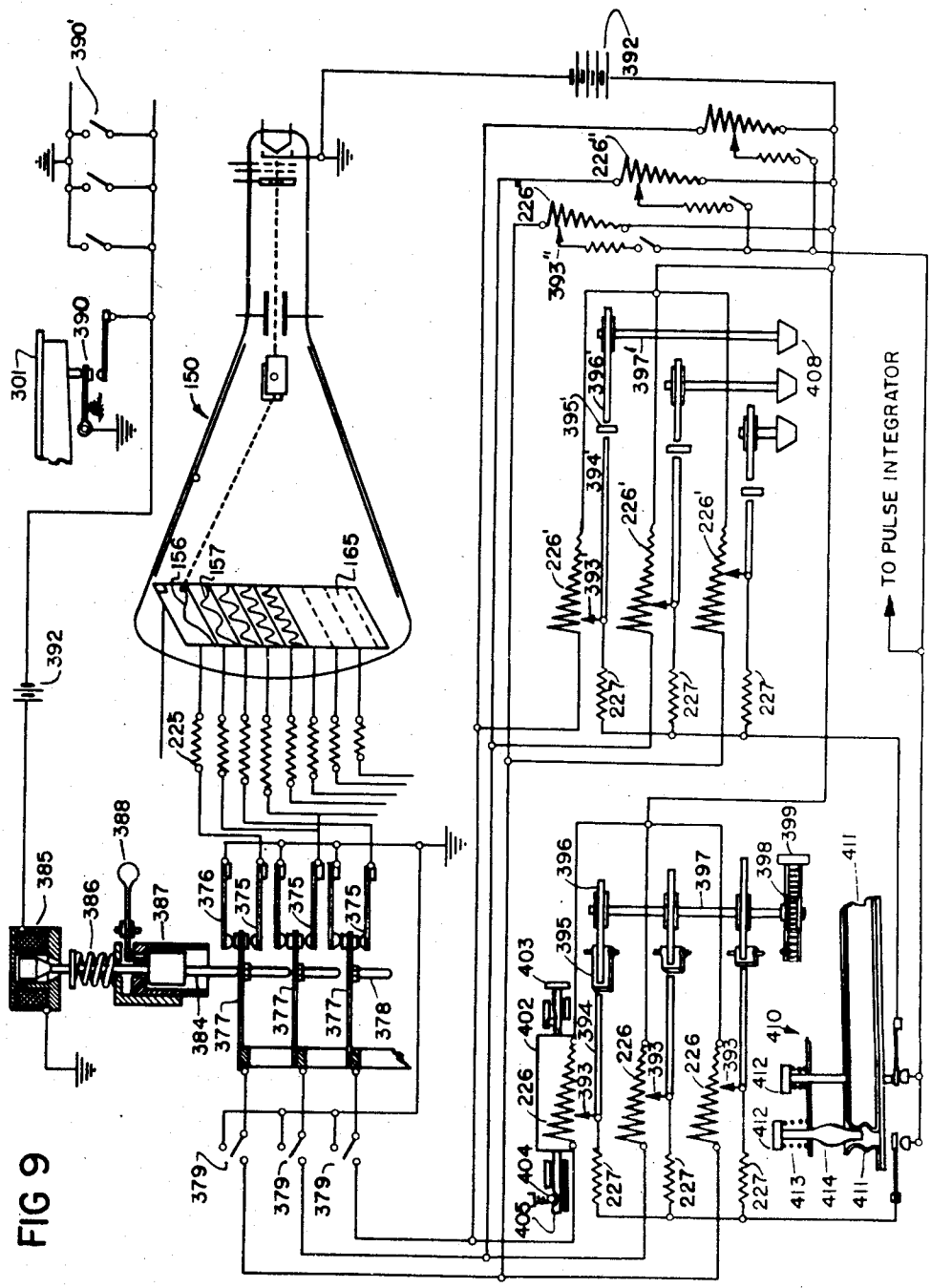


FIG 9

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FIG 11

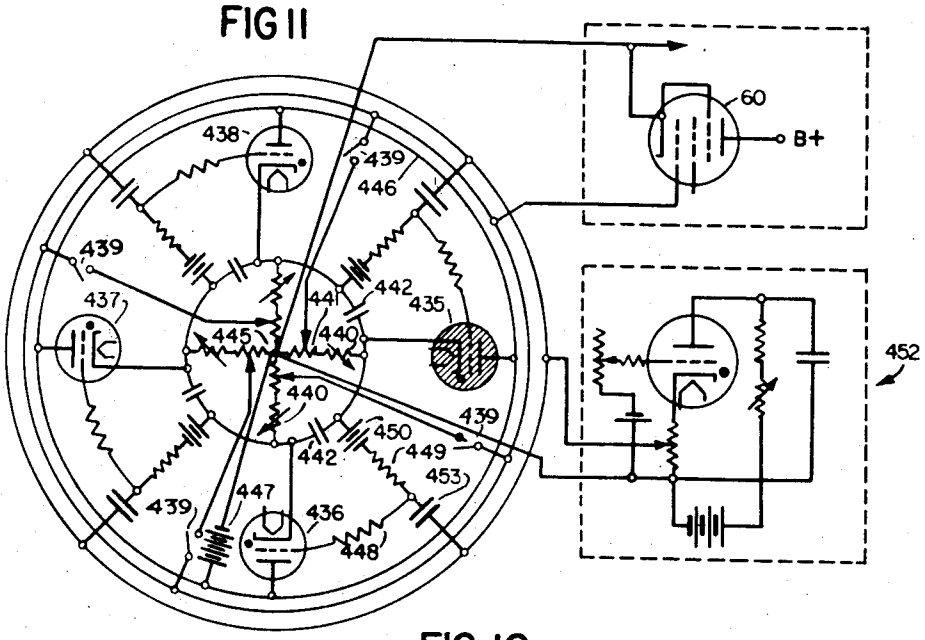
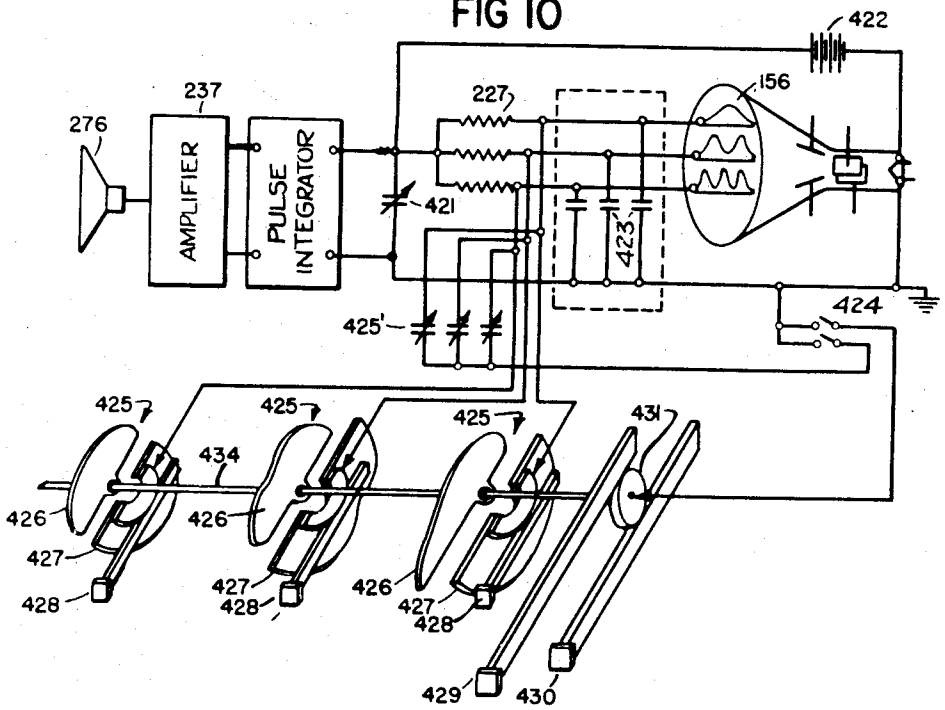


FIG 10



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FIG 12

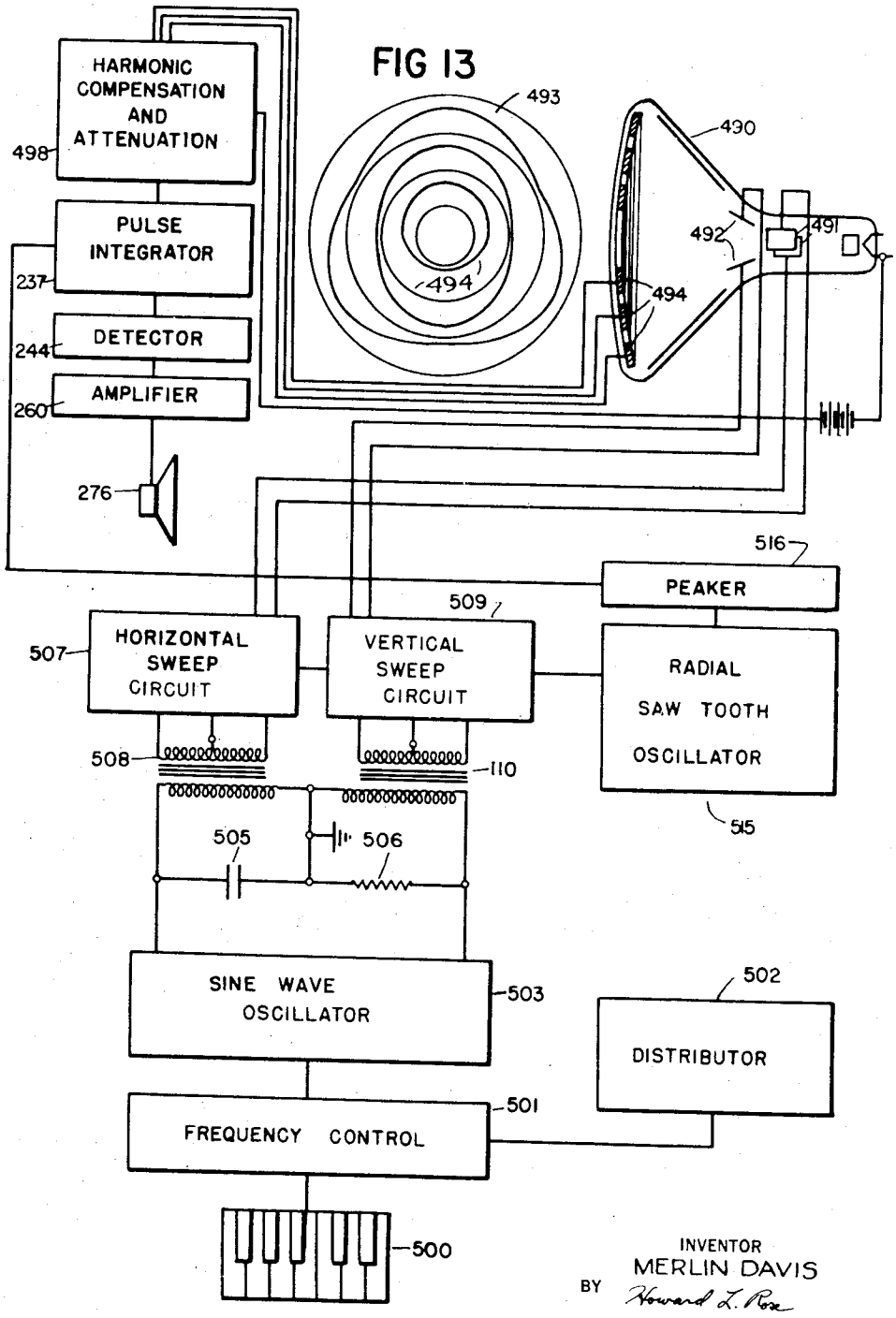


FIG 13

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FIG 14

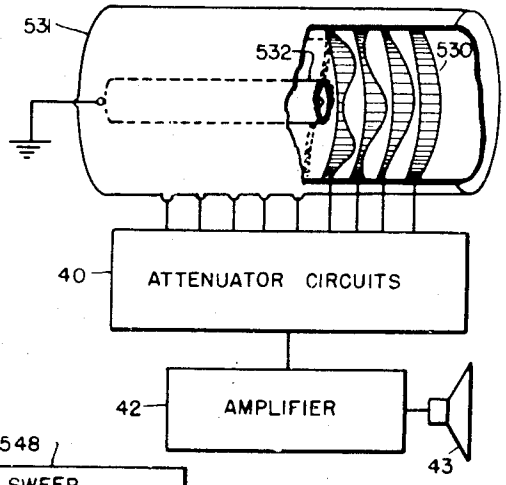
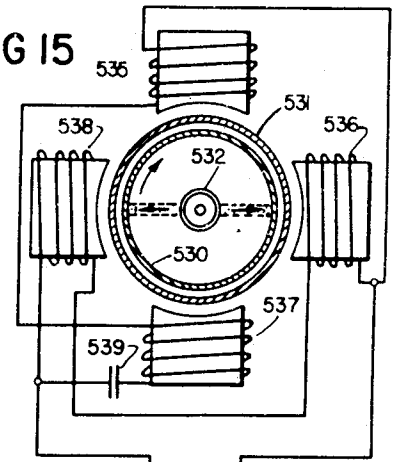


