

Aug. 30, 1949.

L. HAMMOND ET AL
ELECTRICAL MUSICAL INSTRUMENT

2,480,132

Filed Jan. 16, 1946

5 Sheets-Sheet 1

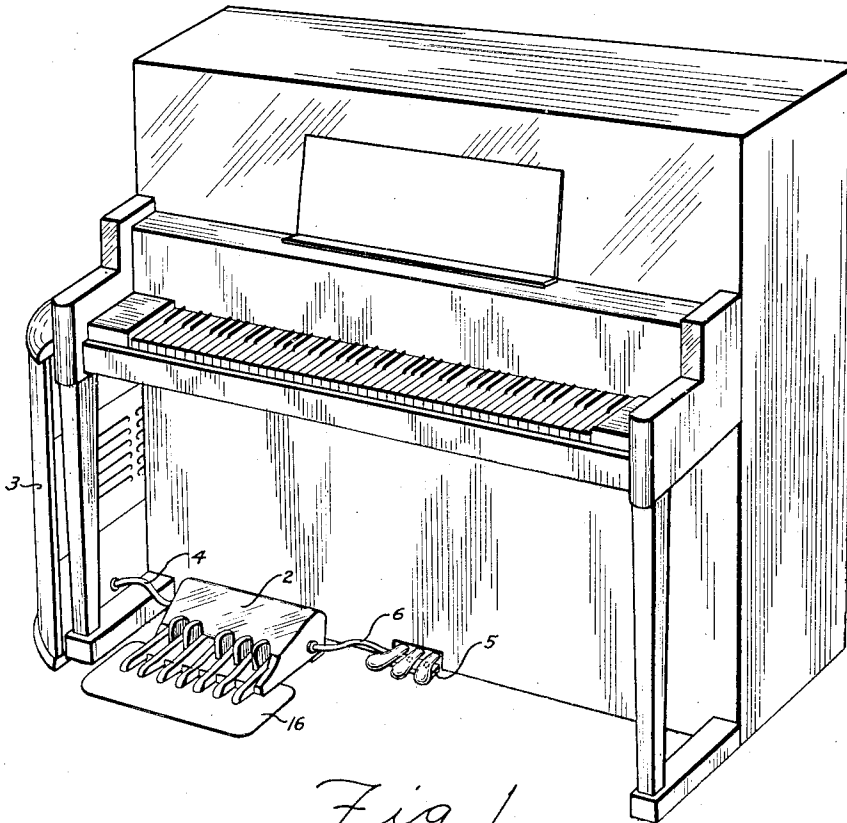


Fig. 1

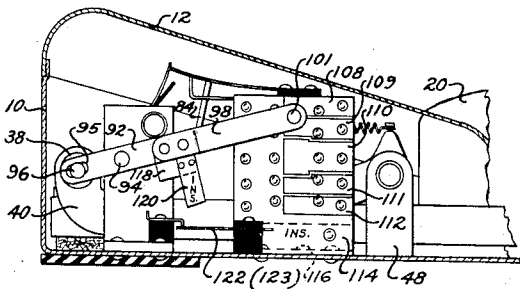
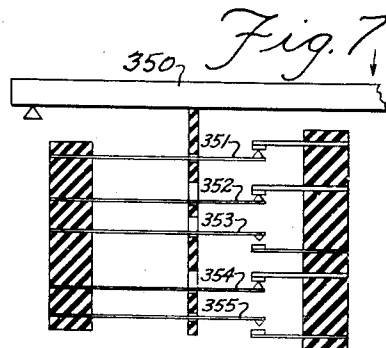


Fig. 4



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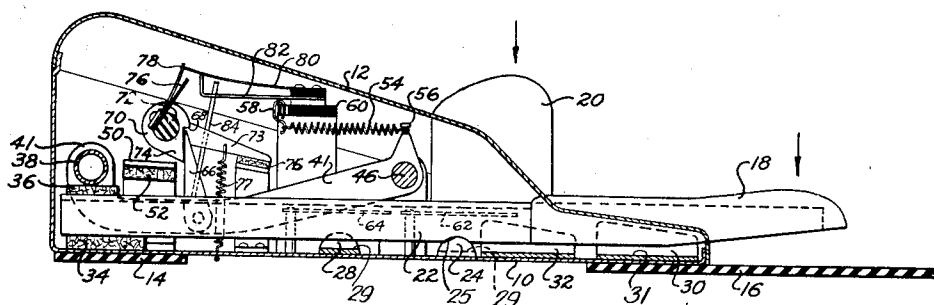


