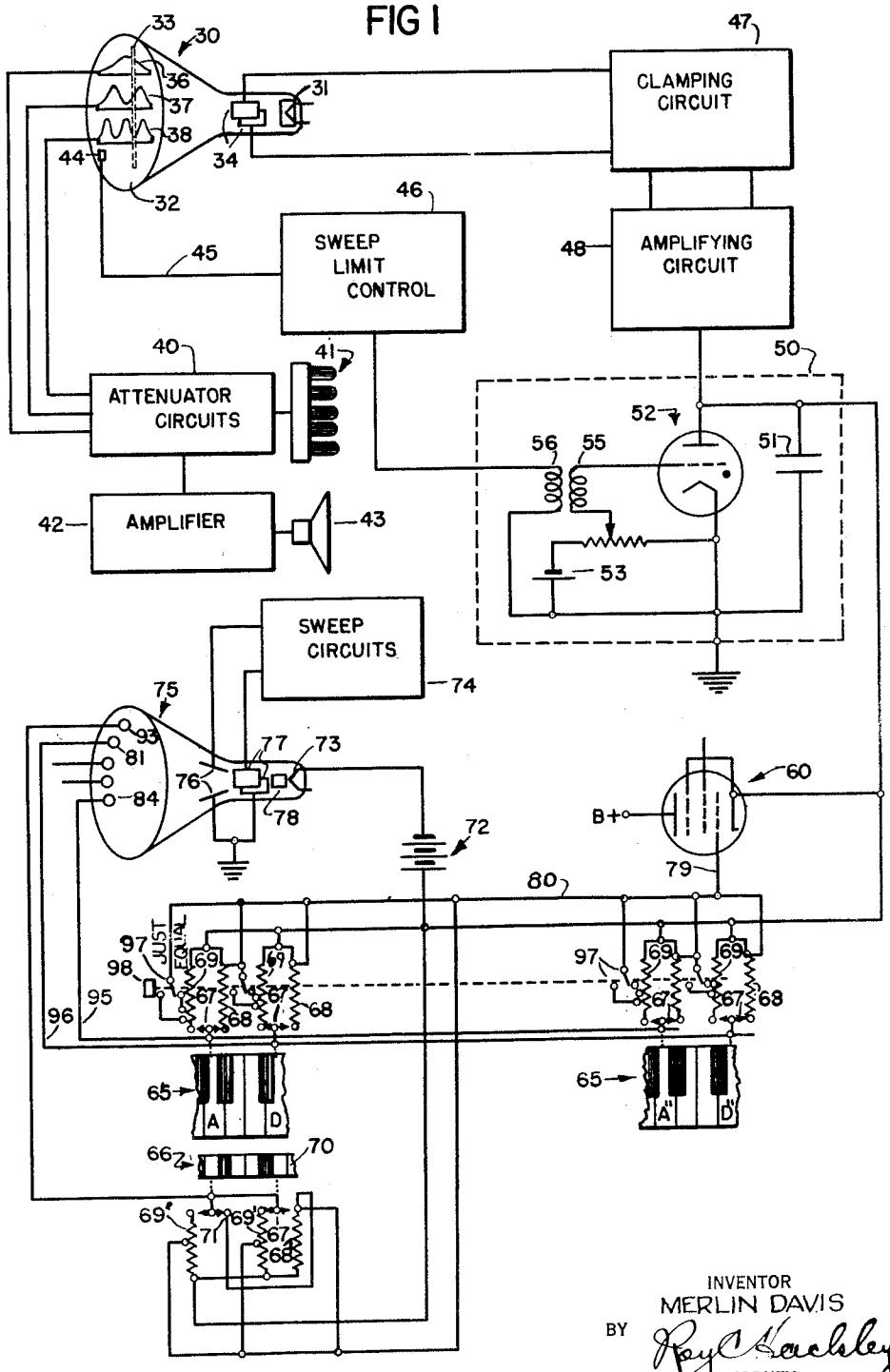
June 24, 1952 M. DAVIS 2,601,265

ELECTRONIC MUSICAL INSTRUMENT

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FIG I



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June 24, 1952 M. DAVIS 2,601,265

ELECTRONIC MUSICAL INSTRUMENT

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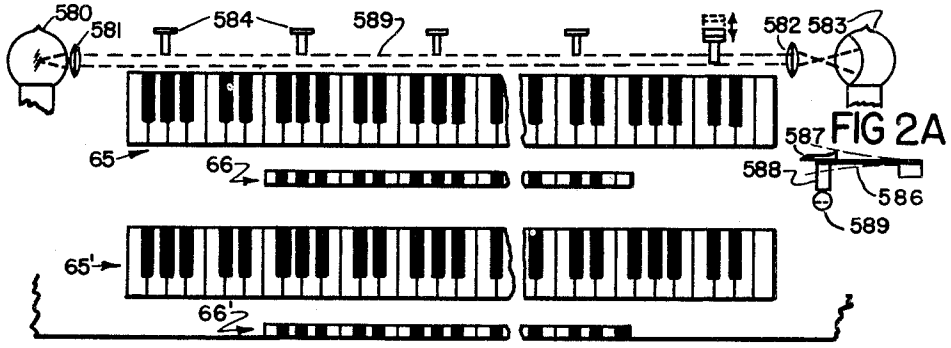