FIG 15



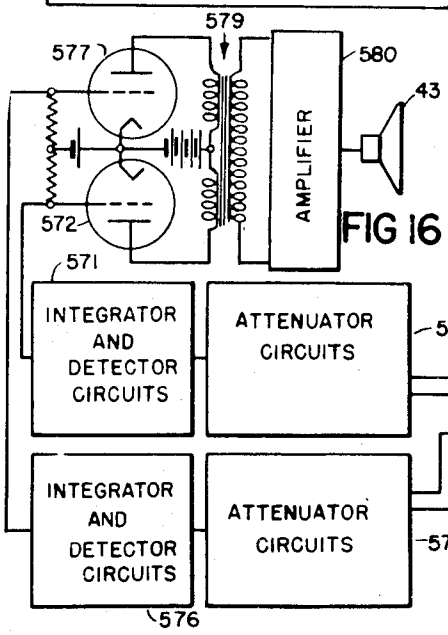


FIG 16

FIG 17

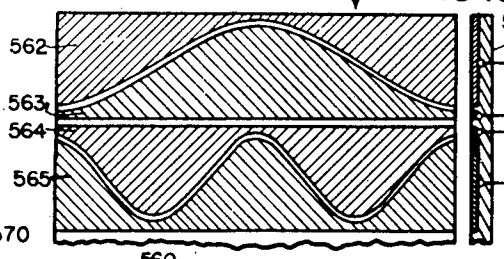
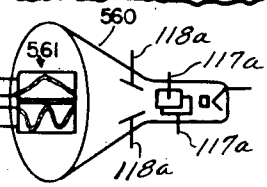


FIG 18





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United States Patent Office 2,900,861 Patented Aug. 25, 1959

2,900,861

ELECTRONIC MUSICAL INSTRUMENTS

Merlin Davis, Washington, D.C.

Original application June 6, 1947, Serial No. 753,118, now Patent No. 2,601,265, dated June 24, 1952. Divided and this application May 15, 1952, Serial No. 288,068

17 Claims. (Cl. 84—1.28)

(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States for governmental purposes without the payment to me of any royalty thereon in accordance with the provisions of the act of April 30, 1928 (ch. 460, 45 Stat. L. 467).

This invention relates to an electronic musical instrument and more specifically to an electronic instrument for the production of complex sounds. This application is a division of my copending application, Serial No. 753,118, filed June 6, 1947, which issued on June 24, 1952, as U.S. Patent No. 2,601,265.

Each individual musical note has pitch, quality, and intensity. The pitch is determined by its frequency or by the number of vibrations per second it causes in the air. This characteristic determines whether a note is high or low. The quality of the note depends upon whether it is heard as a pure sine wave containing only one frequency or whether it is a compound wave containing a dominant fundamental frequency along with one or more harmonics or multiples of the fundamental. Quality is the characteristic which allows distinction between notes of the same pitch produced by different instruments. Intensity is a measure of the amplitude of the sound wave and is the characteristic which determines loudness. Control of the intensity of a note or of any part of a rendition is known as dynamic control.

Musical notes as sounded by instruments also have a distinguishing characteristic in the variation of intensity with respect to the time of duration of the note. In some instruments such as the organ each note is of substantially uniform intensity as long as the keyboard lever is held down. In other instruments, such as those in which a string is struck or plucked, the intensity may with more or less rapidity build up to a maximum and die away with more or less slowness. The increase of volume during the initial part of the note is known as the "attack" and the decrease in intensity as the note dies away is known as the "decay." This characteristic also provides a distinction between notes of the same pitch of different instruments.

Some instruments such as the piano and organ permit the sounding of a plurality of notes simultaneously to produce harmony. Two or more notes thus played at once produce a chord. If the ratio between the frequencies of the notes in a chord has a low value, beat notes of slow frequency are produced and such chords are pleasing to the ear and are said to be consonant. However, if the beat notes produced have a relatively high frequency the sound is displeasing to the ear and the chord is said to be dissonant.

The diatonic scale used in modern music has eight notes or steps in an octave, if the last note, one octave higher than the first note, is counted. The octave appears to the ear as a truly natural interval, a note being of twice the frequency of a note an octave lower. In the diatonic scale the intervals between notes have been selected to obtain the maximum of consonance when the notes are sounded simultaneously in chords. The succession of

intervals between notes in the diatonic succession is as follows: tone-tone-semitone-tone-tone-tone-semitone.

The modes or arrangements of succession of the diatonic scale as used today are the major and minor. In the major mode the arrangement is as given above. In one minor mode the same succession of intervals is arranged as follows: tone-semitone-tone-tone-semitone-tone-tone.

In the application of the diatonic scale it is natural to select the lowest note of which the scale is composed as the key-note. In music the key-note is invested with special significance making the other six subservient to it. In the scale of C major the lowest note is C and the arrangement of intervals up the scale must be as outlined above for the major mode. Music is written with 12 different keynotes and, because the diatonic scale intervals are more or less incommensurate, it is found that each of these keys requires a different keyboard on a musical instrument for exact intonation.

To avoid either twelve keyboards or fifty keyboard levers per octave as would be necessary to accurately render music in both modes and in the various keys, a compromise is customarily made in musical instruments by providing in each octave twelve notes the spaces between which are equally proportioned. Such an arrangement is known as equal temperament and provides a close approximation for each of the keys. The scale having 12 notes per octave, the notes being approximately a half-tone apart is known as the chromatic scale. This arrangement does not allow accurate rendition of each key since the sharp of one note is not, as so often supposed, the same as the flat of the note following. An instrument arranged for accurate tonal rendition of a key is said to have just temperament.

It is an object of this invention to produce a musical instrument in which a plurality of differently pitched notes may be produced successively by a single means for producing oscillations.

It is also an object to provide a musical instrument in which a complex sound may be produced appearing to the ear as a chord composed of several notes of different pitch being sounded simultaneously, said complex sound being produced by a single means for producing oscillations.

It is also an object to provide a musical instrument in which a single keyboard in cooperation with a single oscillation producing means will produce a chord appearing to the ear to consist of thirteen notes of the chromatic scale sounded simultaneously, two of which notes are separated by an octave.

It is also an object to provide a musical instrument which may be simply adjusted to play either in just or equal temperament.

It is also an object to provide a musical instrument which may be simply and selectively adjusted to play in any of a plurality of modes and in any of a plurality of keys so that the keyboard may always be manipulated in one desired key while the music is produced in a key corresponding to the adjustment.

It is also an object of this invention to provide a musical instrument wherein the quality of the notes produced may be generally adjusted.

It is also an object to provide a musical instrument wherein the quality of each note may be separately adjusted to vary with respect to time of duration of the note.

It is also an object to provide a musical instrument in which the intensity of each note may be controlled by the pressure exerted on the corresponding keyboard lever.

It is also an object of this invention to provide a musical instrument in which the intensity of each note may be varied in predetermined manner with respect to the time of duration of said note.

It is also an object of this invention to provide a musical instrument in which a main keyboard representing the notes of the chromatic scale is provided with a supplementary keyboard whereby operation of a key on said supplementary keyboard will sound a corresponding note and simultaneously a note one octave higher or lower.

Other objects will become apparent from the following description taken in connection with the drawings in which:

Fig. 1 is a schematic diagram of one embodiment of this invention.

Fig. 2 shows a 2-manual keyboard to be used with this invention.

Fig. 2*a* shows a detail of part of the tremolo producing means.

Fig. 3 is a detailed cross-sectional perspective view of one keyboard manual.

Fig. 4 is a simplified block diagram of one embodiment of this invention.

Figs. 5*a* to 5*f* are curves used in explaining the operation of Fig. 4.

Fig. 6 is a schematic diagram of one embodiment of this invention.

Fig. 7 is a schematic diagram showing one system of dynamic control that may be used with this invention.

Fig. 8 is a schematic diagram showing a portion of the volume control used with this invention.

Fig. 9 is a schematic diagram showing one system of quality control that may be used with this invention.

Fig. 10 is a schematic diagram of an alternative system of quality control.

Fig. 11 is an alternate electronic distributor device that may be used with this invention.

Fig. 12 is a block diagram of an embodiment of this invention using concentric wave patterns.

Fig. 13 is an elevation view of the wave patterns used in the embodiment of Fig. 12.

Fig. 14 is a partial block diagram showing an embodiment of this invention using cylindrical wave patterns.

Fig. 15 is a partial block diagram showing other elements of the system of Fig. 14.

Fig. 16 is a block diagram of an embodiment of this invention using complementary wave patterns connected in push-pull relation.

Fig. 17 is an elevation view of the push-pull patterns used in the system of Fig. 16.

Fig. 18 is a sectional side view of the patterns shown in Fig. 17.

Reference is now made more particularly to Fig. 1 of the drawing in which cathode ray tube **30** has an electron gun **31** for producing an electron beam. Tube **30** is so arranged that the beam has the shape of a ribbon having a comparatively long vertical dimension and a short horizontal dimension, the cross section of the beam as it impinges on the end wall **32** being substantially a line as shown at **33**. Deflecting plates **34** are provided for deflecting said beam horizontally. End wall **32** carries a plurality of patterns **36**, **37**, and **38** which may vary sinusoidally in form and which may be made of metal foil. The uppermost pattern **36** consists of one complete sine wave. The second pattern **37** while of substantially the same length as pattern **36**, consists of two sine waves. Pattern **38** which is of the same length consists of three sine waves. It will thus be seen that pattern **37** represents a wave which is the second harmonic of wave **36** while pattern **38** represents a wave which is the third harmonic of pattern **36**. Patterns **36**, **37**, and **38** are connected through attenuator circuits **40**, which are controlled by stops **41**, and through amplifier **42** which is in turn connected to speaker **43**. Attenuator circuit **40** is constructed to selectively attenuate the signals picked up by patterns **36**—**38** as will be disclosed in greater detail below.

Electrode **44**, also carried by end wall **32** of tube **30**, is located in alignment with one end of the patterns **36**—**38**. Electrode **44** is connected through conductor **45** to sweep-limit control circuit **46**. A circuit suitable as a sweep limit control circuit will be described in detail with respect to Fig. 6. Deflecting plates **34** are connected through clamping circuit **47** and amplifying circuit **48** to saw-tooth oscillator circuit **50**.

Saw-tooth oscillator circuit **50** comprises a condenser **51** connected in parallel with a gas-filled triode **52**. The cathode of vacuum tube **52** is connected to ground. The grid of tube **52** is connected to ground through a biasing battery **53**, and is inductively coupled through coils **55** and **56** to sweep-limit control circuit **46**. The plate of tube **52** is connected through frequency control pentode **60** to plus battery and through the battery to ground completing the circuit for charging condenser **51** through pentode **60**. Condenser **51** is discharged through triode **52**. The cathode of tube **60** is connected to the plate of tube **52** and the plate of tube **60** is connected to plus battery.