Fig. 3

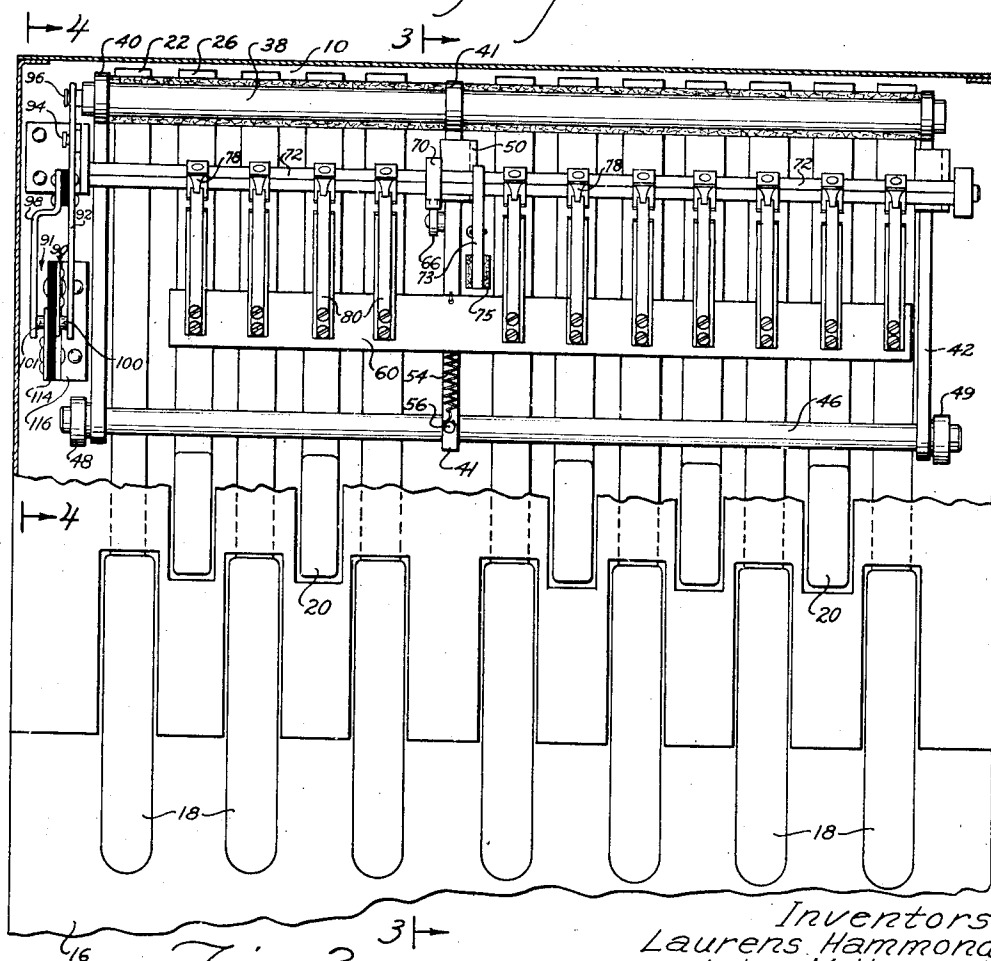


Fig. 2

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5 Sheets-Sheet 3

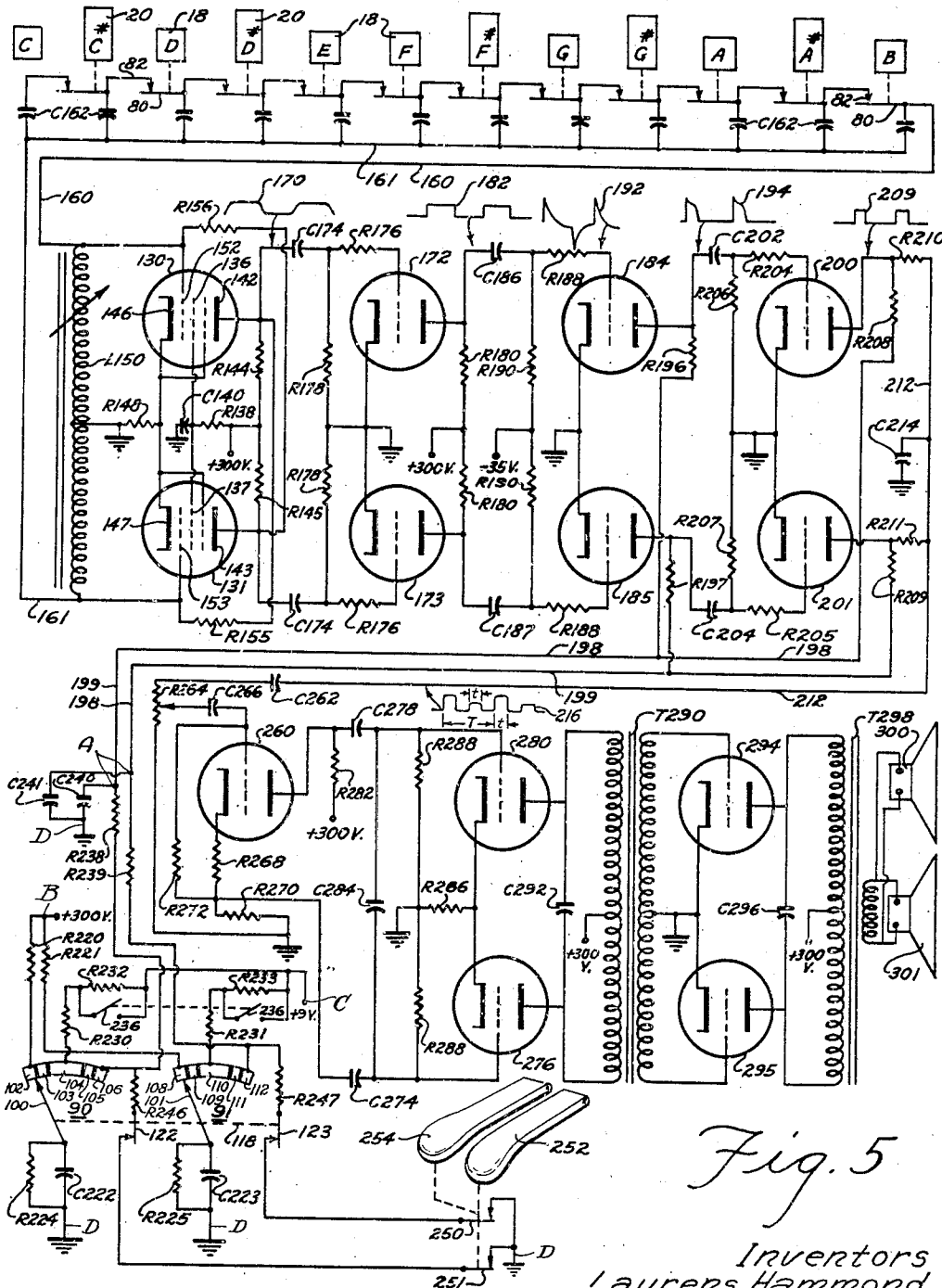


Fig. 5

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5 Sheets-Sheet 4

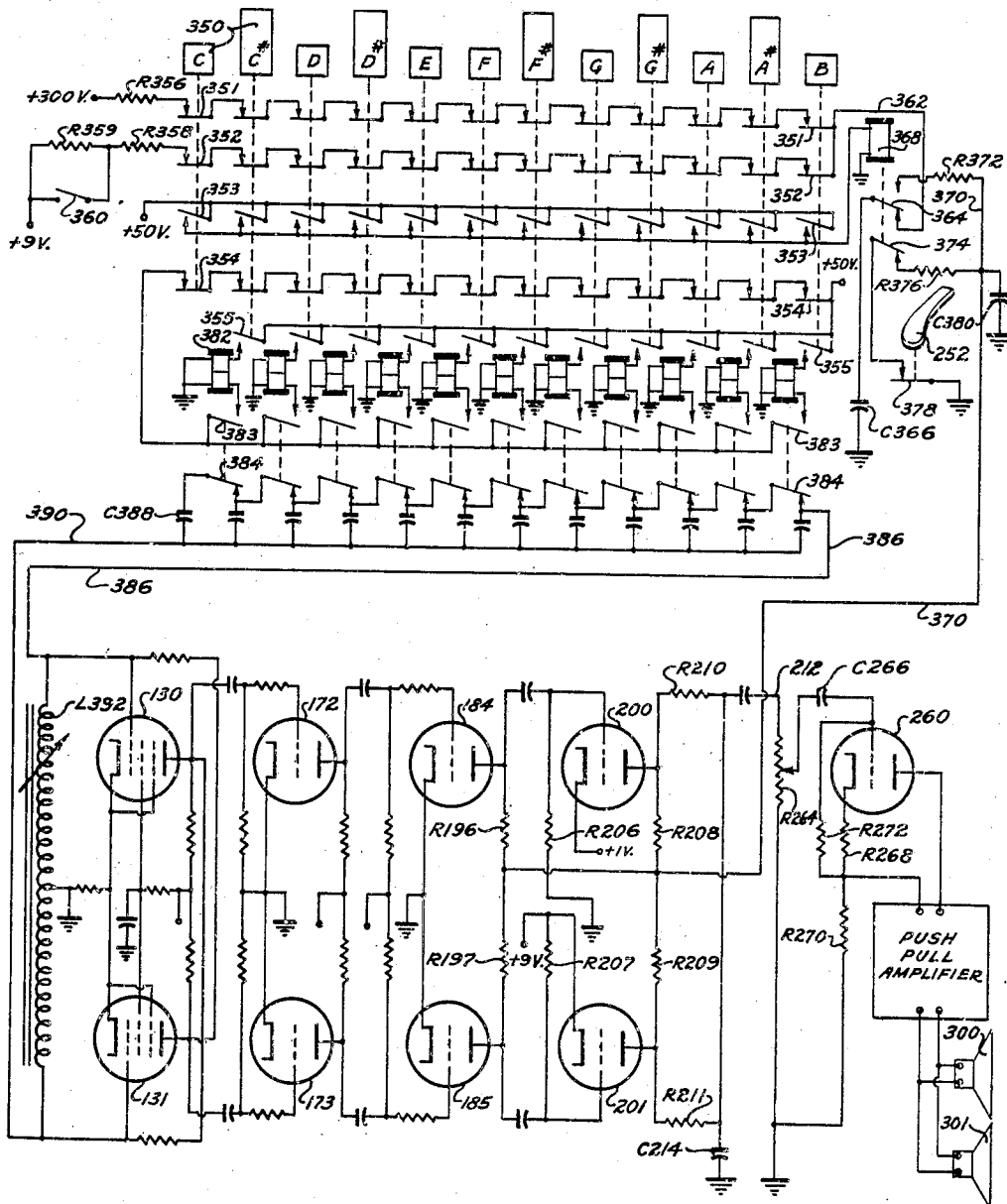


Fig. 6

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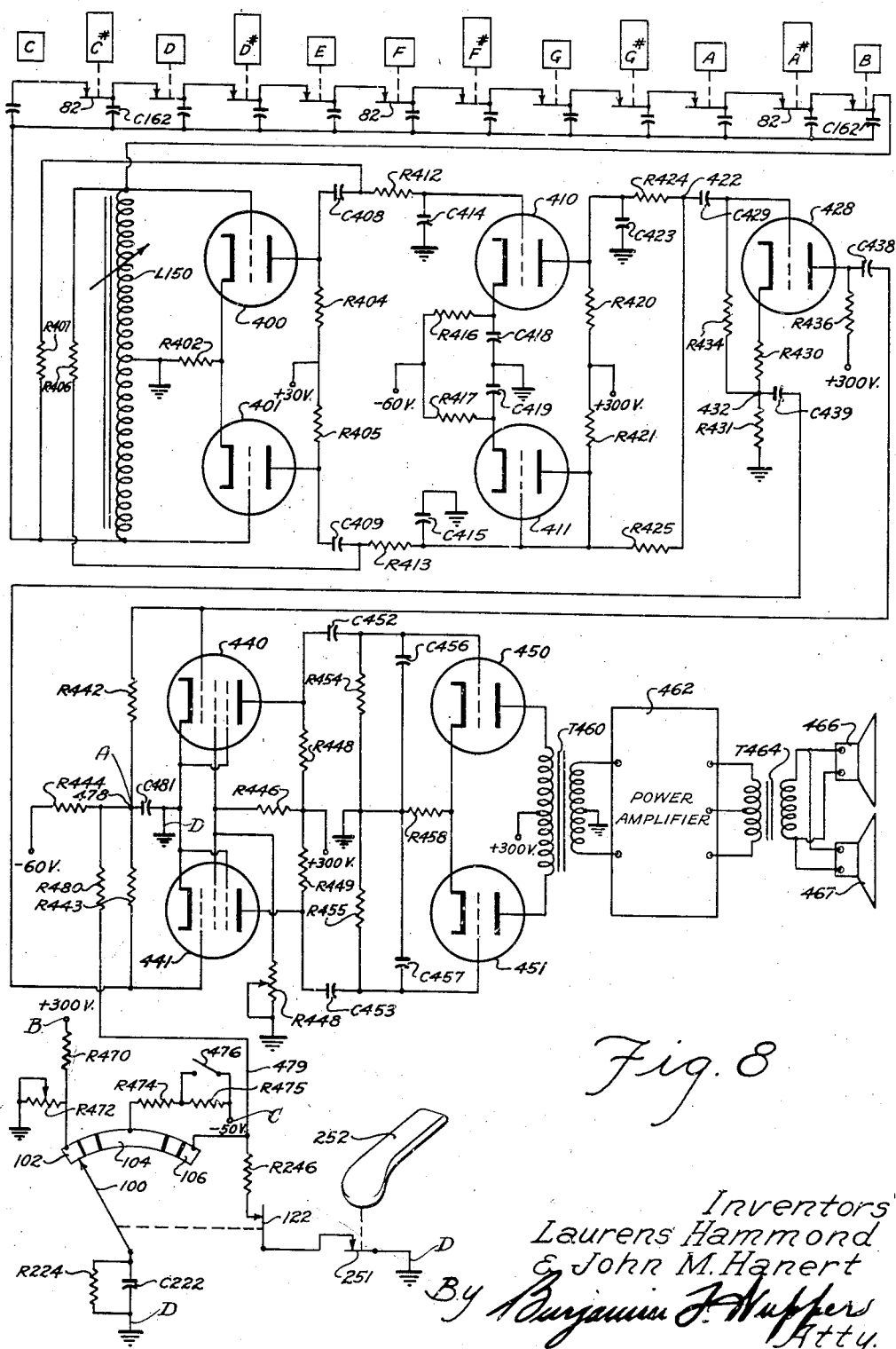
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ELECTRICAL MUSICAL INSTRUMENT

Filed Jan. 16, 1946

5 Sheets-Sheet 5



UNITED STATES PATENT OFFICE

2,480,132

ELECTRICAL MUSICAL INSTRUMENT

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Application January 16, 1946, Serial No. 641,598

43 Claims. (Cl. 84—1.24)

1

The invention relates generally to electrical musical instruments and more particularly to an instrument of this character combined with a piano to produce accompaniment bass tones.

As more fully pointed out in the prior patent to John M. Hanert, No. 2,357,191, the musical scope of the piano is greatly enhanced by the addition of pedal clavier controlled electrical means to supplement the bass tone producing abilities of the piano. In accordance with the underlying principles of the present invention, the electrical bass tone producing means are in part controlled by the piano sustaining pedal so that the tonal output of the piano and of the electrical portion of the instrument are coordinated in rendering a musical selection. The pedal clavier electrical instrument thus is an integral part of the piano, not only physically, but with respect to the tonal output of the ensemble.

It is thus an object of the invention to provide an improved combined piano and electrical musical instrument in which the tonal output of the electrical portion of the instrument is controlled in part by the operation of the foot controls of the piano.

A further object is to provide an improved musical instrument in which bass tones are produced under the control of the pedals of a clavier, and in which the duration of the tones are controlled in part by the sustaining or sostenuto pedal of the piano.

A further object is to provide an improved pedal clavier for the control of the output of an electrical musical instrument, in which there is provided a common means for controlling the tone intensity envelopes of all of the tones controlled by the pedal clavier.

A further object is to provide an improved pedal clavier in which the operation of any one of the pedals causes the operation of a tone intensity envelope controlling instrumentality in response to the velocity of depression of the pedals of the clavier.

A further object is to provide an improved pedal clavier for electrical musical instruments having electrical circuits controlled thereby which are effective to cause the tone of the last depressed pedal to persist with gradual decay until a second pedal is depressed.

A further object is to provide an improved electrical musical instrument having a pedal clavier and an oscillating tone signal generator tuned to the note frequencies of the various pedals upon depression of the pedals, and in which the generator is maintained in operation at the frequency

2

corresponding to the last depressed pedal until another pedal is depressed.

A further object is to provide an improved pedal clavier having a plurality of switches, at least one operated by each of the pedals, and in which each operated switch is maintained in operated condition and released only upon the depression of another pedal.

A further object is to provide an improved electrical musical instrument in which the tone and its octave are simultaneously produced, and in which the higher tone decays at a more rapid rate than the lower tone.

A further object is to provide a variable quality tonal decay envelope in which two tone generating sources, generating signals of different amplitude and in 180° phase relation are employed, and in which the decay rate of the lower amplitude signal is faster than the decay rate of the higher amplitude signal, whereby the quality of the composite tone will change as the tone decays.

A further object is to provide a touch responsive control tube system in which the exact characteristics of the control tubes are relatively unimportant.

A further object is to provide a touch response control tube mechanism and circuit in which the decay of the note is substantially asymptotic to zero amplitude.

A further object is to provide a touch responsive control tube system in which spurious effects of interelectrode capacitance and grid rectification are obviated by removing the input signal as well as the DC plate supply source from the control tube.

A further object is to provide a tone quality generating mechanism in which two primary sources of fundamental frequency signals are provided in 180° phase relation and in which amplitude limiting means are provided to convert the signals into symmetrical rectangular pulses, and in which further rectification means are provided to convert the symmetrical rectangular pulses into asymmetrical tone signals thereby to produce a long and desirable series of both even and odd harmonics.

A further object is to provide a musical instrument in which the quality of the tone changes smoothly over the compass of the instrument, the lower pitch tones being progressively richer in harmonic content.

A further object is to provide an improved electrical musical instrument having a plurality of keys, in which each key is provided with a plurality of switches operated in a predetermined

3

order to provide an intensity envelope controlling circuit responsive to the time interval between the operation of several of the key operated switches, and in which relay means controlled by one of the key operated switches are provided to control the transmission to the output of the instrument of the selected tone signals.

A further object is to provide an improved electrical musical instrument having a keyboard, a tone signal generating system, and a plurality of switches operated by each of the keys of the keyboard, one of the switches of each key being provided to close a circuit through one winding of a relay, in which a subsequently operated key switch controls the pitch of the tone produced by the instrument.