FIG 2A

FIG 2

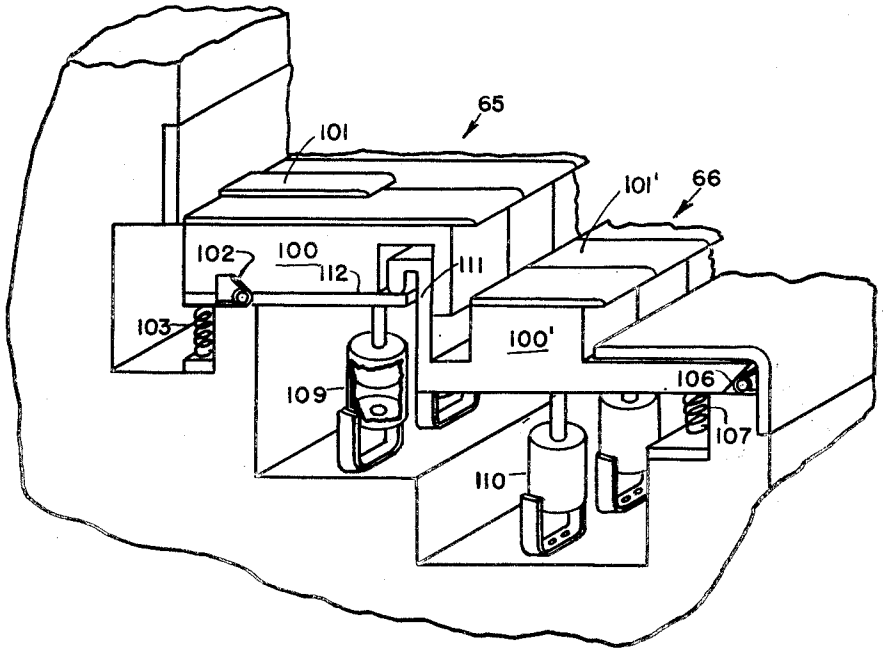


FIG 3

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ELECTRONIC MUSICAL INSTRUMENT