A keyboard **65** is provided along with a supplementary keyboard **66**. Keyboard **65** comprises the usual black and white levers of the piano or organ as will be described in greater detail below. Keyboard **66** consists of very short levers, one corresponding to each of the black and white levers on keyboard **65**, each keyboard lever in keyboard **66** being directly in front of and closely adjacent to the corresponding lever in keyboard **65**. Each lever in keyboard **65** and **66** is provided with a contact shown at **67**. In their normal unoperated position, these contacts engage one end of resistors **68** or **68′** shown on the right side of the contacts **67**. When the levers are pressed, contacts **67** engage one end of resistors **69** or **69′** shown on the left side of contacts **67**. The other ends of resistors **68** and **69** are connected together and through battery **72** to the cathode **73** of cathode ray tube **75**.

Thirteen electrodes such as shown at **81**–**93** are fixed to the end wall of tube **75**. Tube **75** is also provided with deflecting plates **76** and **77** for deflecting the cathode ray beam in mutually perpendicular directions, the cathode ray beam being produced by electron gun **78**. Deflecting plates **76** and **77** are supplied by sweep circuits **74** with sine waves 90 degrees out of phase so that the electron beam is swept in a continuous circle over electrodes **81**–**93** at a super-audible speed. Twelve of these electrodes **81**–**93** are each connected to one of the contacts **67** in each octave of the normal keyboard **65** through conductors such as **95** and **96**. The thirteenth electrode **93** is connected to contacts **67** of the supplementary keyboard **66**.

One keyboard lever **70** of keyboard **66** has associated therewith resistors **68′** and **69′** corresponding to resistors **68** and **69** of keyboard **65**. Keyboard lever **70** controls a contact **67** which engages one end of resistor **68′** when the lever is unoperated and one end of resistor **69′** when the lever is pressed. However, the other levers of keyboard **66** have associated therewith a contact **71** which is connected to the end of said resistor **68′** which engages contact **67** associated with lever **70**. The other ends of resistors **68**, **68′**, **69**, and **69′** are connected to battery **72** and also to the cathode of pentode **60**. The contacts such as **71** in connection with keyboard **66** may be used in place of the plurality of resistors **68′** as shown in connection with keyboard **65** because only one lever of keyboard **66** is ever depressed at one time whereas a plurality of levers on keyboard **65** are operated simultaneously therefore one "silent" resistor will serve the entire keyboard **66**.

Resistors **68**, **68′**, **69** and **69′** are successively connected in a circuit including battery **72**, the electron beam of tube **75** and one of contacts **81**–**93**. Connections are made from the other ends of resistors **68** and **68′** and selected points on resistors **69** and **69′** to the grid of tube **60**. Resistors **68**, **68′**, **69** and **69′** therefore form parts of potentiometers and the voltage picked up across resistors **68** and **68′** is sufficient to prevent tube **60** from passing current while the voltage picked up from the intermediate taps of resistors **69** and **69′** causes tube **60** to

pass current commensurate with the tone of the keyboard lever pressed.

The selected points of resistors 69 mentioned above are shifted slightly along said resistors through the action of switches 97. There is one switch 97 provided for each resistor 69. Switches 97 are ganged for group action and are operated by a single operating handle or stop 98 marked "just-equal." Switches 97 are effective to connect either of two selected points to the grid of tube 60. Changing the point at which a resistor 69 is connected to the grid of tube 60 obviously will change the pitch sounded by the associated keyboard lever. The points on resistors 69 tapped by switches 97 are so selected that with stop 98 in one position the instrument will play in just temperament and with the stop 98 in the other position the instrument will play in equal temperament. Switches, not shown, similar to switches 97 should be provided for resistors 69' of keyboard 66.

In just temperament a change in the key note from one note to the next higher note means that the pitch of all the notes is raised by being multiplied by the pitch ratio of said two key notes. In just temperament this pitch ratio between adjacent notes will not be the same for every two adjacent notes. In equal temperament a change from one key note to the next higher key note means that the pitch of all notes is raised by being multiplied by 1,059, a number such that its product and succeeding products will divide an octave into twelve equal intervals. In equal temperament since all the notes are raised by one factor when the key note is changed the key signature stop may operate one set of switches adjusting the resistance of one resistor in the connection between cathode 73 of distributor 75 and keyboards 65 and 66.

In operation, when levers of keyboard 65 are unoperated the contacts 67 engage resistors 68 but when the levers are depressed the contacts 67 engage resistors 69. Current flows from battery 72 through one or the other of resistors 68 or 69 thence through whichever one of the electrodes 81 to 93 on which the beam generated by electron gun 78 is impinging, and back to battery 72. Resistors 68 and 69 thus operate as potentiometers and a voltage will be applied through line 80 to the control grid of pentode 60, said voltage being determined by the position of the intermediate tap of the resistor 69 or the voltage across resistor 68 which are associated with the lever pressed. Supplementary keyboard 66 operates in a similar manner current passing through electrode 93 and through whichever resistor 69' that corresponds to the lever pressed. However, when a lever is pressed on keyboard 66 the corresponding lever is also operated in keyboard 65 because of a mechanical linkage, to be described more in detail later, between the levers of keyboard 66 and 65. This arrangement allows two notes one octave apart in pitch to be sounded simultaneously on one keyboard.

Various voltages are thus applied in quick succession to the control grid of tube 60, these voltages corresponding in magnitude to the pitch represented by the levers pressed on keyboards 65 and 66. The current through tube 60 varies in accordance with the voltage on its control grid and charges condenser 51 at varying rates of speed. Condenser 51 is discharged by triode 52. Upon actuation by the impinging of the electron beam in tube 30 on electrode 44 sweep-limit control circuit 46 applies a pulse to the grid of triode 52 through inductively coupled coils 55—56 to cause tube 52 to conduct. This causes condenser 51 to discharge as trace 33 completes its sweep over patterns 36—38 and causes trace 33 to return to the beginning of its sweep.

The voltage to which condenser 51 is charged is amplified by circuit 48 and converted into two oppositely swinging voltages each of which swings in a direction opposite to the other and at a rate in accordance with the charging rate of condenser 51. These oppositely swinging voltages are applied to clamping circuit 47 which fixes the upper limit of the swing of each of the voltages and applies them to the deflecting plates 34 of tube 30 to limit the travel within the bounds of the patterns on the side opposite electrode 44. This causes the ribbon beam of tube 30 to swing back and forth across patterns 36, 37 and 38. At any instant more or less current will flow from patterns 36—38 in accordance with the area of said patterns that is being impinged upon at that instant by the electron beam. Thus it will be seen that the current will flow representing the fundamental in accordance with pattern 36 and also the harmonics represented by patterns 37 and 38. The current picked up by patterns 36—38 is attenuated in circuits 40, as controlled by stops 41, is amplified in circuit 42 and reproduced audibly by speaker 43.

If no levers on keyboards 65 or 66 are pressed the control grid of tube 60 is so biased that condenser 51 is not being charged. Hence, the ribbon beam in tube 30 is not deflected. A steady current will be passed on to circuit 40 and no vibrations will be audibly reproduced by speaker 43. It will be obvious that the sound could also be extinguished by blocking the beam in cathode ray tube 30 and that the sound could be muffled by partially blocking said beam.

If one lever is pressed on keyboard 65, on each instant that the electron beam of tube 75 passes the corresponding electrode of electrodes 81—93 condenser 51 will be charged at a rate determined by the pitch value of the key pressed. During this instant the ribbon beam in tube 30 will move horizontally along the patterns generating a current having a fundamental and harmonics at a frequency depending on the pitch value of the lever pressed. A corresponding operation will follow from the pressing of the other levers in keyboard 65.

If two levers are simultaneously pressed on keyboard 65, the pitch of one lever will be sounded as the electron beam in tube 75 impinges on its corresponding electrode of electrodes 81 to 93 while the pitch of the other key will be sounded as its corresponding electrode is impinged upon. The rate of sweep of the electron beam in tube 75 is at a superaudible rate so that the pitches of the two notes are heard in succession during very small increments of time. It will then appear to the ear that the two notes are played simultaneously. It will be evident that all twelve notes in the chromatic scale may be sounded at one time, the notes being scattered throughout the octaves on the keyboard.

If two notes an octave apart are to be sounded simultaneously then the lever on the supplementary keyboard 66 corresponding to the lower of the two notes, for right hand execution or higher of the two notes for left hand use is pressed. This action automatically presses the lever opposite and corresponding to the upper or lower octave note in keyboard 65 and it is sounded through the action described above. The pitch resistors 69' are arranged so that the levers of keyboard 66 to the right of the center sound a note one octave lower than the opposing lever on keyboard 65 while the levers of keyboard 66 to the left of the center sound a note one octave higher than the opposing lever of keyboard 65. The lever of keyboard 66 which is pressed contacts a resistor 69' and causes a current to flow by impingement of the beam on electrode 93 of tube 75 causing the note an octave higher to be sounded during the thirteenth increment of the sweep-cycle in tube 75.

It is thus seen that, through the operation of a single oscillation producing means 30, a plurality of pitches may be produced in succession and that these pitches can be produced in such rapid succession that they appear to the ear to be simultaneously sounded.

In Fig. 2 is shown the two-manual keyboard arrangement preferably used in this invention. The two main keyboards 65 and 65' are each associated with auxiliary octave keyboards 66 and 66', respectively. The means for producing a tremolo effect are mounted immediately behind the keyboards and will be described in detail below.

The construction of a main keyboard **65** and octave keyboard **66** is shown in Fig. 3. White lever **100** and black lever **101** of keyboard **65** correspond to the black and white levers on the keyboard of a conventional piano. Levers **100'** and **101'** of octave keyboard **66** are directly in front of corresponding levers **100** and **101**. Lever **100** is provided with a hinge at **102** and maintained in its normal "up" position by tension spring **103**. Lever **100'** is provided with a hinge **106** and maintained in its normal "up" position by adjustable compression spring **107**. Adjustable dashpots **109** and **110** provide a proper inertia to the action of levers **100** and **100'**, respectively. The other levers of keyboard **65** and **66** are similarly provided with hinges, springs and dashpots, and have a similar construction. Hook member **111** fixed to lever **100'** cooperating with member **112** of lever **100** causes lever **100** to be depressed when octave lever **100'** is pressed.

If two notes one octave apart are to be played, the lever of octave keyboard **66** adjacent to the lower note in right hand execution (or adjacent to the upper note for left hand execution) on keyboard **65** is pressed. The operating of the octave lever also operates the lever of keyboard **65**. Thus without unduly stretching the fingers, a note, along with a note an octave higher or lower, as required is sounded by operation of one keyboard lever. The electrical contacts necessarily associated with the levers of keyboards **65** and **66** are not shown in Fig. 3.

Referring now more particularly to Fig. 4 for a general description of a modification of this invention, cathode ray tube **115** is of the type which produces a pencil-like beam of narrow cross-section. Tube **115** includes cathode **116**, horizontal deflecting plate **117**, vertical deflecting plates **118** and patterns **119** and **120**.

Horizontal deflecting plates **117** are connected by leads **117***a* to horizontal sweep circuit **122** which is in turn controlled by keyboard **123**. It will be understood that keyboard **123** and horizontal sweep circuit **122** have associated therewith an octave keyboard and distributor as shown in Fig. 1. Vertical deflecting plates **118** are connected by leads **118***a* to vertical sweep circuit **124**.

Patterns **119** and **120** are connected through frequency compensator circuit **126** and harmonics attenuator circuit **127**, coupling circuit **128** to pulse integrator circuit **129**. Circuit **126** contains a pre-set resistor for each of patterns **119** and **120**, the resistor attenuating the signal picked up by each pattern to compensate for the selective hearing characteristics of the ear. Circuit **127** provides for the circuit of each of patterns **119** and **120** a potentiometer including a tapered resistance. These potentiometers are selectively operable by stops not shown so that the various harmonics can be suppressed or accentuated in order to simulate different musical instruments or produce new complex sounds.

Coupling circuit **128** gives a direct current coupling between harmonics attenuator **127** and pulse integrator **129**. Pulse integrator **129** is a circuit capable of integrating the electrical pulses supplied to it during each vertical sweep of the electron beam in cathode ray tube **115**. Conductor **130** connects vertical sweep circuit **124** with pulse integrator **129** to supply the latter with a tripping pulse at the end of each vertical sweep. Pulse integrator circuit **129** is connected through detector **135** and amplifier **136** to speaker **137**. Circuits **128**, **129**, **135**, and **136** will be described in greater detail below.