Other objects will appear from the following description, reference being had to the accompanying drawings in which:

Figure 1 is a perspective view illustrating the manner in which the electrical portion of the instrument is combined with the mechanical or piano portion thereof;

Figure 2 is a plan view of the pedal clavier with a portion of the top of the casing removed to show the operating parts;

Figure 3 is a vertical sectional view taken on the line 3—3 of Fig. 2;

Figure 4 is a fragmentary vertical sectional view taken on the line 4—4 of Fig. 2;

Figure 5 is a schematic wiring diagram of one form of the invention;

Figure 6 is a schematic wiring diagram of a modified form of the invention;

Figure 7 is a diagrammatic view of a key and the switch operating means employed in the instrument shown in Fig. 6; and

Figure 8 is a schematic wiring diagram of a second modified form of the invention.

Referring to Fig. 1 the instrument comprises a piano of conventional construction, a pedal clavier 2, a speaker and electronic component containing cabinet 3 connected to the pedal clavier by a multi-conductor cable 4 and a box 5 connected to the pedal clavier by a cable 6 and containing one or more switches operable by the sustaining pedal or the sostenuto pedal of the piano. The pedal clavier includes a housing comprising a base 10 (Figs. 2 and 3) and a cover 12. The base 10 is preferably provided with pads 14 and 16 of rubber or similar material, the pad 16 providing a rest surface for the heel of the player. The pedal clavier illustrated includes seven natural pedals 18 and five sharp pedals 20, the instrument thus having a gamut of one octave. The natural pedals 18 each comprise a channel shaped key bar 22 pivoted on a half round fulcrum rod 24, the key bar 22 having suitable arcuate recesses 25 complementary to the rounded surface of the fulcrum rod 24. In a similar manner, the channel shaped bars 26 for the sharp keys 20 are fulcrumed upon a half round rod 28. The rods 24 and 28 have suitable slots 29 so as not to interfere with the operation of the key bars not fulcrumed thereon. The pedals 18 and 20 are preferably of a suitable plastic material molded with the key bars 22 and 26 as inserts.

The natural keys 18 are held against transverse movement by fitting in slots 31 formed in a comb 30 which also forms a down stop to limit downward motion of the forward ends of the key bars 22. In a similar manner the key bars 26 for the sharp pedals 20 are held against lateral displacement by a comb 32 which also forms the down

4

stop for these pedals. The combs 30 and 32 are preferably covered with felt on all surfaces which may contact the key bars.

Due to the spacing of the fulcrums 24, 28 the rearward ends of the key bars 22 and 26 will have the same extent of upward motion upon depression of their pedals. The downward movement of the rearward ends of the key bars 22 and 26 is limited by their engagement with a felt pad 34 which thus forms the up stop for the pedals 18 and 20.

Each of the key bars 22, 26 is provided with a felt pad 36 which is engageable with a tubular cross bar 38 of a bail which also includes three bail arms 40, 41 and 42. The forward ends of these bail arms are pivoted to a rod 46 which is supported from the base 10 by a pair of bearing brackets 48, 49. Upward movement of the bail arms 40 and 41 is limited by a stop bracket 50, provided with a felt pad 52. The bail is normally held in its down position, in which it is shown, by a tension spring 54, one end of which is hooked over an ear 56 forming part of bail arm 41 and the other end of which is anchored to a clip 58 secured to an insulating cross bar 60. Each of the pedal bars 22 is resiliently biased to the positions in which they are shown in Fig. 3 by a suitable spring 62 while the sharp key bars 26 are biased to their normal positions by suitably mounted springs 64.

The center bail arm 41 has a spring pressed pawl 66 pivoted thereto, the tooth portion of the pawl normally resting in a notch 68 formed in a throw out element 70 which is rigidly secured to a rotatably mounted shaft 72, the element 70 having a tail portion 74. Rigidly secured to the shaft 72 is an arm 73 and insulating pads 76, each having a latching spring finger 78 normally lying adjacent the upper or rearward surface thereof. These spring fingers 78 normally engage the ends of switch arms 80, as shown in Fig. 3, but are adapted to flex forwardly (to the right, Fig. 3) whenever the adjacent switch arm 80 is raised, and thus assume a latching position beneath the switch arm 80 to hold the latter in raised position. The switch arms 80, of which there is one for each pedal, except the lower "C" pedal, are secured to the insulating cross piece 60, and normally press against the upwardly extending end portion of a relatively rigid complementary switch arm 82. Each of the key bars 22, 26 is provided with a suitably insulated actuating pin 84 which may be rigidly secured to the key bar and the upper end of which is adapted to engage its associated resilient switch arm 80 and raise the latter from contact with the end of the relatively rigid switch arm 82 to open the switch.

Since the bail rod 38 overlies the ends of all of the key bars 22, 26 the bail is swung clockwise upon depression of any one of the keys. During the upward movement of the bail, the point of the pawl 66 engages in the notch 68 and swings the element 70 counter-clockwise so that the arm 73 which is secured to the shaft 72 is raised from its stop pad 75 and moved against the tension of the suitably anchored spring 77. As the bail continues moving upwardly the tail portion 74 of the throw-out element 70 engages the pawl 66 and pushes it out of the notch 68, whereupon the spring 77 will swing the arm 73, shaft 72, and element 70 clockwise until arrested by the stop pad 75. It will be clear that this release of the pawl 66 from the element 70 will occur prior to the completion of the up stroke of the pawl. Thus the push rod of the particular pedal which

has been depressed will hold its associated resilient switch arm 80 upwardly in a position above the end of the spring finger 78 so that upon subsequent release of the depressed pedal the switch arm 80 will be held by the spring finger 78 in a position so as not to make contact with the switch arm 82. As a result, the switch 80, 82 of the last-depressed pedal will remain open until another pedal is depressed. The purpose of this will appear more clearly from the description of the electrical circuits controlled by these switches.

A pair of wiping commutator type switches 90 and 91 (shown diagrammatically in the lower left hand corner of Fig. 5 and shown in elevation in Fig. 4) are operated by the bail 41. The switch 90 comprises a lever 92 suitably pivoted on a stud 94 and having an elongated slot 95 engaging a pin 96 suitably secured in the end of the tubular bail rod 38. The moving element of the switch 91 comprises an arm 98 which is secured to the lever 92 but insulated therefrom. The arm 92 carries a contactor 100, which is preferably of the carbon or graphite brush type, while the arm 96 carries a similar contactor 101. The contactor 100 is cooperable with a series of segmental contacts 102, 103, 104, 105 and 106 while the contactor 101 is successively cooperable with similar segmental contacts 108, 109, 110, 111 and 112. The segmental contacts 102 to 106 and 108 to 112 are suitably mounted on an insulating plate 114 carried by a bracket 116, the latter being secured to the base 10. The contactors 100 and 101 may be resiliently mounted on the lever 92 and arm 96, respectively, or the latter elements may be resiliently biased to maintain these contactors in good electrical contact with the segmental contacts.

From the foregoing it will be apparent that as any one of the pedals is depressed the contactor 100 will successively make contact with the segmental contacts 102—106 and similarly the contactor 101 will make contact with the segmental contacts 108—112, and that the length of time that these contactors are respectively in contact with the segmental contacts 104 and 110 will depend upon the velocity with which the pedal is depressed.

As the lever 92 and arm 96 approach the positions in which their contactors reach the segmental contacts 106 and 112 respectively a projection 118 on the lever 92, having an insulating actuator 120 secured thereto, opens switches 122 and 123. This occurs prior to the time that the contactors 100 and 101 make contact with the segments 106 and 112 respectively.

Referring to Fig. 5, the electrical portion of the instrument comprises a push-pull oscillator consisting of a pair of pentodes 130, 131. A voltage of fixed potential is impressed upon the screen grids 136, 137 of these pentodes through a voltage dropping resistor R138 which is connected to a suitable source of plate current potential indicated as a terminal +300 V. By pass capacitor C140 connects the screens 136 and 137 to ground. Plate voltage is supplied to the plates 142, 143 of the pentodes 130, 131 through plate load resistors R144 and R145 respectively. The cathodes 146 and 147 are connected to ground through a common biasing resistor R148. A tuning inductance L150 has a grounded center tap and has its terminals connected respectively to the control grids 152 and 153 of the pentodes 130 and 131. Feedback paths from plate 142 to grid 153 and from plate 143 to grid 152 are provided through resistors R155 and R156 re-

spectively. The terminals of the inductance L150 are also connected respectively to conductors 160 and 161 across which one or more of twelve tuning capacitors C162 may be connected. Each of the pedals, upon depression, opens a switch 80, 82 associated therewith, these switches being connected in series so that the highest of several depressed pedals renders ineffective the depression of the lower pedals. The pedal for the note C is not provided with a switch 80, 82, since the oscillator will be tuned to the frequency of the lower C when all of the switches 80, 82 are closed, due to the fact that under these circumstances all twelve capacitors are effectively connected in parallel with the inductance L150.

The pentodes 130 and 131 operate as oscillators at the same frequency but in 180° phase relation. Due to the push-pull connection of pentodes 130, 131, the plate voltage will have a symmetrical wave form consisting substantially of the fundamental and the odd harmonics thereof; the even harmonics will have been cancelled. This wave shape is illustrated in Fig. 5 by the curve 170 which is located above the circuit in which it appears.

The output of the pentodes 130, 131 is coupled to the input circuits of triodes 172, 173 through blocking capacitors C174 and series grid resistors R176, grid return paths being provided by grid resistors R178 which are connected to ground. The cathodes of triodes 172, 173 are likewise connected to ground while their plates are connected to a suitable source of plate potential +300 V., through load resistors R180 respectively. Due to the grid rectification and the current limiting action of the series grid resistors R176, a rectangular wave is generated at the plates of the tubes 172, 173, as indicated by the curve 182 appearing above one of the circuits in which this wave appears. It will be understood that the output of the triode 173 will have a wave similar to the curve 182, but of opposite phase.

The output of the triodes 172, 173 is coupled to the input of triodes 184, 185 through small current limiting capacitors C186 and C187 respectively. The grids of the triodes 184, 185 are connected to a negative bias source illustrated as a terminal -35 V. through a series grid resistor R188 and grid return resistors R190. The cathodes of these triodes 184 and 185 are connected to ground. Due to the fact that triodes 184 and 185 are provided with a negative bias voltage (-35 V.), the wave represented by the curve 192 which appears between the capacitor C186 and resistor R188 has only the positive peaks thereof effective to produce plate current flow in these triodes. As a result, the plate voltage wave appearing on the plates of triodes 184 and 185 will be in the form of a series of positive peaks corresponding to the peaks of the wave as indicated by the curve 194. Plate current is supplied to triodes 184, 185 through plate load resistors R196 and R197 which are connected to conductors 198 and 199 respectively. As will be described hereinafter, the amplitude of a signal, such as represented by the curve 194, is generally directly proportional to the voltage appearing on the conductor 198 while the corresponding wave appearing at the plate of the triode 185 will be of amplitude generally proportional to the average potential on conductor 199. The two waves from the outputs of the triodes 184, 185 will be of 180° phase relationship.

The outputs of the triodes 184, 185 are coupled to the inputs of triodes 200 and 201 through

blocking capacitors C202 and C204 respectively and series grid resistors R204 and R205 respectively. The grids are connected to ground through the series grid resistors R204, R205 and grid return resistors R206, R207. The cathodes of the triodes 200 and 201 are connected directly to ground. Plate voltage is supplied to the plate of triodes 200, 201 through a load resistor R208 connected to the conductor 198, while plate voltage is supplied to the triode 201 through load resistor R209. The triodes 200 and 201 function as amplitude limiters to change the form of the signal from that shown by the curve 194 to that of the curve 205.