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FIG 4

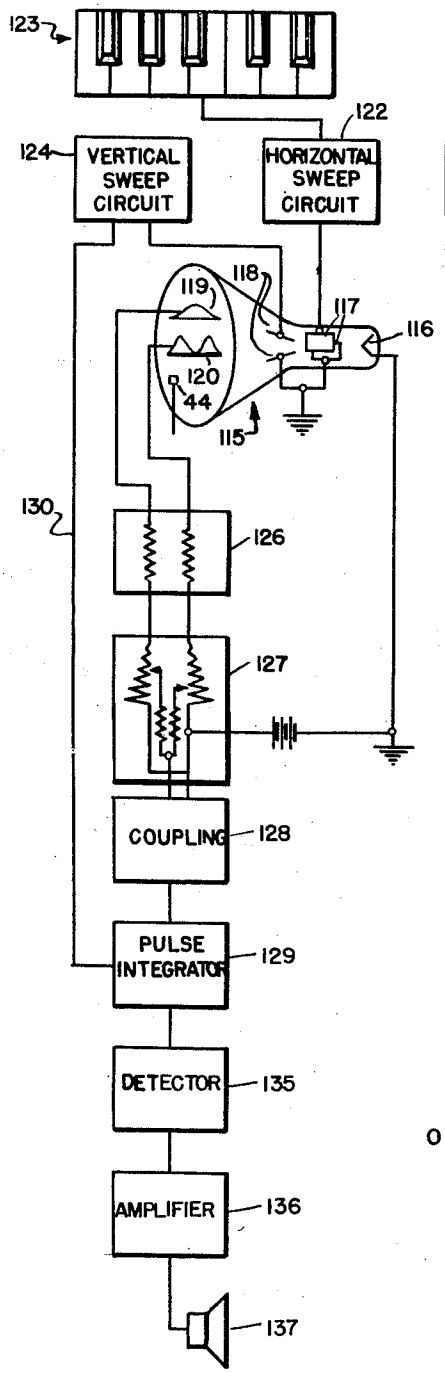


FIG 5a

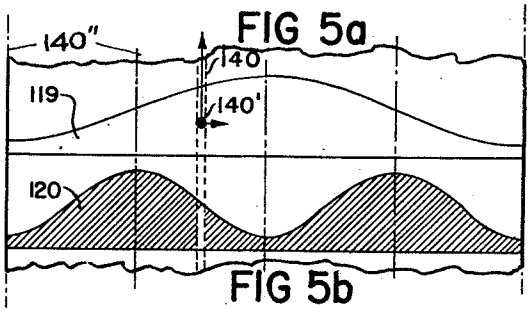


FIG 5b

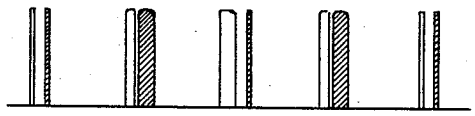


FIG 5c

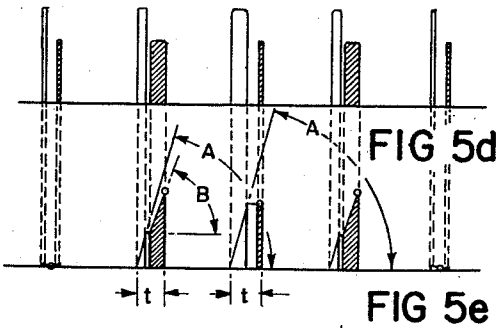


FIG 5d

FIG 5e

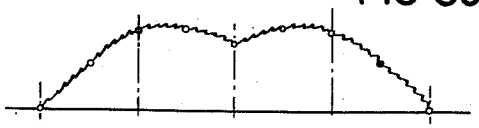
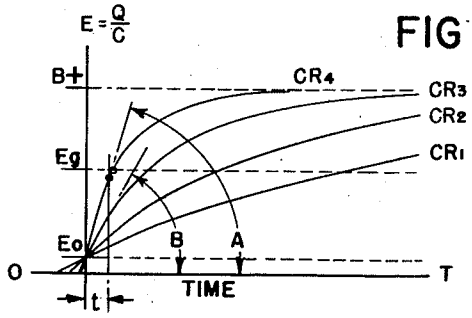


FIG 5f



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June 24, 1952 M. DAVIS 2,601,265

ELECTRONIC MUSICAL INSTRUMENT

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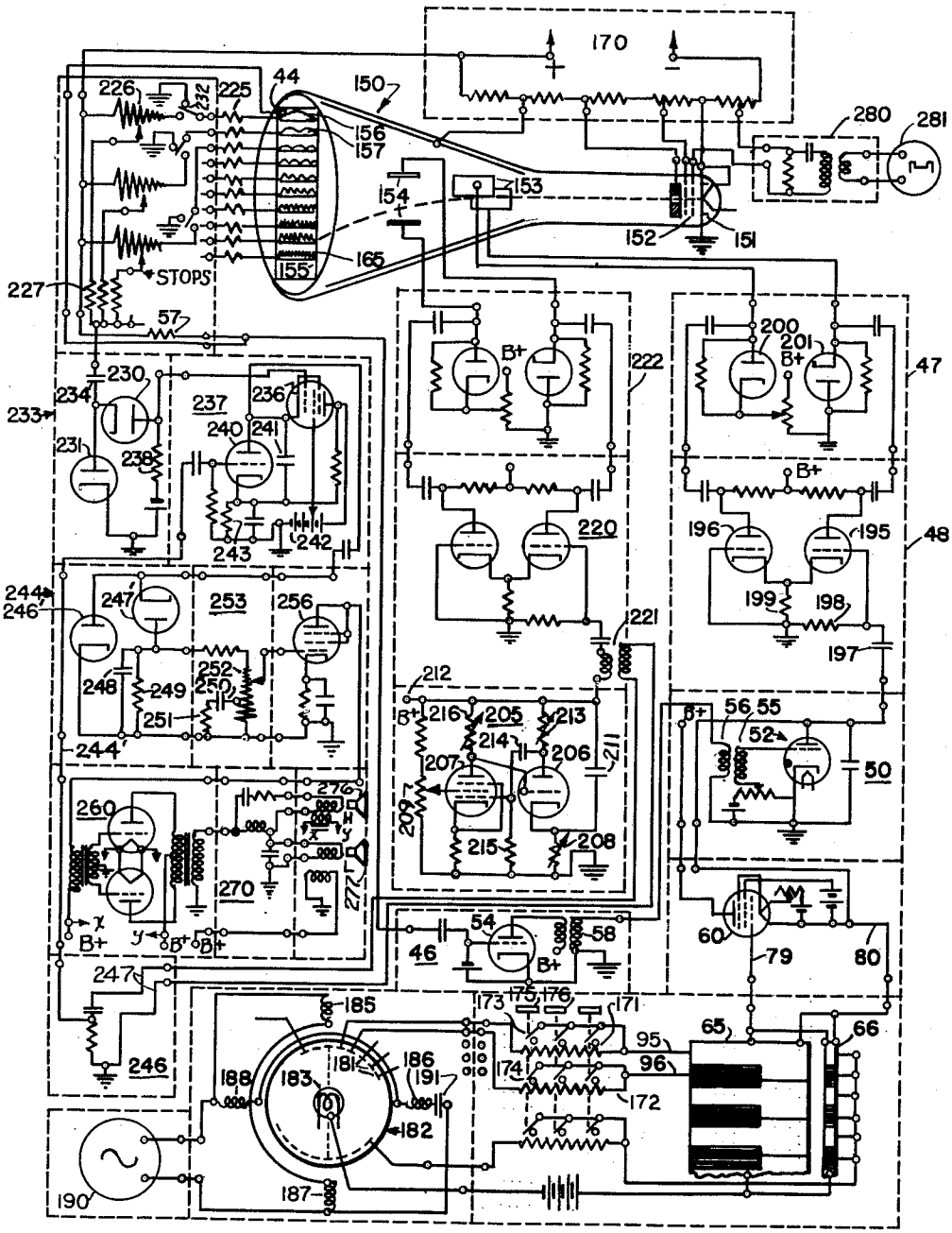