In the operation of the system shown in Fig. 4, the spot trace of the pencil electron beam produced in tube **115** sweeps vertically over patterns **119** and **120** at a relatively rapid rate determined by sweep circuit **124**. The pencil beam of tube **115** sweeps across patterns **119—120** horizontally at a rate which depends on the lever being operated in keyboard **123** but at a rate which is always slow compared to the vertical sweep rate.

In Fig. *5a* there are representations of fundamental pattern **119** and second harmonic pattern **120** with line **140** representing the trace of spot **140'** of the pencil beam. Arrows indicate components of beam travel. Although shown vertical the beam trace would have a slight slope as it proceeds in zigzag fashion across the patterns. The return trace of the beam is ignored because it is so rapid as to produce a negligible signal. If desired the return trace may be blanked out by use of a blanking pulse applied to a control grid in cathode ray tube **115**. Fig. *5b* shows the signal produced by the patterns **119—120**, neglecting the effects of frequency discrimination compensator circuit **126** which would govern the relative amplitude of the signals emanating from the patterns in accordance with auditory requirements. In Fig. *5b* the unshaded and shaded pulses represent the signal produced by transit of the beam across patterns **119** and **120** respectively along representative traces **140''** shown in Fig. *5a*. It will be obvious that as the beam traverses the patterns in a nearly vertical direction there will be produced by each pattern a pulse having a duration equal to the time during which the beam impinged on the pattern, and since the vertical deflection rate is uniform, the pulse duration will be a measure of the pattern height at the position of that trace.

Fig. *5c* shows the pulses produced by patterns **119** and **120** after attenuation by compensating network **126** and harmonics attenuator **127**. In this figure the pulses representing the second harmonic have been appreciably attenuated either to compensate for the selective characteristics of the ear or because of selective suppression of this harmonic to achieve a desired effect, or for both reasons.

Fig. *5d* shows the output of pulse integrator **129** in which a condenser is charged as shown in Fig. *5f* by the pulses shown in Fig. *5c*. Fig. *5f* shows the condenser charge voltage plotted against time. The higher the voltage of the pulse, the higher will be the charging rate of the condenser, curves CR_1—CR_4 showing different charging rates. As seen in Fig. *5d*, the condenser will be charged at a high rate (angle A) for a high pulse and at a slow rate (angle B) for a short pulse and will be discharged at the end of each complete vertical sweep through action of tie **130** between pulse integrator circuit **129** and vertical sweep circuit **124**.

Detector **135** detects the pulses produced by integrator circuit **129** and produces a curve such as shown in Fig. *5e*, it being understood that in practice there would be a large number of integrated pulses as shown in Fig. *5d* to give a relatively smooth curve as shown in Fig. *5e*. The speed with which the electron beam in tube **115** is deflected horizontally depends on the lever pressed on keyboard **123**. This rate of horizontal deflection determines the length in time of the wave shown in Fig. *5e* which, in turn, determines the pitch of the note sounded.

Reference is now made to Fig. 6 for a detailed description of an embodiment of this invention operating with a pencil cathode ray beam as generally described with respect to Figs. 4 and *5a–5f*. Cathode ray tube **150** includes cathode **151**, control grid **152**, horizontal deflecting plates **153**, vertical deflecting plates **154** and on its end wall there is a mounting plate **155** carrying patterns **156—165**. Power supply **170** provides voltages to the various electrodes of tube **150** to produce a pencil beam of relatively small cross section.

In Fig. 6 the conductors **95**, **96**, etc. corresponding to the conductors of like number in Fig. 1 lead to the contacts of the distributor tube through resistors **171**, **172**, etc. Resistors **171** and **172** are arranged with shorting switches **173** and **174**, respectively, arranged to selectively shunt parts of said resistors. Shorting switches **173**, **174** are ganged to operate from key signature stops **175** and **176**, each stop operating one shorting switch of each resistor. It will be understood that the wires associated with each keyboard lever each contain a potentiometer like **68**, **68'**, **69**, **69'** of Fig. 1. The resistors **171** and **172** lead to the contacts **181** of a distributor tube **182**. This distributor tube corresponds to distributor tube **75**

in Fig. 1. Tube **182**, however, is an alternate type being a cylindrical tube having its contacts **181** in cylindrical array and the cathode **183** running axially of the tube. Deflection coils **185**, **186**, **187** and **188** are fed with an alternating current from source **190**. Condenser **191** is connected in series with coil **186** so that a rotating field will be produced about tube **182** and cause a planar sheet of electrons to be emitted from cathode **183** and sweep radially around the tube and across the contacts **181** at a speed determined by the frequency of the source **190**.

The anodes **181** of distributor tube **182** may be separated and shielded from each other to prevent the beam from impinging on two anodes at the same time. The resistance of the beam contact as it passes from one anode **181** to the next is so low in comparison to the impedance in series with it that the effect should not be apparent until the beam has almost passed over one anode prior to contact with the next.

The switching speed of the electronic distributor tube **182** of Fig. 6 is limited only by the magnetic properties of the rotary sweep circuit and this may be as high as 10,000 cycles per second which would allow 130,000 switchings per second. Switching from one audible frequency to another is performed at a supersonic rate.

Resistors such as **171** and **172** appearing in the potentiometer circuit associated with each keyboard lever will obviously affect the current passing through these potentiometer circuits in accordance with the amount of the resistances **171**, **172**, etc. that are shorted out by the key signature stops such as **175** and **176**. This amount of shorting in turn will affect the voltage applied to the grid of tube **60** through conductor **79** and thus affect the pitch of the note sounded. Shorting switches such as those designated as **173** are positioned along resistor **171** so that operation of one key signature stop such as **175** operating to close one shorting switch in each resistor **171**, **172**, etc. will cause the notes sounded by keyboards **65** and **66** to be in any one of the various keys and modes represented by stops **175** and **176**. Other stops arranged in equal manner may be employed to provide alternate potentiometer taps to cause the instrument to play in equal or just temperament and in the various modes.

The switches such as **173** may be arranged so that the over-all pitch lever is raised by the resistors such as **171** until the base frequency or pitch sounded by the white keyboard lever normally producing C-natural is equal to that of the key note represented by the signature. The white keys which normally represent the scale at the key of C now will represent the scale in the key selected. The signature written on the music will remain as usual but the musical notation will need to be transposed to the key of C. In this system, except for transposing accidentals, all music will be played on the white keyboard levers and the given note position on the staff will always be represented by the same keyboard lever. Each keyboard lever will therefore sound a different pitch depending upon the key selected in contrast with piano operation in which each keyboard lever always sounds the same pitch. If the scale pitches are selected in the just tempered scale then true harmony will result. Adjustment from equal to just temperament or vice versa is affected by gang selector switches operating on the pitch potentiometer such as switches **97** in Fig. 1. In order to play in the various minor as well as the major modes from 12 to 26 key signature change switches will be required. Since the minor mode scale step arrangement differs from the major mode, additional gang selector switches such as **173** in Fig. 6 operating on the pitch potential circuit will be required. The black keyboard levers would then be arranged to represent intermediate frequencies between key scale steps for modulation purposes. These might have equal tempered values or just temperament attuning to selected transposition keys.

Alternatively, the switches such as **173** in Fig. 6 may be arranged so that music written in keys other than the key of C (i.e. written in sharps or flats) may be played on the keyboard as though written in the key of C. In this system the musical notation would be used unmodified. The keyboard would be played as usual except that the key signature flats and sharps would be disregarded and executed as though natural. The shift of the white keys to the proper sharps and flats would be done by depressing key signature switches such as **173** in Fig. 6. In this system all of the notes are not shifted by a certain ratio but the various notes are changed in pitch each by its required amount.

Wire **79** from keyboards **65** and **66** is connected with the control grid of pentode **60**. The cathode of pentode **60** is connected to conductor **80** from keyboards **65** and **66**. Frequency control tube **60** is connected to saw-tooth oscillator circuit **50** as explained with respect to Fig. 1. The output of saw-tooth oscillator circuit **50** is fed to paraphase amplifier circuit **48** containing triodes **195** and **196**. The plate of gas-filled tube **52** is connected through condenser **197** to the grid of tube **195**. The junction of condenser **197** and the grid of tube **195** is connected through resistors **198** and **199** to the cathodes of tubes **195** and **196**. The junction of resistors **198** and **199** is connected to the grid of tube **196**.

The particular form of paraphase amplifier employed in circuit **48** employs coupling between the cathodes of the two tubes **195** and **196**. Current from both tubes flows through the common cathode resistor **199**. Grid voltage on tube **196** is the voltage developed across cathode resistor **199** and is of opposite sense to that directly on the grid of the amplifying tube **195**. The output of triode **196** is thus inverted with respect to the output of tube **195**. The plates of triodes **195** and **196** are each connected through a separate resistor to a common source of plus potential. The outputs of paraphase amplifier **48**, two mutually inverted saw-tooth waves, are fed to clamping circuit **47**.

Clamping circuit **47** comprises diodes **200** and **201**. The output of triode **195** is connected to the cathode of tube **201** and also to one of the horizontal deflecting plates **153** of cathode ray tube **150**. The output of triode **196** is connected to the plate of diode **200** and also to the other of deflecting plates **153**. The plate of diode **201** is connected to ground while the cathode of diode **200** is connected to an adjustable biasing source of potential. It will be obvious that diodes **200** and **201** will conduct in opposite directions when the mutually inverted deflection voltages attain sufficient amplitude. This results in clamping one extreme of each opposed saw-toothed horizontal deflecting voltage at one point and causes one side of the sweep of the electron beam to remain always fixed regardless of amplitude variations.

The vertical deflection voltage is initiated in saw-tooth oscillator **205**, a vacuum tube oscillator capable of generating a frequency of 100,000 cycles per second or more. Oscillator circuit **205** comprises triode **206** and pentode **207**. The potential of the cathode of triode **206** is maintained above ground by cathode resistor **208**. The grid of tube **206** can be made highly negative with respect to its cathode since it is dependent upon the current through pentode **207**. The current through pentode **207** may be regulated by adjustment of its screen grid voltage through manipulation of potentiometer **209**. Triode **206** will be non-conducting while condenser **211** is being charged from source of plus potential **212**. As condenser **211** becomes charged triode **206** becomes conducting regardless of the highly negative grid. This results in plate current through resistor **213**. The grid of pentode **207** is thereby affected through condenser **214** and resistor **215**. The grid of pentode **207** then goes negative and current decreases through pentode **207**. Because of the grid connection of triode **206** with plate resistor **216** triode **206** becomes more conducting and finally positive. Condenser **211**

discharges very quickly through this tube. When voltage across condenser 211 decreases enough the grid of triode 206 gains control and the cycle repeats.

The output of oscillation generator 205, a saw-tooth wave, is fed to the input of paraphase amplifier 220 through the primary of transformer 221. The secondary of transformer 221 operates to trip the pulse integrator in a manner to be described later. Paraphase amplifier 220 has a construction and operation similar to that already described for paraphase amplifier 48. The output from paraphase amplifier 220 is connected through clamping circuit 222 to vertical deflecting plates 154 of cathode ray tube 150. The construction and operation of clamping circuit 222 is similar to that described above with respect to clamping circuit 47.

In tube 150 each of patterns 156 to 165 are connected through frequency compensating resistors such as 225 to tapered harmonic-attenuator resistors such as 226. Resistor 226 forms part of the potentiometer circuit going back to voltage supply 170. The adjustable tap along each logarithmically tapered resistor 226 feeds through a resistor 227 to the cathode of diode 230 and the plate of diode 231 in positive coupling circuit 233.

Frequency compensating resistors 225 correspond to the resistors in circuit 126 of Fig. 4 while the tapered potentiometers, such as 226, correspond to those in the circuit 127 of Fig. 4. The function and purpose of circuits 126 and 127 has already been explained with respect to Fig. 4. Since the voltages from potentiometers such as 226 must be combined before being amplified for the speakers, high series resistors such as 227 must be added in the voltage tap line of each potentiometer 226 to prevent short-circuiting when these lines are connected to a common lead. A switch such as 232 is shown between each resistor 225 and potentiometer 226 is provided whereby each anode 156 may be grounded when not used in order to prevent the anodes from accumulating a charge when disconnected.