The signal voltage appearing at the plates of the triodes 200 and 201 will, as more clearly appear hereinafter, be substantially proportional to the voltage appearing on the conductors 198 and 199 respectively. It will also be clear that when the voltage on conductors 198 and 199 is zero, the signal on the grids of triodes 200 and 201 will be substantially zero. It will therefore be apparent that the signals at the plates of the triodes 200 and 201 will be zero.

The output of the triode 200 is coupled through a decoupling resistor R210 to a signal conductor 212 while the output of the triode 201 is similarly connected to the conductor 212 through a resistor R211. The conductor 212 is connected to ground through a capacitor C214 which provides a by-pass for undesirably high harmonic frequencies. The resistor R210 is preferably of a value approximately one half that of R211, with the result that the signal appearing on conductor 212 will be of the wave shape illustrated by the curve 216. It will be noted that this curve represents a predominantly even harmonic series which corresponds to a strong octave harmonic component, for instance, similar to the effect of striking the octave on the piano. The highest generally rectangular voltage excursions appearing on the wave 216 are due to the signal from the triode 200 while the lower voltage excursions are due to the signal from the triode 201 provided by the decoupling resistor R211. The dimension t of the wave 216 is relatively constant irrespective of the frequency at which the oscillator 130, 131 operates, but as the oscillation frequency decreases the proportion of t relative to the duration of the cycle, (the dimension T of the curve 216) becomes less. As this occurs the harmonic content of the tone represented by this signal increases, thus, it becomes "brighter." This is a desirable feature since low pitch tones having high harmonic development are more pleasing to the ear than such tones with lesser harmonic development. Furthermore, the general musical effect is more interesting when the quality of the notes is not precisely the same at all pitches, but rather smoothly changes over the compass of the keyboard.

Referring further to curve 216, it will be clear that due to the difference in values of resistors R210 and R211 the high amplitude peaks of the wave 216 will be the result of the signal in the plate of triode 200 and will thus be dependent upon the voltage appearing upon conductor 198. On the other hand, the intermediate low amplitude peaks of the wave 216 are derived from the signal appearing on the plate of triode 201 and thus depend upon the voltage appearing upon conductor 199.

The voltages appearing on the conductors 198 and 199 are respectively controlled by the com-

mutating switch mechanisms 90 and 91 previously described. In these switch mechanisms the commutator segments 102 and 108 are connected to a suitable high potential source indicated as a terminal +300 V. through small anti-spark resistors R220 and R221. The contactor 100 is connected to ground through a capacitor C222 which has a discharge resistor R224 in parallel therewith. In a similar manner the contactor 101 is connected to ground through a capacitor C223 having a resistor R225 in parallel therewith. The values of the capacitor C222 with respect to its parallel resistor R224 is such that the drop in voltage due to leakage of the charge of the capacitor across the resistor R224 will be at a rate such that the signal appearing on the plate of the triode 200 will decay in substantially the same manner as a sustained bass tone of a well constructed piano. Assuming capacitors C222 and C223 to be of the same value, the resistor R225 would be of a value of approximately one half of that of the resistor R224. Thus the discharge rate of the capacitor C223 would be twice that of the capacitor C222. The significance of these differing discharge rates will appear hereinafter. The segments 103, 105, 109 and 111 do not have any electrical connections thereto. The segment 104 is connected through discharge resistors R230 and R232 to a suitable source of constant low voltage (e. g. 9 volts) shown as a terminal indicated as +9 V. In a similar manner the segment 110 is connected to the +9 V. terminal through discharge resistors R231 and R233. To change the rate of discharge, the resistors R232 and R233 may be shunted out of their circuits by closure of switches 236.

The segment 106 is connected to conductor 199 through an attack resistor R238 while the segment 112 is similarly connected to the conductor 198 through an attack resistor R239. The conductors 198 and 199 are connected to ground through potential storing capacitors C240 and C241 respectively. Disregarding for the moment the remaining connections to the segments 106 and 112, it will appear that the capacitors C222 and C223 are each initially charged to a potential of +300 volts. As the contactors 100, 101 swing clockwise along the commutator segments and engage the center segments 104 and 110, the potential on the capacitors C222 and C223 decreases rapidly due to the discharge of these capacitors through resistors R230—R232 and R231—R233 respectively. Thus when the contactors 100 and 101 reach the segments 106 and 112 respectively, the charges on the capacitors C222, C223 will have decreased by amounts proportional to the length of time that the contactors 100, 101 were in contact with the segments 104 and 110 respectively, and it is apparent this time interval depends upon the velocity of pedal operation. Thus the capacitors C240 and C241 will likewise be charged to potentials depending upon the velocity at which the pedal is depressed. Therefore, the amplitude of the signal appearing upon the conductor 212 will be determined by the velocity of pedal depression.

Before the contactors 100, 101 leave segments 104, 110 respectively they open switches 122 and 123. Upon removing the foot from the pedal, and upon the consequent return swinging movement of the bail rod 38, the contactors 100, 101 will swing counterclockwise, and after contacting the segments 104, 110, will permit switches 122 and 123 to close. These switches are connected

to the segments 106 and 112 through resistors

R246 and R247 respectively. The switches 122 and 123 are connected in series respectively with switches 250, 251, the other poles of these switches being connected to ground. The switches 250 and 251 are adapted to be operated whenever the piano sustaining pedal 252 or the sostenuto pedal 254 is depressed. Thus when the contactors 100 and 101, on the return stroke of the bail, leave the segments 106, 112, and close switches 122, 123, the charge on the capacitors C249 and C241 is dissipated relatively rapidly through the resistors R238 and R239, R246 and R247, switches 122, 123 and switches 250, 251 to ground, because the values of the resistors R238, R239, R240, R246 and R247 are low relative to the plate load resistors R196, R197, R208, R209 and the internal plate resistance of the triodes 200, 201 as well as the internal plate resistances of the triodes 184, 185. However, if either the sustaining or damper pedal 252, or the sostenuto pedal 254 is depressed, such discharge of the capacitors C240, C241 can not take place and the only path for the discharge of these capacitors is through the plate circuits of the triodes 200 and 201 as well as the plate circuits of triodes 184, 185. The time constant of the capacitor C222 discharging through the resistor R224 is made substantially the same as the time constant of the capacitor C240 discharging through the plate circuits of the triodes 184 and 200. Similarly the time constant of the capacitor C223 discharging through the resistor R225 is made to be substantially equal to that of the capacitor C241 discharging through the plate circuits of triodes 185 and 201.

The output signals of the triodes 200 and 201 appearing on the conductor 212 are coupled to the input of a phase splitting triode 260 through a blocking capacitor C262 and a volume control resistor R264 and a second blocking capacitor C266. The cathode of triode 260 is connected to ground through self-bias resistor R268 and a load resistor R270, the junction of these resistors being connected to the grid through a grid resistor R272 and being connected through a blocking capacitor C274 to the grid of a triode 276. The plate of triode 260 is connected through a capacitor C278 to the grid of a triode 280. Operating plate voltage for the triode 260 is supplied from a suitable source, indicated as +300 v., through a load resistor R282. The grids of triodes 276 and 280 are connected together through a capacitor C284 which by-passes undesirably high harmonic frequencies present in the signal. The cathodes of triodes 276 and 280 are connected to ground through a biasing resistor R286 while the grids thereof are connected to ground through suitable grid resistors R288. The plates of the triodes 276 and 278 are connected to the terminals of the primary winding of a driver transformer T290, the center tap of which is connected to a suitable plate current source, +300 v. A capacitor C292 connected across the terminals of the primary of T290 offers a further path for by-passing undesirably high harmonics of the signal. The secondary of transformer T290 has its terminals connected to the grids of class B power amplifier triodes 294 and 295. A capacitor C296 is connected between the plates of triodes 294 and 295 offering an additional by-pass path for undesirably high frequency harmonics. A power output transformer T298 has the terminals of its primary connected to the plates of triodes 294, 295 and has its secondary winding connected in parallel to the voice coils of speakers 300, 301.

In view of the fact that the triodes 184 and 185, and 200 and 201 operate in a non-linear manner, it is unnecessary that their characteristics be maintained with a high degree of precision as might be necessary if they operated as class A amplifiers. In their operation they are either operating in one of two conditions, namely, full plate current or completely cut off plate current. By virtue of this fact a large series of extremely high harmonics are introduced into the signal by the distortion and it is therefore necessary to repeatedly filter the signal as by means of the by-pass capacitors C214, C284, C292 and C296. These capacitors round off the corners of the signal wave shape and make the resulting tone more pleasing to the ear.

In view of the fact that the time constants of the capacitors associated with the commutating switches 90 and 91 are different, the signal appearing on the conductor 212 will initially be of the form indicated by the curve 216. Since the plate potential on the triode 201 drops more rapidly than that of the triode 200, the smaller intermediate peaks will decrease in amplitude much more rapidly than the higher amplitude peaks of the wave. In fact, the smaller amplitude peaks will decay to such low value as to be inaudible in the ultimate tone produced while the higher amplitude peaks of this wave will still provide a clearly audible signal. This is of distinct musical advantage because at lower volume levels the ear is less sensitive to low frequencies and therefore the removal of the high frequencies tends to produce a bass compensation effect which is highly desirable from the musical standpoint. Also the tone is more interesting in that its quality continuously changes as the tone decays.

Since the intensity of the tones produced by the instrument may readily be controlled by the player in response to the velocity at which he depresses the pedals, it is unnecessary to provide additional volume controls. The variable resistance volume control provided by resistor R264 is preferably an adjustment which is made upon installation of the instrument in a particular location, and is designed to provide sufficient bass radiation to be acoustically equipped for the particular room or auditorium in which the instrument is to be played.

Under some circumstances it may be desirable to alter the degree of pedal velocity responsiveness of the instrument. This may readily be accomplished by closing the switches 236, thereby shunting resistors R232 and R233 from the capacitor discharge circuits. Under these circumstances, the rate of discharge of the capacitors C222 and C233 to the +9 V. terminal will be controlled mainly by the resistors R230 and R231 respectively. When these switches are closed, the sensitivity of the velocity of pedal depression is substantially increased, and the effect corresponds in sensitivity to that of the piano keys. The absolute values of the resistors associated with the attack and decay control circuits must not only be correlated with the values of the capacitors employed in these circuits, but must also be correlated with the physical dimensions and the inertia of the pedals, and to the spring tension applied thereto. In other words the speed with which a pedal may be depressed by an average player will determine the constants of the electrical components of the attack and decay circuits, particularly the values of the capacitor discharge resistors R230 and R231.

In the use of the instrument it is placed in a

position relative to the piano as shown in Fig. 1 with the switches 250, 251 arranged to be opened upon depression of either of the damper or sustaining pedal 252, or the depression of the sostenuto pedal 254 of the piano. In playing the instrument the musician need merely tap the pedals 18, 20 with the desired velocity requisite to produce tones of the desired loudness. The tone will continue to sound for an interval after the release of the pedal, since the switch 80, 82 associated with the depressed pedal will be retained in open position by the spring finger 78 after the pedal is released. It will be recalled that the switch 80, 82 determines the frequency of operation of the oscillator 130, 131 and the oscillator will thus maintain the frequency to which it was adjusted by opening of the particular switch 80, 82 until the charges on the capacitors C240 and C241 have been dissipated through the plate circuits of the triodes 184, 185, 200 and 201. If prior to the final decay of a tone to an inaudible intensity a second pedal is depressed, depression of the latter will, due to the action of the pawl 86, move the spring finger 78 associated with the previously depressed pedal from beneath the switch arm 80 and permit the latter to close, while at the same time, the push rod 84 of the second depressed pedal will raise its switch arm 80 above the end of its associated switch finger 78 so that this switch 80, 82 will thereafter remain open. The amplitude of the second tone will in all probability be increased over that of the remaining portion of the first tone due to the increase in charge on the capacitors 240, 241 during the operation of the commutating switch mechanisms 90, 91. It is possible that the volume could also be reduced by the subsequent depression of a second pedal but this is rather unlikely.