FIG 6

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BY Royal Hackleyfu

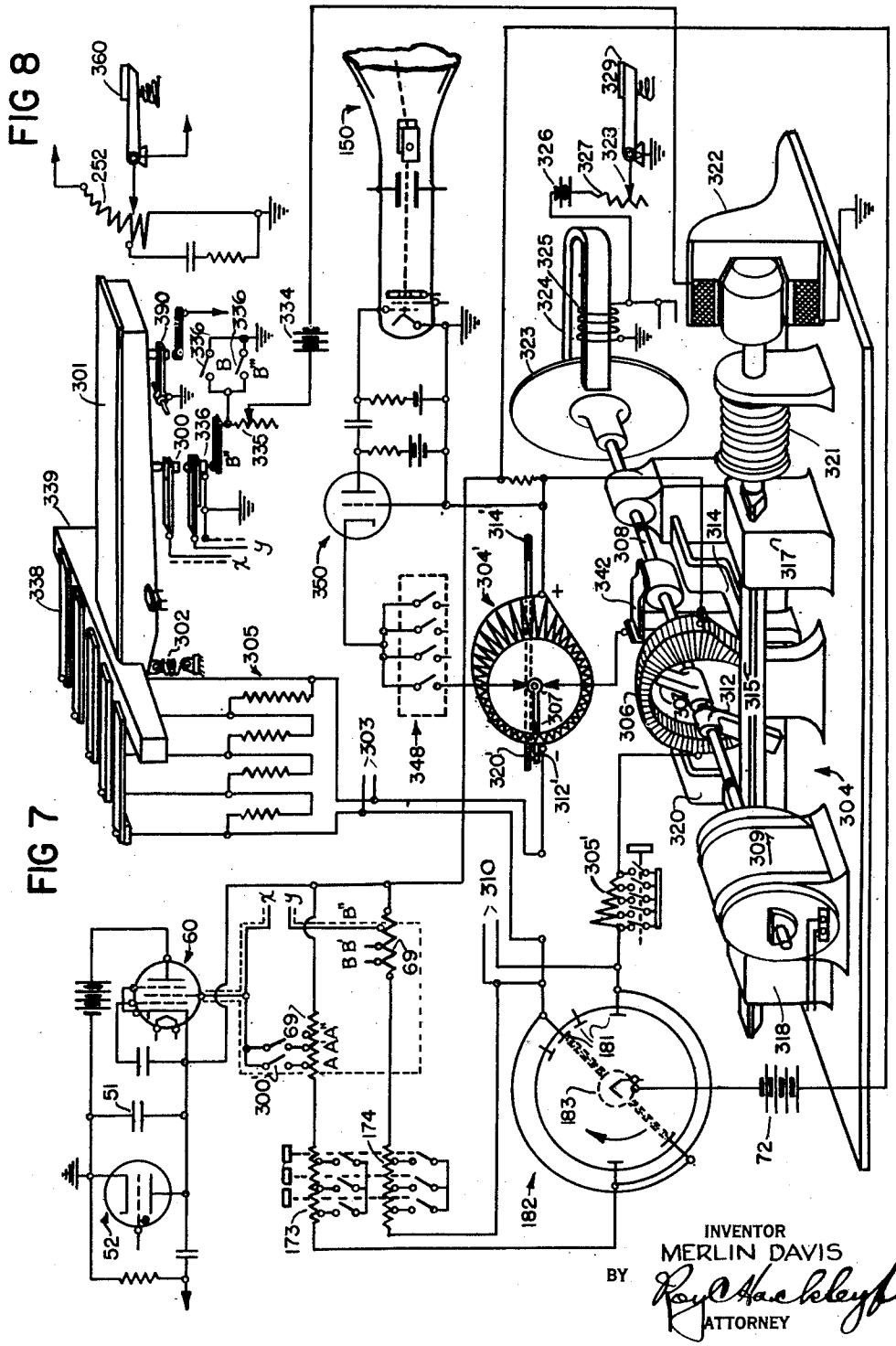
June 24, 1952 M. DAVIS 2,601,265

ELECTRONIC MUSICAL INSTRUMENT

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FIG 8

FIG 7



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June 24, 1952 M. DAVIS 2,601,265