The purpose of the positive coupling stage 233 is to assure that the coupling condenser 234 used to block potentiometer voltage from the grid of the pentode 236 in pulse integrator circuit 237 is not rendered insensitive to the incoming pulses by accumulation of charge, and to insure that the pulsations are transmitted with their full intensity. Incoming pulses are prevented from shorting to ground by the rectifying action of diode 231 while passing unimpeded through diode 230. The voltage drop across grid resistor 238 supplies the signal pulse passed on to pulse integrator circuit 237. In this process a small charge accumulates on condenser 234. During the period following the pulse the condenser becomes neutralized by a flow of current through the grounded diode 231. This current flow has no action on the stage 237 since the direction of this current is opposed by the other diode. The original signals are thereby transmitted through the coupling circuit 233, without alteration by said circuit, as unidirectional pulses to the pulse integrator stage 237.

Pulse integrator stage 237 includes pentode 236 and triode 240. The output of coupling circuit 233 is applied to the grid of pentode 236 in pulse integrator circuit 237. Circuit 237 also includes condenser 241 charged by battery 242 through resistor 243 and pentode 236. Resistor 243 is the cathode resistor of vacuum triode 240, the grid of which is connected through conductor 244', differentiator circuit 246, and conductors 247 to the secondary of transformer 221 in the input of amplifier 220. A by-pass condenser is provided across cathode resistor 243. One side of condenser 241 is connected to the cathode of triode 240. The other side of condenser 241 is connected to the plate of triode 240. The output of integrator circuit 237 is taken from the positive side of condenser 241.

In operation, each pulse, such as those shown in Fig. 5c, impressed on the grid of pentode 236 causes that tube to pass a pulse of current from battery 242 to condenser 241. Current from battery 242 flowing through cathode resistor 243 causes triode 240 to be normally non-conducting with a grid bias E_g (Fig. 5f) within the substantially linear portions of condenser 241 charging curves. However, the high rate of change of the vertical deflection voltage during the return stroke of the electron beam in tube 150 causes a pulse of relatively large magnitude to be induced in the secondary of transformer 221 and timed to discharge condenser 241 before the voltage has reached the cut off voltage E_g. This pulse is properly shaped by differentiator circuit 246 and applied to trip tube 240, making that tube conducting and discharging condenser 241. Differentiating circuit 246 consists of a condenser and resistor in series forming a circuit having a time constant about one-tenth that of the vertical oscillation cycle applied to plates 154 of tube 150. The effect of integrator circuit 237 is as described with respect to the integrator circuit in Fig. 4 and with respect to Fig. 5d.

The output of pulse integrator circuit 237, which is the charge on condenser 241, is applied to the input of detector circuit 244, being connected to the plate of diode 246' and the cathode of diode 247'. A rsiestor 249 and condenser 248, connected in parallel are connected between the cathode of diode 246' and the palte of diode 247'. Detector circuit 244 operates in a manner similar to that of coupling circuit 233 in that it preserves the direct current component of the signal. However, condenser 248 is charged by each pulse, such as shown in Fig. 5d, in the output of the integrator circuit and discharged through resistor 249 between pulses. The output of circuit 244 taken from across condenser 248 is, therefore, the envelope of the input pulses as shown in Fig. 5a.

The output of detector circuit 244 is taken from across condenser 248 and applied across tapered resistor 252 in volume control circuit 253. Condenser 250 in series with resistor 251 tapped to the lower end of resistor 252 provides overall frequency compensation. A tap adjustable along resistor 252 applies the output of volume control circuit 253 to the control grid of pentode 256 which acts as a driver tube to push-pull amplifier 260. Resistor 252 is logarithmically tapered to compensate for the logarithmic sensitivity of the ear so that equal adjustments of the intermediate tap will produce equal changes in volume.

The output of amplifier circuit 260 is impressed on the input of speaker divider circuit 270 where it is divided into high frequencies, which are impressed on high frequency speaker 276, and low frequencies which are impressed on low frequency speaker 277. The high and low frequencies are separately made audible to obtain better sound effect.

Sweep limit control circuit 46 contains triode 54, the grid of which is connected to the junction of resistor 57 and the plus side of power supply 170. When the electron beam of tube 150 impinges on electrode 44, a current flows through said beam, electrode 44, resistor 57 and power supply 170 to the cathode 151 of tube 150. This momentary flow of current through resistor 57 causes a pulse to be applied to the grid of triode 54. The amplified pulse is passed through transformer 58 to trip gas filled triode 52, as explained above, and cause the return of the electron beam in tube 150 to the starting place along the horizontal axis. The electrode 44 is the same as that shown in tube 115 of Fig. 4.

Time beat emphasis circuit 280 receives spaced square waves from generator 281 and applies them to control grid 152 of tube 150. Generator 281 develops square pulses of adjustable amplitude duration and spacing. The pulses applied by circuit 280 to grid 152 momentarily change the intensity of the electron beam of tube 150 and cause the music rendered to have accentuated volume or beats at regular intervals. This may be arranged to give automatic accent of the notes at the end of each measure so that the rhythm of the music may easily be held constant.

The electron beam in tube 150 may also be varied in

intensity to control the attack-decay volume of each note as will be described below with respect to Fig. 7.

Reference is now made more particularly to Fig. 7 for a description of some of the volume or dynamic controls used in this invention. In Fig. 7 is seen distributor tube **182**, battery **72**, pitch resistors **69**, and key signature resistors **173—174** substantially as seen in Figs. 1 and 6. Fig. 7, however, shows a modification of the pitch-potentiometer circuit in that there are no silent resistors **68**, the pentode **60** being so biased that, with no bias applied to its control grid, it will not conduct and no charge will be fed to condenser **51**. Pentode **60** is connected to the taps of the various pitch potentiometers **69** by the pitch contacts such as contact **300** of keyboard lever **301**.

The above described potentiometer circuit for selective pitch control is an additional modification in that the contacts **300** and **300'** break the various potential lines to the grid of the pentode tube **60** rather than the current in the various parallel potentiometer circuits. It will be understood that there is a contact such as **300** and **300'** for each lever on the main keyboard and that each of such contacts is associated with a lever such as **301**.

In Fig. 7 the pitch potentiometer circuit associated with keyboard lever **301** includes the electron beam and a contact **181** of distributor tube **182**, battery **72**, pitch resistor **69** and key-signature resistor **173**. In parallel with this circuit are one or more dynamic control circuits including the electron beam and a contact **181** of distributor tube **182**, battery **72**, attack-decay potentiometer **304** and resistors **305**. Since each of these parallel circuits have high impedances, current drain in one circuit does not materially affect the other.

The attack-decay potentiometer **304** includes a tapered ring-like resistor **306**, the inner surface of which is circular and engaged by rotating contactor **307**. Contactor **307** is fixed to shaft **308** of motor **309**. Shaft **308** is normally prevented from rotating by arm **312** fixed thereto which normally abuts against arresting member **314** carried by bar **315**. Bar **315** is slidably mounted in supports **317** and **318** and carries arresting member **320** capable of arresting arm **312** after it has rotated 180 degrees from member **314**. Bar **315** is moved in an axial direction by solenoid **322** and is biased by spring **321** so that arm **312** normally abuts against arresting member **314**.

When solenoid **322** is energized, bar **315** is moved against the tension of spring **321**; arresting member **314** is moved from under arm **312** and shaft **308** starts to rotate carrying with it contact **307**. With the moving of bar **315** arresting member **320** has now moved in the way of arm **312** and arrests arm **312** after it has rotated 180 degrees. When solenoid **322** is deenergized, bar **315** moves to its normal position, arresting member **320** is moved from over arm **312** and shaft **308** and contact **307** rotate another 180 degrees till arm **312** is again arrested by member **314**. Solenoid **322** is connected in series with battery **334**, adjustable resistor **335**, and contact **336** associated with keyboard lever **301**. Operation of lever **301** therefore energizes solenoid **322** subsequent to closure of pitch contacts **300**.

Shaft **308** also has fixed thereto a conducting disc **323** straddled by the poles of electromagnet **324** having winding **325**. Winding **325** is connected in series with battery **326** and adjustable resistor **327**. Resistor **327** is adjustable through movement of contactor **328** which is controlled by foot pedal **329**. It will thus be seen that the speed of rotation of shaft **308** and contact **307** is controlled by the position of foot-pedal **329**.

Also connected in the dynamic potentiometer circuit are series resistors **305**, each of which is shunted when a corresponding contact spring **338** makes contact with bar **339**. The face of bar **339** engaging springs **338** is tapered so that the springs are engaged in succession. Bar **339** is fixed to keyboard lever **301** and when lever **301** is depressed, bar **339** is raised to successively contact springs **338** and shunt resistors **305** successively out of the dynamic potentiometer circuit, allowing increasing amounts of current to flow in that circuit. Resistor **305'** similar in construction to resistor **305** but associated with a different keyboard lever is shown schematically. It will be understood that each of these resistors or parallel ones extending from lines **303** are also operative keyboard levers which are octaves of this note on the main keyboard.

Dynamic potentiometer **304'** is shown schematically. Potentiometer **304'** is similar in construction to potentiometer **304** but is associated with a different distributor contact **181** and its associated keyboard levers, representing one note and its octaves on the main keyboard. Potentiometer **304'** has contact **307'**, arm **312'**, and stops **314'** and **320'** corresponding to elements **307**, **312**, **314** and **320** of potentiometer **304**.

Contact **307** of potentiometer **304** is connected through shaft **308** which has ends of insulating material and contact **342** to the contacts of the other corresponding potentiometers, such as contact **307'** of potentiometer **304'** and selector switch **348** to the cathode of triode **350**, the plate of which is connected to the control grid of cathode ray tube **150** which contains the sine-wave patterns as seen in Fig. 6. Details of the selector switch stop mechanism will be described later under Fig. 9. There will be thirteen attack-decay potentiometers, such as potentiometers **304—304'**, one for each contact **181** of distributor tube **182**, to give one attack-decay characteristic.

Other sets of such dynamic potentiometers not shown having different attack-decay characteristics may be provided and any set may be selected by means of switches **348**. One stop of switch **348** might bring into operation a set of potentiometers giving the attack-decay characteristics of a piano while another stop might give the attack-decay characteristics of a banjo. The other stops similarly represent other attack-decay characteristics. Each set of attack-decay potentiometers operated by one stop of switch **348** contains one potentiometer such as potentiometers **304** and **304'** for each contact **181** of distributor tube **182**. The volume resistors such as **305** of each keyboard lever are connected in parallel with each of the associated attack-decay potentiometers. Such a connection is indicated by wires **303**. The potentiometers of each attack-decay set are connected to a corresponding contact **181** of distributor tube **182**. Such connections are shown at **310**.

In operation of the circuit shown in Fig. 7, when keyboard lever **301** is pressed, contact **300** is made connecting the grid of pentode **60** with the pitch potentiometer corresponding to lever **301** and causing a note to be sounded by loudspeakers **276—277** (see Fig. 6) said note having a pitch corresponding to lever **301** as explained above. As lever **301** is depressed further, contact **336** is closed energizing solenoid **322** and causing contact **307** of potentiometer **304** to rotate 180 degrees at a speed controlled by the position of foot pedal **329**. As the varying voltage picked up by contact **307** is applied to the grid of triode **350** to control the intensity of the beam in tube **150**, the volume of the note sounded increases at a speed determined by pedal **329** and according to a law determined by the taper of resistor **306** to provide the attack desired.

As long as keyboard lever **301** is held down, arm **312** is held by stop **320** and the note is maintained at constant volume in respect to the control by potentiometer **304** although the volume may be varied by other means to be described below. When the keyboard lever **301** is released sufficiently, contact **336** is disengaged and solenoid **322** is deenergized. This allows contact **307** to complete its revolution and decrease the intensity of the electron beam in tube **150** to diminish the volume of the note according to the taper of the resistor **306** and the position of foot pedal **329** to provide the desired decay.

The volume of each note may be controlled separately

by the pressure applied to the corresponding keyboard lever. The amount of pressure applied to lever **301** results in more or less depression of the lever against the tension of spring **302**. The greater the depression of lever **301**, the more resistors **305** are cut out of the dynamic potentiometer circuit resulting in a greater amount of current flowing in the circuit and causing a greater intensity of the electron beam in tube **150** and a greater volume of sound. The function of switch **390** which is operated by keyboard lever **301** will be described below with respect to Fig. 9.