The technique of playing the instrument is greatly simplified due to the provision of the mechanism and circuits by which a note continues to sound after the pedal controlling it is released. This gives the musician adequate time to shift from one pedal to another without silence between successive pedal notes. It also enables the player to play the pedalboard in a more leisurely manner so that ample time is always afforded between the initiation of the successive tones, which latter time is substantially wholly utilizable by the player in moving his foot from one pedal to another. This feature is of great importance and constitutes a substantial improvement over other pedal operated instruments such as the organ, in which the player must of necessity retain his foot upon the pedal throughout the time interval that he desires the note to sound and, as a consequence, little time is allowed for shifting his foot from one pedal to another. This has constituted a serious limitation on the rapidity with which pedal passages could be played upon the pedal clavier of prior instruments, using but one foot.

If desired, substantially the same results attained by the instrument as shown in Figs. 1 to 5 may be attained by using relay circuits in place of the bail and the switch mechanism operated thereby as described in the preferred embodiment of the invention. Such relay controlled instrument is shown in diagrammatic form in Fig. 6 as comprising a plurality of pedals 350, each except the C pedal operating five switches 351, 352, 353, 354 and 355. These switches are operated in a predetermined sequence by a suitable actuator so that the switch 351 opens first (Fig. 7). The switch 355 may be closed simultaneously

with the opening of switch 351. Thereafter, following a suitable time interval depending upon the velocity with which the pedal 350 was depressed, the switches 352 and 354 are opened and the switch 353 closed.

The switches 351 are connected in series with a source of operating potential shown as a terminal +300 V. through a small anti-spark resistor R356. The switches 352 are likewise connected in series and are connected to a +9 V. terminal through discharge resistors R358 and R359. The resistor R359 may be shunted upon closure of a switch 360 when it is desired to increase the discharge rate. It will be clear that the switches 351 and 352 associated with the pedal B are connected through a conductor 332 and a relay transfer switch 364 to a capacitor C366, the other terminal of this capacitor being connected to ground. The transfer switch 364 is operated by a relay winding 368 which is energized upon closure of any one of the switches 353 since it will be noted that one pole of each of these switches is connected to a +50 V. terminal while the other pole of each of these switches is connected directly to the ungrounded terminal of relay winding 368. When the relay 368 is energized the transfer switch arm 364 connects the capacitor C366 to conductor 370 through an attack resistor R372. Energization of the relay also opens switch 374, preferably before the switch arm 364 connects the capacitor 366 to the resistor R372. The switch 374 is in a circuit connecting the conductor 370, a resistor R376, a piano damper pedal operated switch 378 and ground. The conductor 370 is connected to ground through a capacitor C380, which corresponds in function to the capacitors C240 and C241 of Fig. 5.

It will be recalled that the switch 355 is closed during the early part of the downward movement of a depressed pedal 350. Each of these switches is adapted to complete a circuit from a suitable source, indicated as +50 V., through one winding of a double winding relay 382, to ground. When a relay 382 is thus energized it closes its switch 383 tending to temporarily complete a holding circuit through the other winding on the relay. This holding circuit includes the +50 V. source and the series of switches 354. The latter switches are subsequently opened upon further depression of the pedal but the relay 382 is maintained energized because the associated switch 355 is still closed. Upon release of the pedal the switch 354 closes and thus re-completes the holding circuit initially completed by the operated relay switch 383.

In addition to operating the switch 383, each of the relays 382 upon energization open a tuning switch 384. These tuning switches are connected in series to a conductor 386 and each also has its stationary contact connected to one terminal of a tuning capacitor C388, the other terminals of these capacitors being connected to a conductor 390. The twelve tuning capacitors 388 are thus in parallel with a tuning inductance L392 when all of the switches 384 are closed. When any one of the switches 384 is opened upon energization of its associated relay 382, the capacitors C388 associated with pedals of lower pitch are disconnected from the tuning circuit. It will thus appear that the oscillator which includes the inductance L392 will remain tuned to the frequency determined by a depressed pedal even after the pedal is released, in the same manner as in the previously described embodiment. Upon initial depression of a second pedal the asso-

ciated relay 382 will be energized in the same manner as previously described but upon further depression of the second pedal, its associated switch 354 will open the common portion of the holding circuits for all of the relays 382 and thus the holding circuit for the previously energized relay 382 which was held energized by its holding circuit, will be deenergized and only the relay associated with the second depressed pedal will remain energized.

The push pull oscillator and wave shape amplifying and amplitude controlling tubes operate in the same manner as those in the previously described embodiment and similar reference characters have therefore been applied to corresponding parts. It will be noted, however, that the intensity envelope controlling circuits for the form of the invention shown in Fig. 6 differ from those shown in the embodiment of Figs. 1 to 5 in that the conductor 370 which supplies the controlling potential to the plates of the triodes 184, 185, 200, 201 is connected to the plates of all of these tubes through their associated plate load resistors.

Instead of having the cathodes of both triodes 200 and 201 connected to ground, the cathode of triode 200 is connected to a constant potential source (indicated as +1 V.) slightly above ground potential, while the cathode of triode 201 is connected to a source of constant potential such as a +9 V. terminal. As a result, the signal controlled by the triode 201 will decay to inaudibility prior to the decay to inaudibility of the signal transmitted by triode 200. Since the cathodes of both triodes 200 and 201 will be at a positive potential with respect to their plates when the capacitor C380 is fully discharged, the triodes 200 and 201 will be incapable of transmitting any signal. A further reason that the triode 200 will be completely cut off is that there is one volt negative bias on its grid. Thus as the tone decays, the octave producing component thereof will decay to inaudibility while the fundamental producing component is still quite audible. The remaining portions of the output system of the instrument may be similar to that previously described with reference to Figs. 1 to 5.

In the embodiment of the invention shown in Fig. 8 the oscillator is tuned, as in the previously described embodiments by the operation of pedal actuated switches 82 which determine the number of capacitors C152 connected in parallel with the tuning inductance L150. The oscillator of Fig. 8 comprises a pair of triodes 400 and 401 having their grids respectively connected to the terminals of the inductance L150 and having their cathodes connected to the grounded center tap of inductance L150 through a self-biasing resistor R492. The plates of triodes 400 and 401 are connected to a suitable operating potential source, indicated as +300 V., through load resistors R404 and R405. The terminal of the inductance L150 which is connected to the grid of triode 400 is connected to the plate of triode 401 through a resistor R406 and a blocking capacitor C409 while the terminal of L150 which is connected to the grid triode 401 is connected to the plate of triode 400 through a resistor R407 and blocking capacitor C408, these circuits providing the regenerative feedback necessary to secure self-oscillation.

The outputs of the triodes 400, 401 are coupled to the grids of triodes 410 and 411 through grid resistors R412 and R413. The grids of triodes 410 and 411 are connected to ground through ca-

pacitors C414 and C415 respectively. These capacitors function to suitably round off the peaks of the signal waves as supplied by the oscillator. The cathodes of the triodes 410 and 411 are connected to a suitable source of negative potential indicated as a terminal -60 V. through self-bias resistors R416 and R417 respectively and are connected to ground through bias-storing capacitors C418 and C419 respectively.

The self-biasing resistors R416 are of substantial value such as 5 megohms each so that the grids of the triodes 410 and 411 will be highly biased in a negative direction and consequently only the highest positive peak signals will be effective to cause pulsations of plate current to flow, in a manner similar to that more fully disclosed in the patent to Gilbert Smiley, Reissue No. 20,831. Plate current is supplied to these triodes from a source indicated as +300 V. through load resistors R420 and R421 respectively. The plate of triode 410 is connected to an output terminal 422 through a decoupling resistor R424 while the plate of triode 411 is connected to said terminal 422 through a decoupling resistor R425. The plate of triode 410 is connected to ground through a capacitor C423.

The value of R424 is preferably made equal to R425, and R420 is likewise preferably made equal to R421. If the capacitor C423 were not connected in the circuit, a signal at the junction point 422 would be of double fundamental frequency and would thus sound at the interval of the octave. The capacitance C423 is chosen of such value as to limit the output amplitude of triode 410 to approximately one half that of triode 411 at the low end of the pedalboard compass (32.7023 C. P. S.), and thus produces a composite tone of the octave in which the octave harmonic series is of a somewhat more mellow tone quality than the fundamental harmonic series. Thus as the musician plays up the scale the effect is one of a smooth reduction in the degree of octave tonality, the latter effect being very desirable from a practical standpoint. This is because the impedance of the capacitive reactance of C423 is considerably greater relative to the other constant resistive impedances of R420, R421, R424 and R425 at the high frequency end of the pedalboard. Thus the octave coupler effect is large at the bass end of the pedalboard, and small at the treble end.

The output of the triodes 410 and 411 is impressed upon the grid of a preamplifier triode 428 through a blocking capacitor C429. The triode 428 operates as a phase-inverter to change the single-end output which appears at the terminal 422 into a push-pull output, and its cathode is therefore connected to ground through a biasing resistor R430 and a load resistor R431, the junction 432 between these resistors being connected to the grid of the triode through a grid resistor R434. The plate of the triode 428 is connected to a suitable source of operating potential such as 300 V. through a load resistor R436. The signals of opposite phase respectively appearing at the terminal 432 and at the plate of the triode 428 are transmitted through blocking capacitors C438 and C439 respectively to the control grids of pentodes 441 and 440. The pentodes 440 and 441 are preferably of the variable mu or remote cut-off type. Their variable gain property is utilized to obtain various note intensity envelopes substantially free of distortion.

The control grids of the pentodes 440 and 441 are connected to a suitable negative biasing po-

tential source, such as the terminal -60 V., through grid resistors R442 and R443 respectively and through a common relatively high value resistor R444, the value of the latter being preferably in the order of 5 megohms. The cathodes of pentodes 440 and 441 as well as their suppressor grids are connected to ground, while the screen grids thereof are connected through a voltage dropping resistor R446 to a suitable potential source such as a $+300$ V. terminal. The screen grids are also connected to ground through a zero volume adjustment resistor R448 which, together with the resistor R446, forms an adjustable voltage divider to determine the potential on the screen grids of these pentodes. The plates of these pentodes are connected to the $+300$ V. terminal through load resistors R448 and R449 and the output of these tubes is impressed upon the grids of triodes 450 and 451 respectively through blocking capacitors C452 and C453 respectively.

The screen potential is adjusted to a value such that the -60 volt grid bias corresponds to zero plate current as indicated by complete silence in the speaker. This adjustment may be readily made with no pedals depressed and the piano damper pedal released. R448 is made adjustable to accommodate tubes of slightly differing plate current cutoff characteristics.

The grids of the triodes 450 and 451 are connected to ground through grid resistors R454 and R455 as well as through high frequency by-pass capacitors C456 and C457 respectively. The cathodes of the triodes 450 and 451 are connected to ground through a common self-bias resistor R458. The plates of the triodes 450 and 451 are connected to the terminals of the primary winding of a driver transformer T460, the center tap of which is connected to a suitable source of plate potential such as $+300$ V. terminal. The secondary of transformer T460, the center tap of which is grounded, is connected to the input of a push-pull power amplifier 462, and the latter is coupled by a transformer T464 to a pair of speakers 466 and 467.