ELECTRONIC MUSICAL INSTRUMENT

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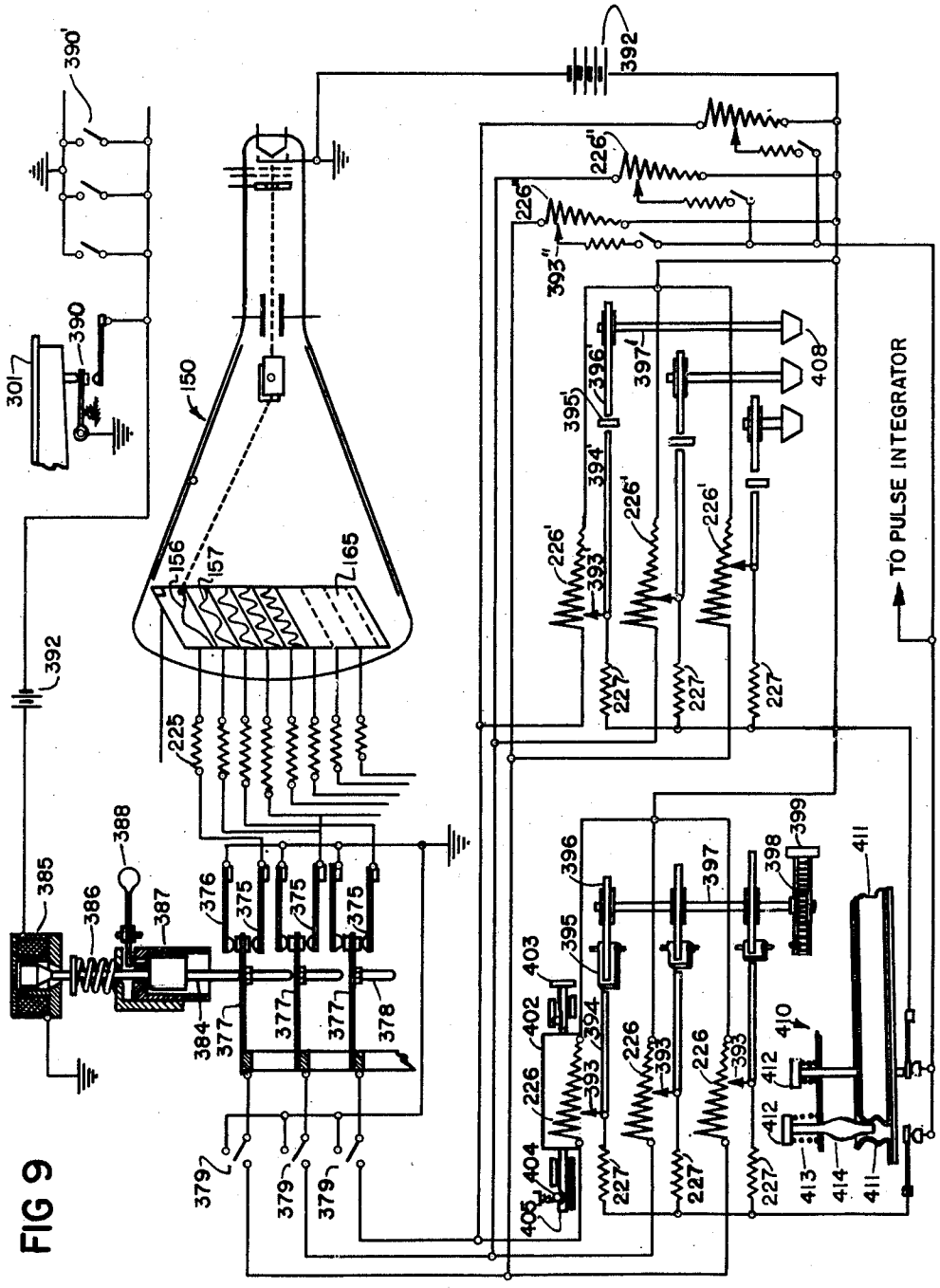


FIG 9

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June 24, 1952 M. DAVIS 2,601,265