It will be understood that it might be desirable in some music that the duration of the decay of a note extend until a time after the finger has been lifted from the keyboard lever. Furthermore the keyboard levers **301** could be arranged with a slight purposeful misalignment of key lever contact position so that chords will automatically be played with slightly different initiation times and decay periods in order that a too mechanical effect be avoided.

A tremolo effect may be produced directly by rapidly varying the pressure on each keyboard lever since volume is a function of the amount by which the lever is pressed. However, a more sustained effect may be produced by the means shown in Figs. 2 and 2*a*. A light source **580** produces light which is directed into a beam **589** by optical element **581**. The light beam **589** is focused by optical element **582** on the cathode of photosensitive cell **583**. Directly adjacent light beam **589** are a plurality of reed elements **584**. Each reed element **584** as seen in Fig. 2*a* consists of a thin reed **586** anchored at one end to the frame of the musical instrument. The other end carries an obturating means **588** and handle means **587**. Photocell **583** controls the grid of a tube in the amplification circuit.

In operation, when a sustained automatic tremolo effect is desired, the musician displaces one of reeds **584** by pressing and rapidly releasing handle **587**. The reed will then continue to vibrate, alternately blocking, or partially blocking, light beam **589** from photocell **583** and causing the volume of the music to vary rapidly in volume in accordance with the period of vibration of the reed caused to oscillate. The reeds **584** are each of different length or thickness so that each will vibrate at a different frequency. The reeds may be made to vibrate singly or in any desired combination. Electromagnetic driving means may be arranged for causing the reeds to continuously vibrate. This means for producing automatically a tremolo effect is preferably placed closely behind the keyboard as shown in Fig. 2 for the convenience of the musician. It will be obvious that such a tremolo producing means could be used with each manual for individual results or even with each harmonic of a note.

In Fig. 8 is shown over-all volume potentiometer **252** also shown in Fig. 6. The adjustment of potentiometer **252** is controlled by foot pedal **360**. The position of foot pedal **360** therefore controls the over-all volume of the instrument.

There being a dynamic potentiometer circuit corresponding to the one containing potentiometer **304** associated through switch **348** with each contact **181** of tube **182**, the action of distributor tube **182** is to cause the electron beam of tube **150** to be modulated successively during small increments of time in accordance with the keyboard levers operated, the proper attack or decay volume being impressed on each note as it is sounded during its increment of time.

Reference is now made more particularly to Fig. 9 for a description of a quality control circuit used in this invention. Tube **150**, patterns **156**—**165**, and compensating resistors **225** correspond to those elements shown in Fig. 6. Resistors **225** are each connected to a contact spring **375**. Opposing contact springs **376** are connected to ground. Between contacts **375** and **376** are intermediate contact springs **377** each having fixed thereto a downwardly extending projection **378** of insulating material. Springs **377** are normally in contact with springs **376**. Intermediate springs **377** may each be connected through switches **379** to harmonic attenuator resistors **226**. Alternately switches **379** may connect selected harmonic patterns to ground eliminating the harmonics so connected.

Immediately above the top intermediate spring **377** is the end of a plunger **384** fixed to the core of solenoid **385**. The plunger **384** is biased upwardly by spring **386** and extends through dashpot **387**, the action of which is regulated by handle **388**. Solenoid **385** is connected in series with battery **392** through contact **390** of keyboard lever **301**.

When keyboard lever **301** is depressed, it will be seen that solenoid **385** will be energized by the closing of contact **390**. Operation of solenoid **385** will urge shaft **384** downward against the tension of spring **386** at a speed determined by dashpot **387** and the setting of regulating handle **388**. As shaft **384** progresses downwardly, first spring **377** will disengage spring **376** and engage spring **375**, thus disconnecting fundamental pattern **156** from ground and connecting it in the parallel circuits of harmonic resistors **226** and **226′** or **226″**.

As shaft **384** moves further down the second spring **377** is moved to disconnect the second harmonic pattern **157** from ground and connect it in the potentiometer circuit of resistors **226**, **226′** or **226″** associated with the second harmonic. The remaining harmonics are thus added to the audible note in rapid succession.

Paterns **156**—**165** may be connected through resistors **225**, contact springs **375**—**377**, switches **379**, through harmonic attenuators **226** and **226′** connected in parallel, through battery **392** and the electron beam of tube **150** to form a complete potentiometer circuit. Sliding contacts **393** are fixed to rods **394** moved against a restraining spring, not shown, by floating bars **395** which in turn are moved by cams **396**. Cams **396** are mounted on shaft **397** which is turned by rack and pinion **398**. The rack is fixed to stop **399**.

Movement of stop **399** to various positions will be seen to suppress or accentuate the various harmonics as determined by the shapes of the cams **396**. When resistors **226** control quality, there may be simulated quality within one tone classification, i.e. woodwinds, while movement of stop **399** may produce variation within that classification, such as oboe, clarinet, etc.

Each resistor **226** is mounted on a resistor support **402** which is slidable with respect to contact **393** as determined by the position to stop **403**. A spring tensioned ball **404** fitting in a notch on shaft **405** of stop **403** allows the operator of the instrument to know by touch when the stop is in its normal position. Stops **403** allow each harmonic to be separately adjusted.

Alternate harmonic attenuator resistors **226′** have contacts **393′** moved by shafts **394′**. Shafts **394′** are moved by floating bars **395′** against restraining springs, not shown, which are in turn moved by cams **396′**. Each cam **396′** is rotated by a shaft **397′** and each shaft **397′** is rotated by a separate knob **408**. Thus the attenuation of each harmonic may be pre-adjusted or pre-set to a degree, before starting a rendition chosen by the musician. Cams **296′** aid in keeping contact **393′** at the selected position and allow the contact **393′** to have a different motion from that of knobs **408**.

A third set of alternate harmonic resistors **226″** are provided. These resistors are for independent separate harmonic control and are connected to stops in the form of calibrated sliding handles or to levers for rapid manipulation. They are not intended for group action. Resistors **226″** are always connected and are intended for rapid manipulation to achieve variations in the quality already set in the instrument by the musician.

Switch **410**, at the operation of the musician, selectively connects the contacts of the potentiometers containing resistors **226**, or **226′** to the pulse integrator and thus

causes the notes sounded to be in accordance with the harmonic attenuation determined by the harmonic-attenuator group selected. It will be understood that there would be a number of sets of resistors such as **226** representing tone families such as the oboe, clarinet, etc., and that there could be a number of sets of resistors such as **226'** at the command of the musician.

Switch **410** includes curved clamps **411** having opposed concave curves, said clamps being urged together under tension to have opposite parallel motion when forcibly separated. Buttons **412** are urged upwardly by springs **413** and have lower bulbous portions **414** adapted to be squeezed between clamps **411**. As one button **412** is pressed down and the associated bulbous portion **414** squeezes clamps **411** apart, the bulbous portion already between clamps **411** will escape, forced up by its spring **413**. Switch **410** operates to connect one set of contacts **393** or **393'** to the pulse integrator and thus allows selection by the musician to the type of quality control used. This selector device would also be adaptable for use with dynamic selector switch stop **348** of Fig. 7. Switches such as **390'** are operated by other keyboard levers.

In Fig. 10 is shown an alternate form of quality control employing capacity attenuation. As explained by Figs. *5a–5f*, the beam current is in the form of high frequency pulses which may be attenuated by capacitance. In Fig. 10 patterns such as **156** are each connected to a resistor **227**, all of which are connected through overall attenuation condenser **421**, coupling circuit pulse integrator, detector **420** and amplifier **237**, these elements being similar in function to elements **128**, **129**, **135**, and **136** of Fig. 4, and loud speaker **276**. Voltage is applied between anode patterns **156** and cathode of the cathode ray tube by battery **422**. The various attenuating bleeder circuits, condensers **421**, **423**, **425** and **425'** discharge between pulses except **421**, which discharges directly, through resistors **227** and battery **422** to cathode. Other types of impedance, either variable resistors or inductors, may replace the condensers shown here.

In the modification of Fig. 10, frequency compensation for the natural characteristics of the ear is accomplished by condensers **423** which vary the voltage at the junctions of the patterns such as **156** and resistors **227**.

In parallel with condensers **423** are harmonic-attenuator condensers **425**, one condenser **425** being connected between each pattern, such as **156** and the electron beam potential supply. Condensers **425** provide tone families similar in function to stop **399** of Fig. 9 and **425'** for use similar to stop **408** or resistors **226'** (Fig. 9) that is for pre-set qualities or independent control. Switches **424** permit alternate selection of the system including condensers **425** or the system including condensers **425'**. Condensers **425** comprise a relatively movable plate, or plates, **426** and a relatively fixed plate, or plates, **427**. Movable plates **426** are shown to be mounted on shaft **434** for rotation. Shaft **434** has mounted thereon a pinion **431** which is rotated by oppositely acting stops **429** and **430** each of which carries a rack meshing with an opposite side of pinion **431**. Plates **426** can therefore be rotated to any desired degree by pushing one or the other of stops **429—430**. Plates **426** and **427** are shaped to attenuate the various harmonics to achieve the sound effects desired for the various settings of stops **429—430**.

Relatively fixed plates **427** may also be separately rotated with respect to plates **426** by stops **428** carrying racks meshing with pinions fixed to plates **427**. Stops **428** allow individual adjustment of the attenuation of the various harmonics within the tone family compass as desired by the musician.

In Fig. 11 is shown an alternatively distributor-switch arrangement in which a plurality of gas filled tubes such as tubes **435**, **436**, **437**, and **438**, each have an anode, control grid, and cathode. Each of the cathodes of tubes **435–438** is connected to a common junction point **445** through a variable cathode resistor **440** and a potentiometer **441**. The anodes of tubes **435–438** are connected together through conductor **446** and to the cathode through common junction point **445** and battery **447**. Cathodes of adjacent tubes **435–438** in the ring-like series are connected through condensers **442**. The grid of each tube **435–438** is connected to the cathode of the preceding tube in the series by resistors **448** and **449**, and battery **450**. Voltage taps on potentiometers **441** are connected to the grid of pentode **60** which corresponds to pentode **60** in Fig. 6. Switches **439** between the taps on potentiometers **441** and the grid of tube **60** constitute keyboard lever switches corresponding **300** and **300'** of Fig. 7.

Relaxation generator **452** of conventional construction generates a succession of positive pulses of steep wave front at supersonic distributor frequency. The interval between pulses is the increment of time during which one note will be sounded until it is reached again by operation of the distributor circuit. The pulses generated by oscillator **452** are applied to the grids of tubes **435–438** through condensers **453**. It will be understood that in the actual circuit used there will be thirteen gaseous triodes such as tubes **435–438**, one corresponding to each of the electrodes **181** in tube **182** of Fig. 7.

In explaining the operation of the circuit of Fig. 11, it will be assumed that tube **435** is conducting. Since tube **435** is conducting, current is flowing through resistor **440** connected with the cathode of that tube and hence the negative bias on the grid of tube **436** is lowered because of the connection through resistors **448** and **449** and battery **450** to resistor **440**. Batteries such as **450** are for the purpose of maintaining a negative bias on the grids of tubes **435–438**. When the next positive pulse from relaxation oscillator **452** is applied to all the grids of tubes **435–438**, tube **436** will begin to conduct since it has a sufficiently low grid bias. Tubes **437** and **438** do not have a sufficiently low grid bias to be rendered conducting by the pulse. When tube **436** begins to conduct the drop across its resistor **440** charges the condenser between the cathodes of tubes **435** and **436** making the cathode of tube **435** so positive that the tube stops conducting. On arrival of the next pulse from oscillator **452** tube **437** will begin to conduct and tube **436** will be cut off. This process is continuously repeated, each pulse from oscillator **452** causing the next tube to conduct and the tube presently conducting to be cut off. Similar circuits employing vacuum tubes are known to the art and may be employed in place of the gas filled tube circuit shown.

Reference is now made more particularly to Figs. 12 and 13 for a description of an embodiment of this invention using continuous harmonic patterns. In this embodiment cathode ray tube **490** which includes horizontal and vertical deflection plates **491** and **492**, respectively, carries on its end wall **493** and concentric therewith a plurality of ring-like, substantially flat, continuous patterns **494**, the radial dimensions of which vary in sinusoidal manner. The innermost of patterns **494** varies in radial dimension as a single complete sine wave. The adjacent pattern varies to form two complete sine waves and the succeeding patterns similarly form the successively higher harmonics.