As mentioned heretofore, the grid bias on the pentodes 440 and 441 is made just sufficiently great, due to the connection of the grids to the -60 V. terminal, as to cut off the plate currents of these tubes. Upon depression of any of the playing keys this grid bias is changed at a predetermined rate due to the operation of the contactor 100, which is normally in contact with segment 102. Segment 102 is connected to a suitable potential source such as $+300$ V. through a voltage divider resistor R470 and connected to ground through a volume controlling potentiometer R472. Resistors R470 and R472 form a voltage divider determining the maximum possible potential on the segment 102. The long center segment 104 is connected to a -50 V. terminal through resistors R474 and R475, the latter resistor being arranged to be shunted upon closure of a manually operable switch 476.

The -50 volt potential is carefully chosen as representing the minimum initial volume which could ever be desired in playing with the piano. Thus the sensitivity of the pedals is no greater than is actually necessary to accompany the piano and this decrease in sensitivity makes the touch characteristic pedal playing technique easier to attain. Another important reason for making the potential correspond to a minimum initial volume rather than complete silence is that it automatically affords a very desirable reduction

in the dynamic range afforded by the touch responsive feature when playing at low volumes. This greatly facilitates playing at low volumes where trouble would otherwise occur in lightly depressed pedals causing signals so weak as to fall below the threshold of hearing or be masked out completely by the piano tones.

The segment 106 is connected to a junction point 478 through a conductor 479 and attack resistor 480. The conductor 479 is normally connected to ground through resistor R246, and switches 122 and 251. It will be recalled that the switch 122 is opened prior to the engagement of contactor 100 with the segment 106 as the contactor 100 swings clockwise, and that the switch 251 is operable by the piano sustaining pedal 252. A capacitor C481 is connected between the terminal 478 and ground.

The operation of the instrument shown in Fig. 8 is generally similar to that of the previously described embodiments. The oscillator comprising the triodes 400, 401 and associated circuit elements oscillates continuously and impresses the signal upon the distorting triodes 410 and 411 which operate to transmit only the high peak portions of the signal waves. The output of the triode 410 has its amplitude materially reduced by the capacitor C423, and the signal thus modified, together with the relatively high amplitude output signal of the triode 411, is impressed upon the input of the phase-inverter triode 428. Since the signal pulses of the triodes 410 and 411 are in 180° time phase relation, the signal impressed upon the phase-inverter triode 428 will comprise a succession of pulses in which alternate ones are of higher amplitude than the intermediate pulses, the intermediate pulses being consequently more rounded, with the result that the combined signal will be heard as the fundamental tone with its harmonics and the octave of the fundamental, likewise with its harmonics, namely, the well known octave coupler effect. This octave coupler effect will be most pronounced at the low frequency end of the pedalboard.

The charge normally on the capacitor C222 due to the engagement of the contactor 200 with the segment 102 will be determined by the adjustment of the volume controlling variable resistor R472 to be of a relatively high value somewhere between 0 (ground) and $+50$ volts so that as the playing pedal or key is depressed and the contactor 100 wiped past the segment 104, this charge will be dissipated through the resistor R224, and, at one of two pre-selected rates, through the resistors R474 and R475 or through R474 alone. Thus when the contactor 100 reaches the segment 106 the charge on the capacitor C222 will depend upon the length of time that the contactor engaged the segment 104 and thus open the velocity at which the pedal was depressed. This charge is then applied to the capacitor C481 through R480 and the charge divided with the latter capacitor, the rate at which this transfer of charge takes place, and hence the rate of tonal attack, being dependent mainly upon the values of R480 and C481. Since R444 is of relatively high value, in the order of 5 megohms, the potential change on the capacitor C481 will appear on the grids of the control pentodes 440 and 441 and render the latter capable of transmitting the signal. Capacitor C481 may be equal in value to C222, and resistor R444 may be equal to R224.

If the playing pedal or key is held depressed, the switch 122 will, of course, be open, and the charges on the capacitors C222 and C481 will

decay at a rate determined mainly by the values of R224 and R444 which are sufficiently great to cause gradual or slow decay. However, when the playing pedal is released and the piano sustaining pedal 252 is not depressed the switches 122 and 251 are closed and the charge on the capacitor C481 is rapidly dissipated through the relatively low value resistor R426 and switches 122 and 251. If the sustaining pedal is depressed and the playing key released, the charge on the capacitor C481 can be dissipated only through flow of current to the -60 V. terminal through R444, and the note will therefore decay very gradually. This is likewise true if the playing key or pedal is held depressed sufficiently to hold open the switch 122. This is because the time constant of R444 and C481 equals that of R224 and C222. Thus the variable gain pentodes 440 and 441 are used as volume controlling devices and do not distort their input signals.

The combined instrument utilizing the electrical circuits of Fig. 8 is played in the same manner as the previously described embodiments, it being possible to produce bass tones having an intensity determined by the velocity of pedal depression, and having a slow decay rate if the piano sustaining pedal is depressed, or the depressed tone controlling pedal is held depressed, or having a rapid decay rate if the depressed tone controlling pedal is released while the sustaining pedal is not depressed.

The combined instrument is capable of producing many acoustic effects and musical results not obtainable with the piano alone, even assuming that some means were provided to permit operation of the bass keys of the piano by means of a pedal clavier. For example, the bass tone produced by the electrical portion of the instrument may be damped by release of the sustaining pedal. When the instrument is played with the piano sustaining pedal depressed, then as successive pedals of the pedal clavier are depressed each tone produced by the electrical portion of the instrument will continue sounding only until another pedal is depressed. This result could not be obtained by the piano alone since it would require a technique almost impossible of achievement to manipulate the playing keys and sustaining pedal in such a manner as to damp the strings of one note immediately prior to the depression of another key. Using a conventional piano, a pianist is limited to producing either of two effects, with reference to the playing of the bass accompaniment: he may hold the sustaining pedal down while depressing successive bass keys in which case the result will be, if the passage is of ordinary tempo, that several of the bass tones will be sounding simultaneously to produce a muddying dissonant effect; or, on the other hand, if the player attempts to operate the piano sustaining pedal just prior to the depression of each successive bass key, there will be intervals of silence between the successive tones. The latter effect is especially undesirable in non-reverberative rooms, while the former effect is undesirable under practically all conditions.

In the rendition of many musical selections, it will be found that the left hand will have to execute a low bass chord and then several higher bass chords, and in many cases this shift of the hand through an octave or more along the keyboard must be executed rather rapidly. Such rapid execution makes it extremely difficult for the player to strike the keys for low bass chord with the proper velocity since the player's hand

must be moving rapidly toward the low bass chord and then slow up suddenly to strike this chord lightly, should this be desirable in the rendition of the selection. This limitation is not present in the instruments herein disclosed, since the bass accompaniment tone may be sounded at practically any desired intensity, depending only upon the velocity of depression of the bass pedal.

In the several embodiments of the invention the initial tuning of the oscillator to a predetermined frequency is accomplished by adjustment of the variable inductances L150 (Figs. 5 and 8), L392 (Fig. 6). In general, it will usually be found desirable to have the pitch range of the oscillator be from 32.703 C. P. S. to 61.735 C. P. S. These frequencies represent the frequency of the high amplitude peaks of the output wave 216 (Fig. 5). The interposition of the intermediate low amplitude peaks will result in the addition of the octave and its harmonics so that the tones produced will contain fundamental tones, of 32.703 to 61.735 C. P. S. plus their harmonics as well as tones of 65.406 C. P. S. to 123.470 C. P. S. and their harmonic partials.

The constants of the intensity envelope control circuits are preferably such that the intensity range of the electrical portion of the instrument is of the order of 26 db., and thus comparable to the dynamic range of the piano portion.

By the use of any of the several forms of the invention the musician is able to render a large variety of musical compositions of an orchestral character with great facility since his left hand is free to play additional accompaniment and counter melody parts simultaneously with the bass part which is played on the pedal clavier. Furthermore, music in rapid tempo may be readily performed because the player's left hand need cover but a relatively narrow range of the keyboard and the player's foot need only cover the short compass of the bass clavier. The limitation in playing technique, due to the time interval which has heretofore been necessary for the pianist to move his left hand from the low bass register of the piano to the middle accompaniment register, is removed.

Because the sustaining feature of the electrical portion of the instrument is controlled by the sustaining or sostenuto pedals of the piano, or by both, the player need only tap the pedals to produce the bass tones. As explained heretofore, following the tapping of one bass pedal the player's foot is free to move leisurely toward the next bass pedal. Thus it becomes an easy matter for the player accurately to locate his foot over each pedal before depressing it.

A further important musical result achieved with the apparatus of this invention is that of a general legato effect, which is attained because, throughout most of the time that the instrument is being played, there is some sound being produced by the bass instrument, except for the brief intervals of time during which the piano damper pedal is released. This degree of legato playing is highly desirable in rooms which are non-reverberative. It would be impossible to achieve this effect on the ordinary organ type of pedal clavier because of the relatively long interval of time required to move the foot from one pedal to another, during which time the legato effect would be lost.

Upon depression of a pedal the oscillator is immediately tuned to a frequency related to the pitch of the note represented by the pedal, and it will continue oscillating at this frequency until

another pedal is depressed, but when a second pedal is depressed the frequency of oscillation changes instantly to that related to the second depressed pedal. Rapid passages may therefore be played on the pedals without having any overlapping of successive tones even though the sustaining pedal is held depressed. This effect can not be obtained on the piano, for the piano strings continue vibrating after the key is released, and in playing rapid passages in this manner, the simultaneous sounding of a number of bass tones produces a "muddy" effect. It would be impossible for the pianist to avoid this effect by releasing the sustaining pedal just prior to depressing each key. This would require too rapid operation of the sustaining pedal and would necessarily result in discontinuities in the tonal output of the piano.

The tonal output of the combination instrument is far superior to that which could be obtained from the piano alone even if the piano were played by two musicians, one devoting his attention solely to the bass score. The instrument is relatively simple in construction and may be economically manufactured so as to be available to a large majority of owners of pianos. It may readily be combined with the piano merely by suitably arranging for the operation of the switches by the sustaining, or by either the sustaining or the sostenuto pedal of the piano. The addition of the electrical portion of the instrument to a conventional piano can therefore be accomplished without materially altering the piano structure or in any way disfiguring it.

While two forms of the invention have been disclosed herein, it will be apparent to those skilled in the art that numerous modifications and variations may be made in the form and construction thereof, without departing from the more fundamental principles of the invention. We therefore desire, by the following claims, to include within the scope of our invention all such similar and modified forms of the apparatus disclosed, by which substantially the results of the invention may be obtained by substantially the same or equivalent means.

We claim:

1. In a pedal clavier for electrical musical instruments, the combination of a plurality of relatively long natural pedals, a plurality of relatively short sharp pedals, pivots for said pedals, said pivots being substantially at the centers of the pedals whereby the rearward ends of the pedals will have substantially the same travel upon equal depression of their forward ends, a pivoted bail having a rod extending across the rearward ends of the pedals so as to be swung about its pivot upon depression of any of the pedals, a switch for each of the pedals, a switch actuator secured to each of the pedals for operating its associated switch, a latch for each of the switches to hold it in operated position, and means operated during the upward swinging movement of the bail upon the depression of a pedal to move all of the latches out of switch engaging position and to return them to switch engaging position prior to the commencement of the return strokes of the bail and pedal.

2. In a pedal clavier for electrical musical instruments, the combination of a base, a plurality of pedals pivotally mounted on the base, a rod extending across the pedals so as to be moved upon depression of any of the pedals, a switch for each of the pedals, a switch actuator secured to each of the pedals for operating its associated

switch, a latch for each of the switches to hold it in operated position, and means operating by the movement of the rod during the depression of a pedal to move all of the latches out of switch engaging position and to return them to switch engaging position prior to the commencement of the return strokes of the rod and pedal.