ELECTRONIC MUSICAL INSTRUMENT

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FIG 11

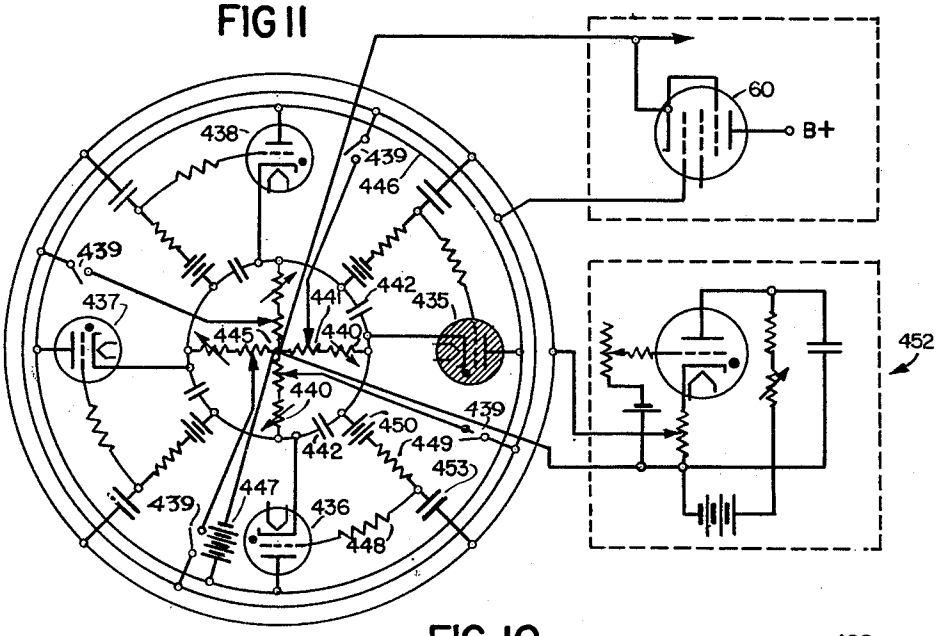
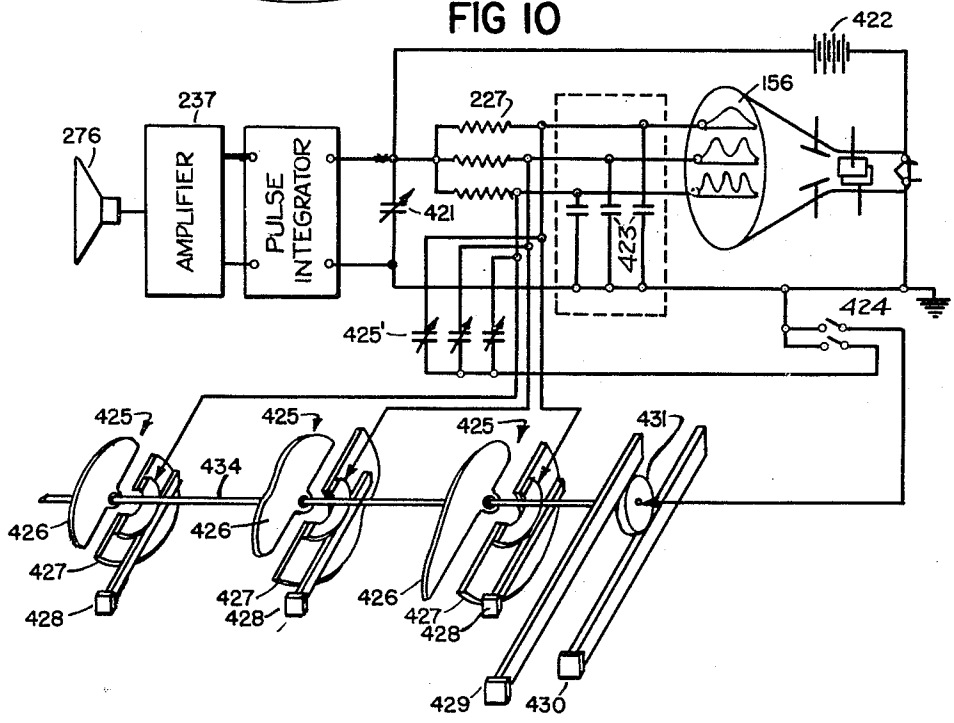