Patterns **494** are each connected to the harmonic compensation and attenuation circuit **498** which is in turn connected through pulse integrator circuit **237**, detector **244** and amplifier **260** to speaker **276**. Harmonic compensation and attenuation circuit **498** contains compensation and attenuation resistors **225** and **226** shown in Fig. 6. Circuits **237**, **244**, and **260**, and speaker **276** have a similar construction and operation to that of the same numbered circuits in Fig. 6. Frequency control circuit **501** contains tube **60** and its associated circuit shown in Figs. 1 and 6. Distributor **502** contains and electronic distributor tube similar to tube **182** of Fig. 6. Keyboard **500** is interconnected with frequency control circuit **501** and

distributor circuit **502**, so that there is produced in the output of frequency control circuit **501** a voltage having a magnitude indicative of the pitch of the note being played on keyboard **500** and sounded at that increment of time. Distributor **502** operates to cause the output voltage of frequency control circuit **501** to successively represent over small increments of time the various notes played on keyboard **500**.

Sine wave oscillator **503** produces a sine wave of a frequency controlled by the output voltage of frequency control **501**. Such circuits for modulating frequency are well known. The sine wave produced by circuit **503** is split into two sine waves 90 degrees apart in phase but each having the frequency of the original sine wave. The splitting of the output of circuit **503** is accomplished by the circuit including condenser **505** and resistor **506**. One of the quadrature sine waves is applied to horizontal sweep circuit **507** through transformer **508** while the other quadrature sine wave is applied to vertical sweep circuit **509** through transformer **110**. Vertical and horizontal sweep circuits **507** and **509** are modulator circuits which modulate the amplitude of the voltages applied to the input circuits thereof. This amplitude modulation is controlled by saw-tooth oscillator **515** which is a circuit capable of generating a saw-tooth wave having a frequency relatively high compared to the frequency of sine wave oscillator **503**. The saw-tooth wave produced by oscillator **515** is applied to sweep circuits **507** and **509** to modulate in amplitude the quadrature waves from circuit **505** and **506**. The deflection waves produced by horizontal sweep circuit **507** and vertical sweep circuit **509** are applied to horizontal deflection plates **491** and vertical deflection plates **492**, respectively, of tube **490**.

Saw-tooth oscillator **515** is connected to pulse integrator **237** through peaker circuit **516** which is constructed similarly to peaker circuit **246** in Fig. 6 and operates to derive a pulse from the radial return deflection voltage of the saw-tooth wave developed by circuit **515**. The pulse from peaker **516** trips integrator **237**, discharging the condenser therein as explained above.

In the operation of the embodiment of the invention shown in Fig. 12, keyboard **500**, distributor **502**, and frequency control circuit **501** act to produce a series of voltages, each representing the pitch of the keyboard lever depressed and each lasting over an increment in a supersonic distribution period as explained above. Each short voltage level frequency modulates sine wave oscillator **503** to produce a sine wave having a frequency indicative of the pitch of the keyboard lever producing said voltage level.

The two quadrature voltages produced by circuit **505—506**, having a frequency as produced by sine wave oscillator **503**, cause the pencil beam produced by tube **490** to describe a circular trace on the end wall **493**. Saw-tooth oscillator **515** modulates the amplitude of the vertical deflection voltage causing the circular trace on end wall **493** to be contracted and expanded over the patterns **494** at a high rate of speed. This results in a rapid radial scan which moves circumferentially over patterns **494** at a rate determined by the note played on keyboard **500** that momentarily is being sounded by the instrument through the action of distributor **502**.

The signal produced by patterns **493** passes through circuits **498**, **237**, **244**, and **260** where it is handled in the same manner as described in Fig. 6. Peaker **516** operates to trip pulse integrator **237** and add the signals produced in one radial sweep by the electron beam of tube **490** also as explained in regard to Fig. 6. Speaker **276** produces the audible oscillations.

Another embodiment of part of this invention is shown in Figs. 14 and 15 in which the sine wave patterns **530** have a cylindrical or conical surface and are placed inside of the cylindrical or conical envelope of vacuum tube **531**. Patterns **530** may be mounted on a separate cylindrical mounting member as shown in Fig. 15 or mounted directly on the inner surface of the envelope of vacuum tube **531**. Tube **531** also has a central axial cathode **532**. The patterns **530** are each connected to the attenuation circuits **40** which are in turn connected through amplifier **42** to speaker **43**. The deflection circuit for rotating the electron beam produced in tube **531** by cathode **532** is not shown in Fig. 14.

Fig. 15 shows an end view of tube **531** without the connection to the patterns **530** but with deflection coils **535**, **536**, **537**, and **538**, each of which extends the length of tube **531**. Opposite coils **536** and **538** are connected in series to oscillator **542** through transformer **543**. Opposite coils **535** and **537** are connected in series with condenser **539** and in parallel with coils **536** and **538** through transformer **543** to oscillator **542**.

The tank circuit for oscillator **542** consists of condenser **543** and one of coils **544**, each of which is connected to one of the thirteen electrodes **547** arranged in a circle on the end wall of cathode ray distributor tube **549**. The electron beam of tube **549** is caused to sweep in a circle over electrodes **547** by sweep circuit **548** which impresses quadrature sine waves on the deflection plates of tube **549**. The tank circuit above described is coupled to oscillator **542** by condensers **551** and **552**. Battery **550** supplies the cathode-anode potential necessary to produce the electron beam in tube **549**. The oscillatory current produced by oscillator **542** is prevent from passing through battery **550** by choke coil **545**. Twelve of the coils **544** each represent one note of an octave and have a series of switches **555** one for each octave of the main keyboard such as keyboard **65** of Fig. 2. The thirteenth electrode **547** is connected to a coil having a switch **555** for each keyboard lever of octave keyboard such as **66** in Fig. 2, each switch **555** being operated by a keyboard lever, each coil **544** is connected to oscillator **542** through a switch **546** arranged to be closed along with the closing of any switch **555** associated with the said coil **544**. All of switches **555** and coils **544** are not shown.

In operation of the system shown in Figs. 14 and 15, when no keyboard lever is pressed and no switch **555** is closed, the characteristics of oscillator **542** are such that it does not oscillate. However, when a switch **555** is closed along with the closing of its corresponding switch **546**, through operation of a keyboard lever, oscillator **542** oscillates when the beam of tube **549** impinges on the corresponding electrode **547**, and this oscillation is determined by the amount of coil **544** shorted out and this depends on the pitch represented by the keyboard lever depressed.

The sine wave developed by oscillator **542** is split into two quadrature waves by action of condenser **539**. These quadrature currents applied to coils **535**, **536**, **537** and **538** cause the sheet-like electron beam developed by cathode **532** to rotate and sweep over patterns **530** at a rate of speed determined by the instant frequency of oscillator **542** and in turn by the keyboard lever pressed. It will be understood that the magnetic fields set up by deflection coils **535—538** not only rotate the electron beam of tube **531** but are also effective in forming the electrons from cathode **532** into a sheet-like beam.

The signals generated by patterns **530** as the electron beam sweeps over the varying surface of said patterns is altered by attenuator circuits to achieve the desired quality and amplified and rendered audible all as described with respect to Fig. 1. It will be understood that when a plurality of keyboard levers are pressed simultaneously closing a switch **555** on each of a plurality of coils **544**, that the corresponding notes are sounded successively at a super-audible rate also as described with respect to Fig. 1. It is to be understood that, if space permits, all of the notes and their harmonics may be represented by patterns and no super-audible switching device employed or that other combinations of patterns be used than here described or that octaves be obtained by doubling circuits.

Reference is now made to Figs. 16, 17, and 18 for a description of an alternative embodiment of the discontinuous sine patterns in which complementary patterns are used connected in push-pull relation. Cathode ray tube **560**, of the type which generates a pencil-like beam, carries on its end wall a plurality of sine wave patterns designated generally as **561**.

These patterns are shown more particularly in Figs. 17 and 18 the latter figure showing a side view. Sine wave patterns **562** and **563**, representing a fundamental wave, are complementary and 180 degrees out of phase. Patterns **562** and **563** are mounted in close proximity, but not in contact with each other on insulating member **568**, which may be the end wall of tube **560**. It will be understood that patterns **562—565** are mounted inside the tube **560** for impingement thereon by its electron beam. The second harmonic is represented by complementary patterns **564—565** also 180 degrees out of phase. Although these patterns of Figs. 17 and 18 are shown of the discontinuous type the principal is also applicable to the continuous forms shown in Figs. 12 and 14. It will also be understood that the deflection means associated with cathode-ray tube **560** in Fig. 16 are connected to suitable deflecting circuits in the same manner as illustrated in Fig. 4, for example, by means of the leads **117***a*, **118***a*.

One of each pair of patterns is connected through attenuator circuits **570** and integrator and detector circuits **571** to the grid of tube **572**, an amplifier tube connected in push-pull relation with amplifier tube **577** through transformer **579**. Transformer **579** is connected to speaker **43**. The other of each pair of patterns is connected through attenuator circuits **575** and integrator and detector circuits **576** to the grid of amplifier tube **577**. Attenuator circuits **570** and **575** contain harmonic compensator resistors and harmonic attenuator resistors corresponding to resistors **225** and **226**, respectively, of Fig. 6. Integrator and detector circuits **571** and **576** contain circuits **233**, **237**, **244**, **253**, and **256** of Fig. 6.

In the operation of the embodiment shown in Figs. 16, 17, and 18 the pencil beam of tube **560** is caused to be deflected horizontally successively across the patterns at a speed determined by the pitch of the keyboard lever pressed as explained with respect to Fig. 6. The beam of tube **560** is also deflected vertically at a relatively high rate also as in the embodiment of Fig. 6. The signals produced by the two sets of patterns are 180 degrees out of phase. These two signals are attenuated, integrated and detected as explained with regard to Fig. 6 and are applied in push-pull relation through tubes **572** and **577**, and through transformer **579** to speaker **43**.

The sinusoidal patterns representing the fundamental frequency and the harmonics may be made, as described above, by attaching thin metal foil to the end wall of the cathode ray tube or on a separate insulated mounting plate. These patterns may be made by photoengraving processes from a master plate which has been photographed from an enlarged drawing. The patterns may alternatively be sputtered on the insulated mounting plate through a master template or the whole surface sputtered, then covered with a rubber-like anodically formed background, sand blasted and the rubber removed. Another possibility of producing these patterns would be by forming them on an aluminum plate by an ink, known to those skilled in the art, which resists anodizing. The plate would then be anodized, leaving a non-conducting oxide on the surface except on the inked portion. The ink can then be dissolved leaving sinusoidally shaped aluminum conducting surfaces surrounded by a non-conducting oxide surface.

Another alternate anode construction could be availed of in which there is a conducting plate having sinusoidally shaped holes representing the fundamental and harmonics. Behind each sinusoidally shaped hole, with respect to the electron gun, would be a separate conducting plate at a high positive potential. The front plate having the sinusoidally shaped holes is at a relatively low potential.

The focusing and deflecting of the electron beam in the cathode ray tube containing the patterns may be done by electromagnetic means or electrostatic means or by a combination of electromagnetic and electrostatic means. The form of the anode current fluctuations is determined, as previously explained, by the shape of the anode patterns and the rate of deflection of the electron beam. Consequently pattern shape and sweep characteristics cannot be considered separately. If a known tone quality is to be synthesized, said tone having been analyzed into its elemental sinusoidal vibration components according to Fourier's method, then patterns of sine wave form would be required, assuming that the horizontal or "X" axis deflection is linear. Shapes of anode patterns compensated for non-linearity have been treated in Patent 2,075,802. For the purpose of developing a new tone quality the generated sound wave form originating from each pattern and transmitted to the ear should be such that the sensory response of the ear is itself elemental.

The mounting plate on which the patterns are mounted is preferably of glass, mica or other substance which will withstand outgassing of the tube. Intercapacity coupling between adjacent patterns may be reduced by using separate plates for each wave pattern and mounting them in a frame each at an agnle to the other like the slats in a Venetian blind when partially opened. Although the patterns in Figs. 1, 4, 6, 9, 16, and 17 have been shown flat, it will be understood that in actual practice it is preferable that these patterns present a spherical surface to the electron beam impinging thereon. It may also be advantageous to place control grids in front of the anode patterns and relatively adjacent thereto for control purposes. Grids or other collecting electrodes may also be placed near the patterns to collect secondary electron emission from said patterns and thus derive the anode signal by secondary emission rather than by a direct action of the electron beam upon the anode patterns.