3. In a pedal clavier for electrical musical instruments, the combination of a plurality of depressible pedals, a switch for each pedal, means carried by each pedal for operating its associated switch upon the down stroke of the pedal, latches to hold only the switches in operated position, and means to render all of the latches ineffective during a portion of the down stroke of the pedal.

4. In a pedal clavier for electrical musical instruments, the combination of a plurality of natural and sharp pedals, said pedals having down strokes of substantially equal length, means supporting said pedals for pivotal movement, said means being located substantially centrally of each of the pedals, a bail having its cross rod positioned above the rearward ends of all of the pedals, a switch operable by each of the pedals, a latch for each of said switches to hold the latter in operated position after its pedal has been released, and means operated by the bail to move all of the latches to ineffective positions upon the depression of any pedal during the down stroke thereof.

5. In an electrical musical instrument, the combination of a tone signal generating system, an output system including electroacoustic translating means, a plurality of pedals forming a pedal clavier, a plurality of switches respectively operable by the pedals, means controlled by the operation of said switches to determine the pitch of the tone signal transmitted from the generating system to the output system, means to maintain the last operated switch in operated condition until another switch is operated, a member common to all of the pedals and operated by the depression of any one of the pedals, and a tone intensity envelope controlling means operated by said member.

6. In an electrical musical instrument, the combination of an electrical tone signal generating system, an output system including an amplifier having a terminal the potential of which determines the amplitude of the output signal, a plurality of pedals forming a pedal clavier, a plurality of switches respectively associated with said pedals and operable thereby, means controlled by the switches to determine the pitch of the tone signals transmitted from the generating system to the output system, a latch for each of said switches to hold it in operated position, a member common to all of the pedals and operated upon the depression of any pedal, means operated by said member to render all of said latches ineffective during the down stroke of a depressed pedal, switching means operated by said member, and a capacity and resistance network connected to said switching means and to said terminal and operable to control the potential of the terminal in response to the velocity of pedal depression.

7. In an electrical musical instrument for use in conjunction with a piano having a sustaining pedal, a pedal clavier comprising a plurality of pedals each having a resilient means to bias it to normal position, means for producing musical tones in response to the depression of pedals of the pedal clavier, and means responsive to the depression of the piano sustaining pedal to cause

the tones to continue sounding after the pedal of the pedal clavier has been released and returned to normal position.

8. In a musical instrument comprising an electrical output system including electroacoustic translating means, a piano having a sustaining pedal, a tone signal generating apparatus providing frequencies of the low bass register, a pedal clavier, means operated by the pedals of the clavier to cause transmission to the output system of tone signals from the generating apparatus of pitch corresponding to a depressed pedal, means to cause the generating apparatus to continue to supply the signal to the output system at a decaying amplitude after the depressed pedal has been released, and means operated by the release of the sustaining pedal of the piano to render said last named means ineffective and thereby cause the signal amplitude to decrease rapidly to zero.

9. In an electrical musical instrument having an output system including electroacoustic translating means, the combination of an electrical generator capable of producing musical tone signals of the pitches of the notes of the musical scale, a pedal clavier comprising a plurality of pedals, resilient means for each of the pedals to return it to normal position when it is released, a plurality of devices respectively operable by said pedals to cause musical tone signals of corresponding pitch to be transmitted from the generating system to the output system, means associated with each of said devices to hold it in operated position after the pedal which operated it is released and has been returned to its normal position, and means operable upon depression of any of the pedals to release all of said device holding means.

10. In an electrical musical instrument having an output system including electroacoustic translating means and an amplifier having a terminal the potential of which determines the intensity of the tonal output of the instrument, a plurality of keys forming a pedal clavier, a member moved upon depression of any one of the pedals, three contact segments, a contactor moved by said member to make contact successively with the first, second and third segments as the member is moved by the depression of a pedal, means for maintaining a relatively high potential on the first segment, means including a resistor connecting the second segment to a point of relatively low potential, means including a resistor connecting the third segment to said terminal, a capacitor having one terminal thereof connected to the contactor and the other terminal thereof connected to the point of relatively low potential, a relatively high resistance in parallel with said capacitor, and a second capacitor connected between said terminal and a point of relatively low potential, whereby when said contactor engages the first segment said first capacitor will receive a high potential charge, as said contactor engages said second segment the first capacitor will be discharged at a rate determined by the first resistor, and as the contactor engages the third contact, part of the remaining charge on the first capacitor will charge the second capacitor and thereby determine the potential on the terminal.

11. In an electrical musical instrument having a plurality of playing keys and an output system including a terminal A, the potential of which determines the amplitude of the output signal, a terminal B of fixed relatively high potential, a

terminal C of fixed relatively low potential, a terminal D of ground potential, a commutating switch comprising three segments and a key operated contactor successively contacting the first, second and third segments as a key is depressed, means connecting terminal B to the first segment, a capacitor shunted by a high resistance connected between said contactor and terminal D, a resistor connecting the second segment with terminal C, a conductor connecting the third segment with terminal A, a second capacitor connected between terminal A and terminal D, a circuit including a resistance and two switches connecting the third segment to terminal D, means operated upon depression of any of the keys to open the first of said pairs of switches as the contactor is in engagement with the second segment and to hold it open while the contactor is in engagement with the third segment, and a sustaining pedal for operating the second of the pair of switches.

12. In an electrical musical instrument having a plurality of playing keys and an output system including a terminal A, the potential of which determines the amplitude of the output signal, a terminal B of fixed relatively high potential, a terminal C of fixed relatively low potential, a terminal D of ground potential, a commutating switch comprising three segments and a key operated contactor successively contacting the first, second and third segments as a key is depressed, means connecting terminal B to the first segment, a capacitor shunted by a high resistance connected between said contactor and terminal D, a resistor connecting the second segment with terminal C, a conductor connecting the third segment with terminal A, a second capacitor connected between terminal A and terminal D, a circuit including a resistance and a switch connecting the third segment to terminal D, and means operated upon depression of any of the keys to open the last named switch as the contactor is in engagement with the second segment and to hold it open while the contactor is in engagement with the third segment.

13. In an electrical musical instrument, the combination of an electrical tone signal generating system, an output system including an amplifier having a terminal the potential of which determines the amplitude of the output signal, a plurality of pedals forming a pedal clavier, a plurality of switches respectively associated with said pedals and operable thereby, means controlled by the switches to determine the pitch of the tone signals transmitted from the generating system to the output system, a member common to all of the pedals and operated upon the depression of any pedal, switching means operated by said member, and a capacity and resistance network connected to said terminal and said switches and operable to control the potential of the terminal in response to the velocity of pedal depression.

14. In an electrical musical instrument, the combination of a tone signal generating system, an output system including electroacoustic translating means, a plurality of pedals forming a pedal clavier, a plurality of switches respectively operable by the pedals, means controlled by the operation of said switches to determine the pitch of the tone signal transmitted from the generating system to the output system, a member common to all of the pedals and moved by the depression of any one of the pedals, and a

tone intensity envelope controlling means operated by said member.

15. In an electrical musical instrument having a pulse generating oscillator operating in push pull, a pair of electron discharge devices having their input circuits connected to the oscillator in push pull, each of said devices including a cathode, control grid, and plate, a plurality of playing keys, means controlled by said keys to determine the frequency of oscillation of the oscillator, a pair of sources of plate current for said devices, each of said sources including a capacitor and a resistance network, said networks having different time constants, and means operated upon the depression of any of the keys to charge said capacitors to potentials of value determined by the velocity of key operation.

16. In an electrical musical instrument having an electrical tone signal generating means and playing keys for controlling the pitch of the output signals produced thereby, an output system including a pair of electron discharge devices having signal pulses supplied thereto in 180° phase relation by said signal generating means, a source of plate current for said devices, each including a capacitor, means to discharge said capacitors at different rates, and means for charging said capacitors to potentials determined by the velocity of operation of a key, whereby the amplitude of the signal pulses transmitted by one of said devices will decay to zero amplitude more rapidly than the signal pulses transmitted by the other of said devices.

17. In an electrical musical instrument having an output system including electroacoustic translating means, electrical means for generating electrical musical tone signal pulses in substantially 180° phase relation, a pair of control tubes for controlling the transmission to the output system of the electrical tone signal pulses, one of said tubes receiving the pulses in 180° phase relation with respect to the pulses received by the other tube, means including resistance and capacitance networks respectively associated with said control tubes to determine the amplitudes and decay rates of the output signals thereof, said networks having different time constants whereby the pulses of one phase will decay more rapidly than those of the other phase.

18. In an electrical musical instrument having an output system including electroacoustic translating means, electrical means for generating electrical musical tone signal pulses in 180° phase relation, a pair of control tubes for controlling the transmission to the output system of the electrical tone signal pulses, one of said tubes receiving the pulses in 180° phase relation with respect to the pulses received by the other tube, and means having different decay rates respectively associated with said control tubes to determine the amplitudes and decay rates of the output signals thereof, whereby the pulses of one phase will decay more rapidly than those of the other phase.

19. In an electrical musical instrument having an oscillator forming a source of signal pulses in substantially 180° phase relation, a pair of electron discharge devices having their input circuits connected to the source to receive alternate pulses therefrom, each of said devices including a cathode, control grid, and plate, means biasing said devices to different plate voltage cut-off potentials, a plurality of playing keys, means controlled by said keys to determine the frequency of oscillation of the oscillator, a capacitor

forming a source of plate current for said devices, and means operated upon the depression of any of the keys to charge said capacitor to a potential of value determined by the velocity of key operation.

20. In an electrical musical instrument having a tone generating system and an output system, the combination of a plurality of pedals forming a pedal clavier, a plurality of relays each having a switch operable to determine the pitch of the tone signal transmitted to the output system by the generating system, a circuit completed upon the depression of each pedal for energizing its associated relay, a second circuit for energizing each relay, a source of electrical energy common to all of said second circuits, means operated by each pedal to disconnect said source from said second relay circuits after the first energizing circuit has been completed and operable upon release of the pedal to connect said source to all of said second relay circuits and thereafter to open the first completed relay energizing circuit, whereby the relay energized upon the last depressed pedal will remain energized until another pedal is depressed.

21. In an electrical musical instrument the combination of an oscillator, means operable to tune the oscillator to any one of the frequencies of the notes of the musical scale within the gamut of the instrument, a plurality of depressible keys for operating the tuning means, resilient means for each of the keys to return it from depressed to normal position, means to maintain the oscillator tuned at the frequency represented by the last operated key until another key is operated despite the return of the depressed key to normal position by its resilient means, and tone intensity envelope controlling means having its operation initiated by the operation of any one of the playing keys.

22. In an electrical musical instrument having an output system including electroacoustic translating means, a plurality of playing keys, apparatus controlled by the keys for generating tone signal pulses having a push-pull output, a pair of electron discharge devices each having a cathode, control grid and plate, means for impressing the signal pulses produced by said generating apparatus upon the grids of said devices in push pull, means including a charged capacitor and controlled by the keys for supplying plate current to said devices, and means connecting the cathodes of said devices to points of different fixed potentials, whereby, as the capacitor discharges through the plate circuits of said devices, one of the devices will attain zero signal transmission before the other.

23. In an electrical musical instrument having playing keys, the combination of a source of audio frequency signals having wave shapes of generally symmetrical rectangular character, an electron discharge device having a cathode, control grid and plate, a circuit for impressing signals from said source upon the control grid, means for altering said wave shape including a current limiting capacitor-resistance mesh connected to the control grid of the electron discharge device, means providing a constant relatively large fixed negative grid bias on the device, thereby to produce asymmetrical plate current pulses of time shorter than the period of the rectangular input pulses, and means for applying to the plate of said device a variable potential whose value is dependent upon the velocity with which a playing

key is depressed, thereby to produce an output signal of corresponding amplitude.