FIG 10



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FIG 12

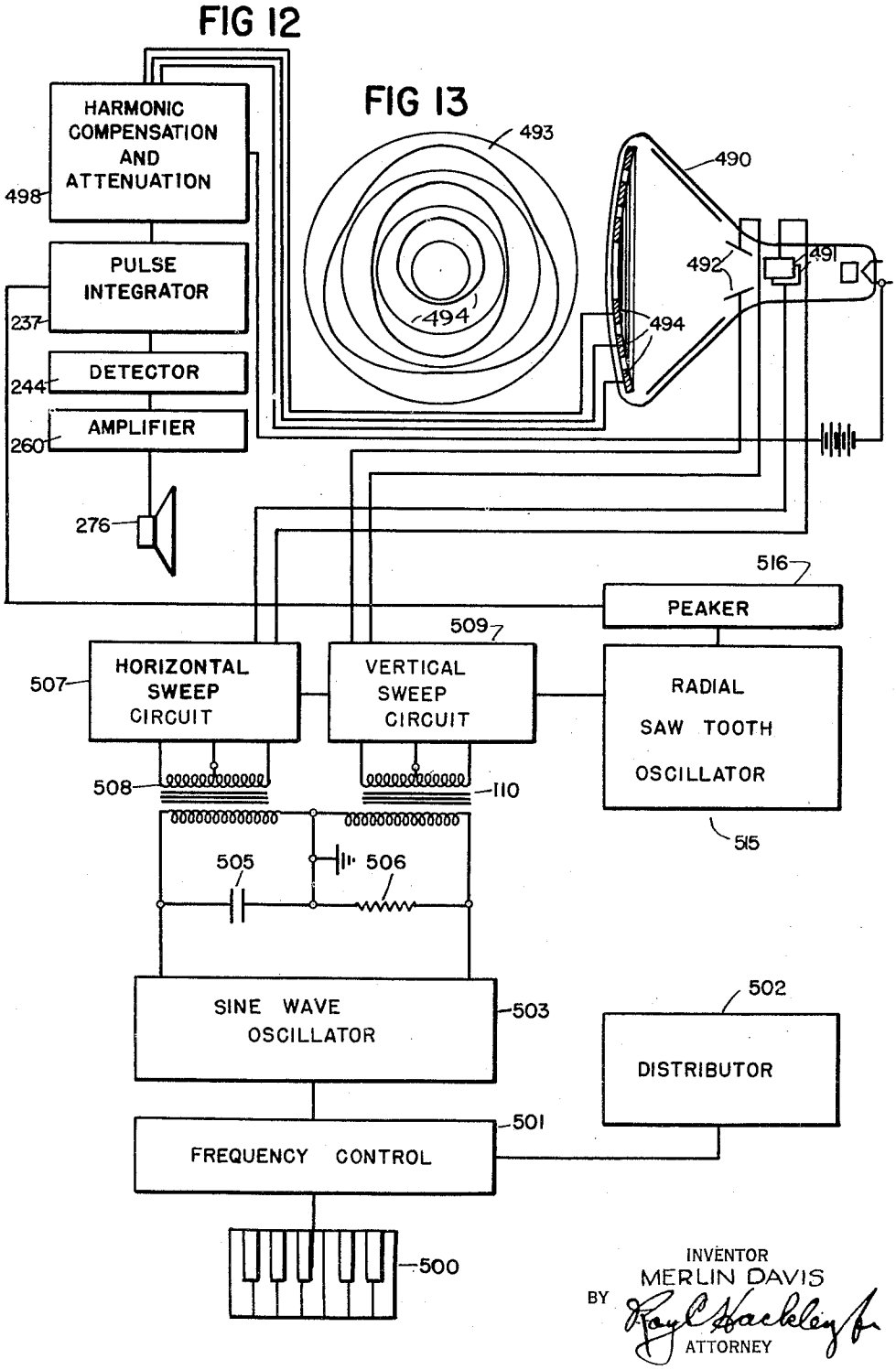


FIG 13

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ELECTRONIC MUSICAL INSTRUMENT

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FIG 14

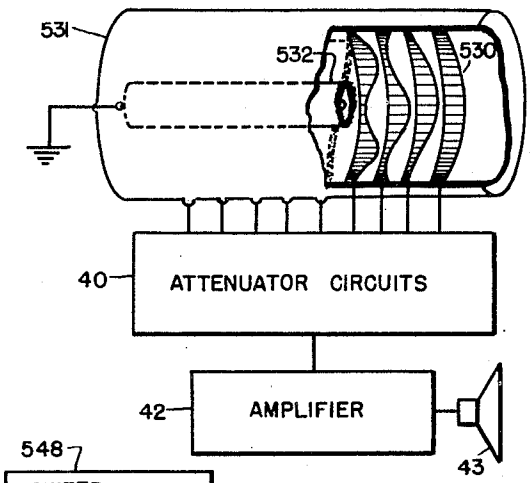
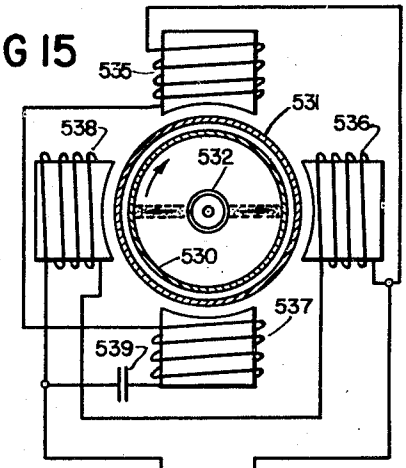


FIG 15



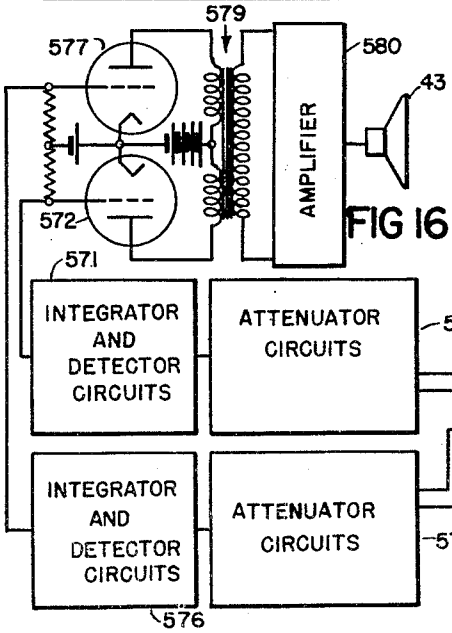


FIG 16

FIG 17

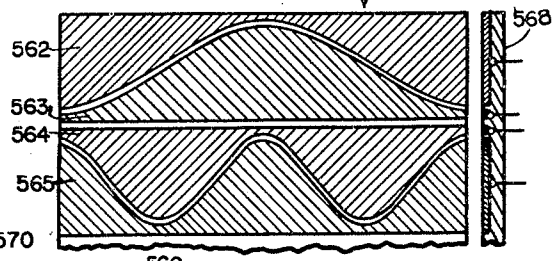


FIG 18

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Patented June 24, 1952 2,601,265

UNITED STATES PATENT OFFICE

2,601,265

ELECTRONIC MUSICAL INSTRUMENT

Merlin Davis, Milton, Pa.

Application June 6, 1947, Serial No. 753,118

12 Claims. (Cl. 84—1.28)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

1

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.

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

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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*–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 alternative 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 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 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 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. 5*a* 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. 5*b* 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. 5*b* 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. 5*a*. 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. 5*c* 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. 5*d* shows the output of pulse integrator 129 in which a condenser is charged as shown in Fig. 5*f* by the pulses shown in Fig. 5*c*. Fig. 5*f* 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. 5*d*, 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. 5*e*, it being understood that in practice there would be a large number of integrated pulses as shown in Fig. 5*d* to give a relatively smooth curve as shown in Fig. 5*e*. 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. 5*e* 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 5*a*—5*f*. 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, 185, 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 incidentals, 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 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 232, 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 resistor 249 and condenser 248, connected in parallel are connected between the cathode of diode 246' and the plate of diode 247'. Detector circuit 244 operates in a manner similar to that of coupling circuit 233 in that is 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. 5e.

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 to 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 electro-magnet 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, con-

tact 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 positions 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 26. 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.