Since the patterns are symmetrical along the horizontal axis a circuit which would supply a wave form with a uniformly slow rise and fall to the horizontal deflecting plates would serve as well as a sawtooth wave having relatively slow rise and relatively rapid fall. This deflecting voltage would have the wave form of an isosceles triangle and is known as a "back to back" wave form. A voltage wave of this shape may be generated by methods known to the art including the combination of a sine wave oscillator followed by a squaring circuit and finally by an integration stage employing a time constant about ten times that of the period of the cycle. Amplification would then be required before the voltage could be applied to the deflection plates. The integrator consists of a potential divider made up of a condenser and resistor in series. The integrated output voltage is derived from the condenser terminals. A trapezoidal voltage wave form may be generated for use where magnetic deflection is employed, as is employed in some types of television scanning.

It is to be noted that it will be possible to simultaneously sound two different dynamic effects as well as two different qualities on a 2-manual instrument having two complete keyboard systems as shown in Fig. 2, each of said manuals being associated with a system containing ordinary patterns as shown in Fig. 6. If push-pull patterns are used as shown in Figs. 16, 17, and 18 one manual can control the sounds produced by one anode of each pair of the push-pull patterns thus permitting the use of one cathode ray tube with two manuals. If a single manual is associated with a cathode ray tube containing push-pull patterns the wave derived from each set of patterns may be differently controlled as to dynamic and qualitative characteristics so that twenty-six different

notes, half of which have a frequency equal to the other half, may be sounded on a single manual.

It will be obvious in the means for producing attack and decay characteristics in the dynamic control system that rotary condensers having shaped plates might be used in the place of the tapered resistor **306** used in potentiometer **304** in the manner that condensers are used in Fig. 10.

It will be understood that various changes may be made in the form and proportion without departing from the scope of the invention as defined in the appended claims.

What is claimed is:

1. In combination, a cathode ray tube having at least one wave shaped pattern, said cathode ray tube having means for generating a beam for impinging upon said pattern, said cathode ray tube also having deflecting means for causing said beam to scan said pattern, a deflecting wave producing means coupled to said tube for applying scanning energy to said deflecting means, a keyboard having levers representative of at least one octave of musical notes coupled to said wave producing means, each lever on being operated controlling the deflection wave producing means to cause the electron beam to scan said pattern at such a speed as to produce an oscillation at a frequency represented by the lever operated, and distributing means connected to said keyboard operating to successively make the levers representing the notes of said octave effective to control said wave producing means.

2. In a musical instrument, means for scanning shaped patterns to produce a musical note, output means responsive to said scanning means for generating signals corresponding to said patterns, attenuation means coupled between said output means and said scanning means, said scanning means including electronic discharge means for controlling the speed of said scanning means, said electronic discharge means comprising a capacitor and a controllable charging circuit therefor variable impedance control means connected to said charging control circuit to charge said capacitor at various rates of speed determined by the impedance of said control means, a main keyboard comprising levers representing notes of a musical scale, an octave keyboard having levers in front of and closely adjacent to certain of main keyboard levers, electrical switch means connected to the levers of each keyboard each octave lever and associated switch being settable in accordance with the note of the corresponding main keyboard lever and a note one octave removed, a distributing means having stationary contacts corresponding to the notes in one octave of the musical scale, and one additional stationary contact representing an octave note, said distributor means including a sweeping contact which sweeps over said stationary contacts at a superaudible rate, circuit means including resistors connecting said switch means to said stationary contacts each of said stationary contacts being coupled to a separate resistor, intermediate taps on said resistors being connected by said circuit means to control the impedance of said electronic discharge means, and each of said keyboard levers and associated switch means operating to couple one of said resistors to said discharge means.

3. An electronic musical instrument as defined in claim 2 in which said scanning means comprises a cathode ray tube including a cathode and a plurality of wave shaped patterns, one of said patterns representing a fundamental wave, the other of said patterns representing harmonics thereof, means for producing an electron beam varying in intensity at a relatively high frequency, means for causing said electron beam to scan said patterns, a circuit connecting each of said patterns with said cathode, each of said circuits including a capacitor means having relatively fixed and relatively movable plates, means to move said relatively movable plates simultaneously to various selected positions, said relatively movable plates being shaped to give a predetermined capacity at each of said selected positions, each of said relatively stationary plates being moved by separate adjusting means, and each of said patterns being additionally coupled to sound producing means.

4. In combination, a cathode ray tube having at least one wave shaped pattern, said cathode ray tube having means for generating a beam for impinging upon said pattern, said cathode ray tube also having deflecting means for causing said beam to scan said pattern, a deflection wave producing means for applying scanning energy to said deflecting means, a keyboard having levers representative of a musical scale, each lever including switch means, a circuit connecting said switch means to said deflection wave producing means, each lever and associated switch means on being operated controlling the deflection wave producing means to cause the electron beam to scan said pattern at such a speed as to produce an oscillation at a frequency represented by the lever operated, clamping means coupled to said deflection wave producing means for causing the position of one extreme of the scan to be always a constant value, an electrode in said cathode ray tube in alignment with one end of said pattern, said electrode being connected to said deflection wave producing means to cause said deflection wave producing means to start its next cycle upon impingement of said electron beam on said electrode, and a distributing device connected in said circuit and cooperable with said switch means for sequentially controlling said deflection wave producing means in accordance with the notes of the scale corresponding to said levers.

5. A musical instrument as defined in claim 2 in which said scanning means comprises a cathode ray tube including a plurality of wave shaped patterns, one of said patterns forming a fundamental wave, the other of said patterns representing various harmonics of said fundamental wave, and means in said cathode ray tube for producing a ribbon-shaped beam of sufficient length to impinge on all of said patterns simultaneously.

6. A musical instrument as defined in claim 2 in which said scanning means comprises a cathode ray tube having at least one wave shaped pattern, means in said cathode ray tube for producing an electron beam having a cross sectional dimension small relative to the size of said pattern, means for deflecting said beam in two mutually perpendicular directions, first means for applying energy to said deflecting means to cause the beam to scan said pattern at a uniform relatively rapid speed in one of said two directions, second means for applying energy to said deflecting means to cause said beam to scan said pattern at a relatively slow variable rate of speed in said other direction, said main keyboard and associated electrical switch means comprising a plurality of levers each associated with said second deffection means, each of said levers and switch means upon being operated controlling the second deflection means and causing the beam to scan at a certain rate of speed in said other direction, means for connecting said patterns to pulse integrating means to store a charge indicative of the time the beam impinged on said patterns during a complete deflection in said one direction, means for discharging said integrating means to form a pulse at the end of each deflection in said first direction, and means for detecting said pulses to obtain a wave containing a fundamental that is proportionate to the deflection speed in said other direction.

7. A musical instrument as defined in claim 6 in which there are a plurality of wave shaped patterns, one of said patterns representing a fundamental and defining at least a portion of a wave having a cycle of a certain length, each of the other of said plurality of waves representing harmonics of said fundamental and defining at least portions of waves having cycles the lengths of which are different integral multiples of the length of said fundamental cycle.

8. A musical instrument as defined in claim 6 in which said scanning means comprises a cathode ray tube having

a continuous pattern with a cylindrical surface the linear elements of which vary in length to form a wave pattern, an axial cathode for producing an electron beam, deflecting means and focusing means for causing said electron beam to be focused into a planar sheet and rotated about said cathode to sweep over said pattern.

9. Amusical instrument as defined in claim 8 in which said cathode ray tube includes a plurality of continuous patterns, one of said patterns having a cylindrical surface varying to form one complete wave cycle, the other of said patterns having cylindrical surfaces varying to form a number of wave cycles of different integral multiples of said first wave cycle, said electron beam operating to sweep over all of said wave patterns simultaneously.

10. A musical instrument as defined in claim 8 in which said deflection means includes a plurality of pairs of opposite magnetic coils, and means for causing current to flow through said coils in such a phase relation that a magnetic field will be caused to rotate about said cathode as an axis.

11. A musical instrument as defined in claim 8 in which said cathode ray tube includes a plurality of continuous patterns, one of said patterns having a cylindrical surface varying to form one complete wave cycle, the others of said patterns having cylindrical surfaces varying to form a number of wave cycles of different integral multiples of said first wave cycle, said electron beam operating to sweep over all of said wave patterns simultaneously, said deflection means including a plurality of pairs of opposite magnetic coils, and means for causing current to flow through said coils in such a phase relation that a magnetic field will be caused to rotate about said cathode as an axis, said magnetic coils being supplied with an oscillating current, the frequency of which is selectively varied.

12. A musical instrument as defined in claim 2 in which said deflection means comprises a cathode ray tube having an end wall, said end wall carrying a plurality of circular concentrically placed patterns, one of said patterns varying in radial dimension to form a sine wave, said other patterns similarly varying to form integral numbers of sine waves, means for producing an electron beam of small cross section compared to said patterns, means for deflecting said beam in two mutually perpendicular directions, means for causing said beam to scan said end wall to form a radial trace, means for causing said radial trace to rotate about the center of said end wall, and means for deriving from said patterns a measure of the time during any radial trace that the beam impinges upon any of the patterns.

13. A musical instrument as defined in claim 12 in which said deflecting means includes means for generating a first electrical sine wave, means for deriving from said first sine wave two sine waves in quadrature, and means for modulating said quadrature sine waves in amplitude.

14. A musical instrument as defined in claim 12 in which said deflection means includes means for generating a first electrical sine wave, means for deriving from said first sine wave two sine waves in quadrature, means for varying the frequency of said first sine wave within a certain range, and means for modulating the amplitude of said two quadrature sine waves at a frequency that is high compared to the highest frequency in said range.

15. A musical instrument as defined in claim 2 in which said scanning means comprises a cathode ray tube having a pair of wave-shaped patterns, said patterns being mutually complementary and 180 degrees out of phase.

16. A musical instrument as defined in claim 2 in which said scanning means comprises a cathode ray tube including a plurality of pairs of patterns adapted to be scanned by an electron beam, one pattern of one of said pairs having a cross section which varies as a complete wave cycle, the other pattern of said one pair also varying in cross section to form a complete wave cycle, said two patterns in said one pair being complementary and 180 degrees out of phase, each of the others of said pairs of patterns being similary constructed and each set of patterns forming different integral numbers of wave cycles, and additionally including two integrating circuits, means connecting corresponding patterns of each of said pairs to one of said integrating circuits, means for connecting the other corresponding patterns of each of said pairs to the other of said integrating circuits, and means for combining the outputs of said two integrating circuits to produce a combined output.

17. In combination, a cathode-ray tube having wave-shaped conducting patterns, electron beam producing means in said tube, means operatively associated with said cathode-ray tube for deflecting said electron beam, means coupled to said deflecting means including a capacitor coupled to said deflecting means for applying deflection energy thereto, means coupled to said capacitor for charging said capacitor at a variable rate, said variable rate charging means comprising a keyboard switch mechanism and a super audible frequency distributor device, said keyboard switch mechanism having levers and switches associated therewith representative of notes of a musical scale, a resistor connected to each of said switches, each lever actuating an associated switch to couple a respective resistor between said capacitor and said charging means during incremental periods of time determined by said frequency of said distributor device, and means coupling said patterns through an attenuation circuit to a utilization device.

References Cited in the file of this patent

UNITED STATES PATENTS

739,052	Beernald	Sept. 15, 1903
1,877,317	Hitchcock	Sept. 13, 1932
2,103,169	Midgley	Dec. 21, 1937
2,142,580	Williams	Jan. 3, 1939
2,144,337	Koch	Jan. 17, 1939
2,147,948	Kent et al.	Feb. 21, 1939
2,148,166	Kucher	Feb. 21, 1939
2,171,936	Kucher	Sept. 5, 1939
2,241,027	Bumstead	May 6, 1941
2,285,132	Weathers et al.	June 2, 1942
2,297,829	Hammond	Oct. 6, 1942
2,471,534	Muth et al.	May 31, 1949
2,525,475	Boykin et al.	Oct. 10, 1950