24. In an electrical musical instrument having playing keys, the combination of a source of audio frequency signals having wave shapes of generally symmetrical character; an electron discharge device having a cathode, control grid, and plate; a circuit for impressing signals from said source upon the control grid; means for altering the signal wave shape to provide asymmetrical plate current pulses of shorter duration than those provided by the source, said last named means comprising a current limiting capacitor-resistance mesh connected to the grid, and means providing a constant relatively large grid bias on the device; a second electron discharge device coupled in series with said first device; and means to apply to the plates of both of said devices a variable potential, the value of which is dependent upon the velocity with which a playing key is depressed, thereby to produce an output signal of corresponding amplitude and to cause complete cessation of signal transmission by the second device when the plate potential applied to both of said devices is zero.

25. In an electrical musical instrument having an output system and a clavier comprising a plurality of keys, an oscillator capable of being tuned throughout a range of frequencies corresponding to that of the clavier, means operable by each of the keys to tune the oscillator to a frequency related to that of the operated key, resilient means to return each of the keys to normal position without affecting the position of one of the last named means which may have been operated, means for causing the oscillator to continue oscillating at the frequency of the last operated key until the operation of another key which requires that the oscillator be tuned to a different frequency, additional switch means operated by the depression of any one of the keys, and signal intensity controlling means forming part of the output system and rendered effective by the additional switch means.

26. An electrical musical instrument comprising, a plurality of depressible resiliently returned keys, a variable frequency oscillator, means operable by the keys to tune the oscillator to a frequency which is related to the pitch of the depressed key, a latch mechanism for holding the tuning means in operated position despite the release and return of the key which operated the tuning means, and means for causing the oscillator to operate at the frequency to which it has been tuned until a key calling for an unrelated pitch is depressed.

27. The combination set forth in claim 26 in which means are provided to cause the signal provided by the oscillator to decay at a predetermined rate.

28. In an electrical musical instrument having an output system and a keyboard comprising a plurality of keys, a musical tone signal generating system for supplying to the output system signals of pitches related respectively to the keys, means operable by the keys to cause the generating system to transmit to the output system an electrical signal of a pitch related to a depressed key and to continue transmitting the signal to the output system until the depression of another key which requires that a tone signal of different pitch be supplied to the output system, and tone intensity envelope controlling means in the output system operable to block transmission of the

signal through the output system a predetermined time interval after the release of a key.

29. A musical instrument comprising a piano having a sustaining pedal, and a pedal clavier associated with the piano for simultaneous playing therewith, said pedal clavier comprising a plurality of pedals; an electron discharge tube oscillator; means operated by the pedals for tuning the oscillator to pitches related respectively to the pitches represented by the pedals; means to cause said last named means associated with one pedal to remain effective until the corresponding means associated with another pedal is operated; means operative upon the signal supplied by the oscillator to cause it to decay at a predetermined rate when the piano sustaining pedal is depressed; and means operated upon release of the piano sustaining pedal to cause the signal to decay at a different rate.

30. In an electrical musical instrument, the combination of a variable frequency oscillator having a tuning circuit including a plurality of tuning elements, a plurality of playing keys, resilient means to return operated keys to normal position, switches respectively operable by the keys and connected in the tuning circuit, each of the switches being effective upon operation of its associated key to cause the connection in the tuning circuit of predetermined tuning elements, latching means to maintain the switch in operated position until a key requiring the tuning of the oscillator to a different frequency is depressed, said latching means permitting returning of the keys to normal position, and means to maintain the other switches in a position to prevent them from changing the tuning of the oscillator from the frequency to which it was tuned by the operation of the last depressed key.

31. In an electrical musical instrument, the combination of a variable frequency oscillator having a tuning circuit, a plurality of playing keys, resilient means to return depressed keys to normal position, means operated by the playing keys to tune the oscillator to a predetermined frequency related to that represented by an operated key, and means to maintain the oscillator tuned to such frequency, despite release of the key and its return to normal position, until a different key requiring the oscillator to be tuned to a different frequency is operated.

32. In an electrical musical instrument, the combination of a variable frequency oscillator, a plurality of playing keys, resilient means to return operated keys to normal position, means operable by each of said keys to tune the oscillator to a frequency related to that represented by an operated key, and means to maintain the oscillator tuned to the frequency of the operated key until a second key is operated calling for the tuning of the oscillator to a different frequency, despite the previous release and return to normal position of the first operated key.

33. In an electrical musical instrument, electrical musical tone signal generating means supplying two harmonically complex pulse type wave form signals of the same fundamental frequency but of opposite phase, two separate transmission channels coupled to the generating means for transmitting respectively the two signals, means for combining the output signals of the two channels and translating the combined signal into sound, and reactive means associated with one of the channels effective to increase the disparity of the amplitudes of the two signals transmitted respectively by the two channels as the frequency

of the signals is increased, whereby a reduction in the octave coupler tonality effect is obtained as the frequency of the signals is increased.

34. In an electrical musical instrument having an output system which includes a terminal the potential of which determines its gain, a pedal clavier comprising a plurality of pedals each operating five switches, namely, a first, a second, a third, a fourth, and a fifth switch, each pedal upon depression being arranged first to open the first switch and close the fifth switch and thereafter to open the second and fourth switches and close the third switch, a potential storing capacitor, an intensity envelope control relay having a pair of switches, a circuit including all of the third switches in parallel for energizing said relay, means connecting all of said first switches in series, a source of potential for charging said capacitor normally connected thereto through a circuit including said series of first switches and one of the relay switches, a relatively low impedance in said charging circuit, means connecting the second switches in series, said series of second switches being connected to said capacitor through said relay switch and being connected to a relatively low potential source through a relatively high impedance, a plurality of pitch determining relays, means operated by each of the fifth switches to energize a pitch determining relay, individual holding circuits for said pitch determining relays, a common source of electrical energy for said holding circuits, said source being connected to said holding circuits through all of said fourth switches, means operated by each of said pitch determining relays for causing a musical tone signal of pitch corresponding to the depressed pedal to be transmitted to the output system, and a circuit for impressing the potential of said capacitor on said terminal of the output system.

35. In an electrical musical instrument for use in conjunction with a piano having a sustaining pedal, the combination of a pedal clavier comprising a plurality of pedals, resilient means associated with each of the pedals to return it to normal position after it has been depressed and released, stop means limiting the return movement of the pedals by the resilient means, a musical tone signal generating system, an output system, switch means respectively operated by the pedals to cause transmission from the generating system to the output system of an electrical musical tone signal of frequency corresponding to that of the depressed pedal, means including switches and forming part of the output system for determining the intensity envelopes of the signals transmitted through the output system, means for operating one of said switches upon the maintained depression of any one of the pedals to cause the tone signal to be sustained, and means for operating another of said switches upon the depression of the piano sustaining pedal, the operation of the last named switch also causing the tone signal to be sustained.

36. In an electrical musical instrument for use in conjunction with a piano having a sustaining pedal, a pedal clavier comprising a plurality of depressible pedal keys each having means to return it to normal position, a bass tone generating system of complex quality, an output system including an electroacoustic transducer, elements operated by said keys for determining the frequency of said generating system during the interval of time that the key is depressed and also effective to determine the frequency of said gen-

erator after the key is completely released, an envelope determining decay apparatus associated with said generator to cause relatively rapid attenuation of the tone supplied to said transducer upon release of the pedal, and an auxiliary connection to the piano sustaining pedal to render said decay apparatus ineffective despite complete release of said keys.

37. In an electrical musical instrument for use in conjunction with a piano having a sustaining pedal, the combination of a plurality of pedal keys, a bass tone generating system of complex quality, an output system including an electroacoustic transducer, envelope determining means operable by said keys to cause the tone signals applied to said transducer to decay at a relatively rapid rate upon complete release of said keys, and an auxiliary sustaining control responsive to the depression of the piano sustaining pedal to render said envelope means ineffective despite complete release of the pedal keys.

38. In an electrical musical instrument having an electrical output system including an electroacoustic transducer, the combination of a plurality of depressible pedals constituting a pedal clavier, a bass tone generating system capable of producing electrical musical tone signals, switches operated by the pedals to determine the pitch of the tone signals supplied by the generating system to the output system, means to hold the switches operated by the pedals in operated condition, a member common to all the pedals and operable by any one of the pedals to render all of the switch holding means temporarily ineffective during the depression of any pedal, control means associated with the output system normally rendering it incapable of transmitting to the transducer the tone signals supplied by the generating system, means affected by the depression of any pedal to cause the control means to transmit the tone signals while the pedal is depressed, and a sustaining switch operable at will by the player and connected to the control means to cause the latter to continue to transmit the tone signals after the pedal has been released.

39. An electrical bass tone producing instrument for use in the accompaniment of a piano which has a sustaining pedal, comprising, an output system including an electroacoustic transducer, a pedal clavier including a plurality of pedals, depressible from normal positions, a bass tone signal generating system to generate and transmit to the output system electrical tone signals, means operated by the clavier pedals to determine the pitch of the tone signals transmitted to the output system by the generating system, means to cause decay of the tone signals to inaudibility upon release of the clavier pedals and their return to their normal positions, and a connection between the piano sustaining pedal and the last named means to render the latter ineffective while the sustaining pedal is held depressed despite the release of the clavier pedals.

40. In an electrical musical instrument to be played in conjunction with a conventional piano having a sustaining pedal, the combination of the pedal clavier comprising a plurality of pedals, an electric output system, a tone signal generating system, means controlled by staccato depressions and release of the clavier pedals to cause the generating system to transmit to the output system tone signals of a frequency corresponding to that represented by the operated pedal when it is depressed and after it is released, means operable upon release of any of the clavier pedals to cause

the tones to decay at a rapid rate, and means connected to the piano sustaining pedal for operation thereby to render said decay causing means ineffective.

41. In an electrical musical instrument having means for producing musical tones of different pitch, a plurality of playing keys, elements operated respectively by depression of said keys, the operated element determining the pitch of the tone produced by the instrument, retaining means associated with each of the elements to maintain it in operated condition upon release of its key, means operated upon the depression of any key to cause the retaining means of all other keys to release their associated elements, and means to cause the intensity of the tone produced by the instrument to decay gradually upon release of a depressed key.

42. In an electrical musical instrument to be played in conjunction with a conventional piano having a sustaining pedal, the combination of a pedal clavier comprising a plurality of pedals, an electric output system, a tone signal generating system, means controlled by the pedals to cause the generating system to transmit to the output system tone signals of a frequency corresponding to that represented by the depressed pedal while the pedal is depressed and after it has been released, means operable by any of the pedals to determine the initial intensity of the tones produced, means to cause the tones to decay at a rapid rate after complete release of the depressed pedal, and means operated by the piano sustaining pedal to render said decay causing means ineffective.

43. In an electrical musical instrument for playing in conjunction with the playing of a piano having a sustaining pedal, musical tone signal producing means, a pedal clavier comprising a plurality of pedals operating on the tone producing means to select the pitch of the tone to be produced, means responsive to the velocity of the depression of any of the pedals to control the initial intensity of the tone, clavier pedal controlled means causing rapid decay of the tone, means rendering said rapid decay causing means ineffective while any pedal of the pedal clavier is held depressed, and means operated by the sustaining pedal for rendering said rapid decay causing means ineffective while the piano sustaining pedal is held depressed despite the release of the depressed pedal.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,105,629	Dixon	Aug. 4, 1914
1,893,895	Hammond	Jan. 10, 1933
2,126,464	Hammond	Aug. 9, 1938
2,126,682	Hammond	Aug. 9, 1938
2,148,478	Kock	Feb. 28, 1939
2,154,778	Schnell	Apr. 18, 1939
2,301,871	Hanert	Nov. 10, 1942
2,357,191	Hanert	Aug. 29, 1944