Patterns 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 of 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 preset 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 of the type of quality control used. This selector device would also be adaptable for use with dynamic selector switch stop 343 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. 5*a*–5*f*, 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 preset 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 alternative 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 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 to 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 an 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 quatrature 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 envelope 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 prevented 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 understod 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 principle is also applicable to the continuous forms shown in Figs. 12 and 14.

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 angle 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 means for producing an oscillation, operating means causing said producing means to produce oscillations while said operating means is operated, amplitude control means for controlling the amplitude of said oscillation in a predetermined manner, said amplitude control means being operated by said operating means, said amplitude control means comprising a circular resistor having a predetermined variation of resistance along its length, a rotatable contactor continuously biased so as to cause its travel along said resistor at a predetermined rate of speed, arresting means having two positions, said arresting means in a first position stopping rotation of said contact in one position along its path of rotation, and said arresting means in a second position stopping said contact in another position along its path of rotation, said operating means also controlling said arresting means so that on operation of said operating means the contact means moves from said one position to said other position at a predetermined rate of speed, and so that on cessation of operation of said operating means said contact moves from said other position to said one position.

2. In a musical instrument, means for producing oscillations, keyboard means for controlling the pitch of the oscillations produced means for controlling the intensity of the oscillations produced, cyclical means associated with the intensity control, said cyclical means operating at spaced intervals to increase the intensity of a terminal note in each measure of music and a separate manually operated means for controlling the intensity of the oscillations.

3. In a musical instrument, an electrical oscillator, a sound producing means connected to said oscillator to convert the output of said oscillator into sound, a keyboard for controlling the pitch of the electrical waves produced by said oscillator, means for controlling the intensity of said waves and a source of spaced electrical pulses, said source being connected to said intensity control means to increase the intensity of a terminal note in each measure of music.

4. In a musical instrument, an oscillator comprising a cathode ray tube having at least one wave shaped pattern and means for producing an electron beam, means for sweeping said beam across said patterns, means to control the rate at which said beam sweeps across said patterns, means to control the intensity of said beam, a source of spaced electrical pulses connected to said intensity control means to vary the intensity of the beam during a terminal note in each measure of music.

5. In a musical instrument, an oscillating means, a keyboard having keys connected to said oscillating means to cause said oscillating means to produce oscillations when one of the keyboard keys is depressed, means for controlling the intensity of said oscillations, said control means comprising a cyclical component which proceeds through a first portion of its predetermined cycle when a key is depressed, means to arrest said control means at a predetermined point of its cycle, and means to allow said control means to proceed through the last portion of its predetermined cycle when the depressed key is released.

6. In a musical instrument, an oscillating means, a keyboard having keys connected to said oscillating means to cause said oscillating means to produce oscillations when one of the keyboard keys is depressed, an automatic cyclical means for controlling the intensity of said oscillations, a first portion of the cycle of said control means being arranged to vary the intensity of said oscillations to produce a predetermined attack characteristic, a last portion of the cycle of said control means being arranged to vary the intensity of said oscillations to produce a predetermined decay characteristic, means to cause said control means to proceed through the first portion of its cycle when a key is depressed, means to arrest the cyclical operation of the control means when the attack portion of the cycle is completed, and means to cause said control means to proceed through the last portion of its cycle when said last mentioned depressed key is released.

7. The combination of claim 6 in which additional means are provided for controlling the intensity of the oscillations.

8. In a musical instrument, an oscillating means comprising a cathode ray tube having at least one wave shaped pattern and an electron beam, deflection means for causing said beam to scan said patterns, a keyboard having keys connected to said oscillating means to cause said oscillating means to produce oscillations when one of the keyboard keys is depressed, means connected to said keys and operated by said keys to vary the intensity of said beam, said beam intensity varying means being connected to a cyclical control means which proceeds through a first portion of its predetermined cycle automatically when a key is depressed, means to arrest said control means at a predetermined point of its cycle, and means to allow said control means to proceed through the last portion of its predetermined cycle when the depressed key is released.

9. In a musical instrument, an oscillating means for producing a plurality of electrical waves, one of said waves having a certain frequency, others of said waves being different harmonics of said one frequency, separate means for adjusting the amplitudes of each of said waves, each of said adjusting means including a cam-surface, a single means for moving each of said cam-surfaces to variously adjust each of said adjusting means, means for combining said waves into one complex wave, and sound reproducing means connected to said combining means.

10. In a musical instrument, an oscillating means for producing a plurality of electrical waves, one of said waves having a certain frequency, others of said waves being different harmonics of said one frequency, a first group of means for adjusting the amplitudes of each of said waves, a second group of means for adjusting the amplitudes of each of said means, switch means to selectively and alternately pass said waves through either of said groups of amplitude adjusting means, means to combine said waves after their amplitude adjustment, sound reproducing means, and a connection between said combining means and said sound reproducing means.

11. The combination of claim 10 in which the separate adjusting means in at least one of said groups are each separately adjustable.

12. The combination of claim 10 additionally characterized by the provision of keyboard keys, means connected to said keyboard keys for operating said oscillating means, additional means operated by said keyboard keys to apply said waves successively and in a predetermined order to the respective adjusting means of the selected group.

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