

May 24, 1960

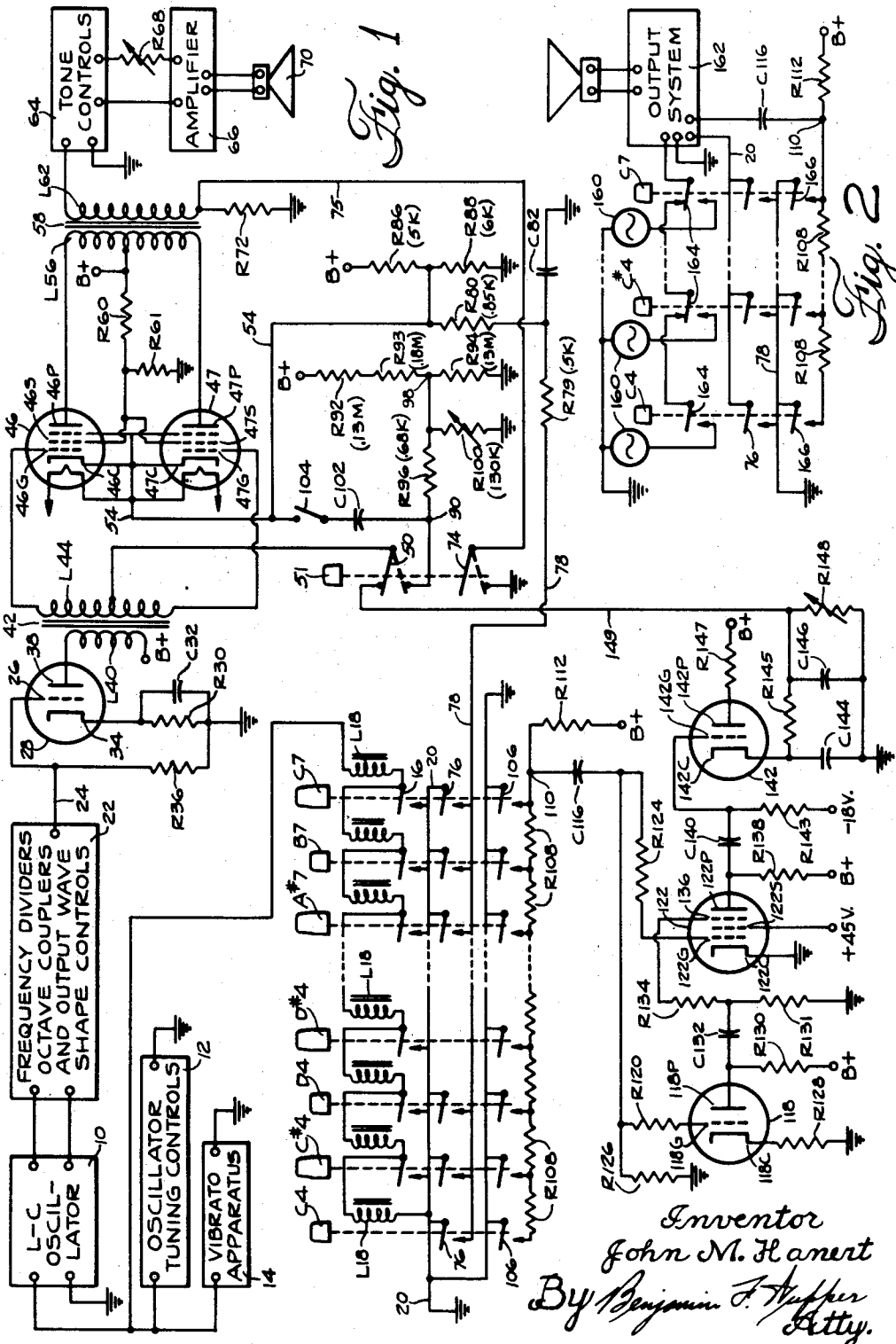
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2,937,556

ELECTRICAL MUSICAL INSTRUMENTS

Original Filed Dec. 28, 1950

5 Sheets-Sheet 1



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ELECTRICAL MUSICAL INSTRUMENTS

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5 Sheets-Sheet 2

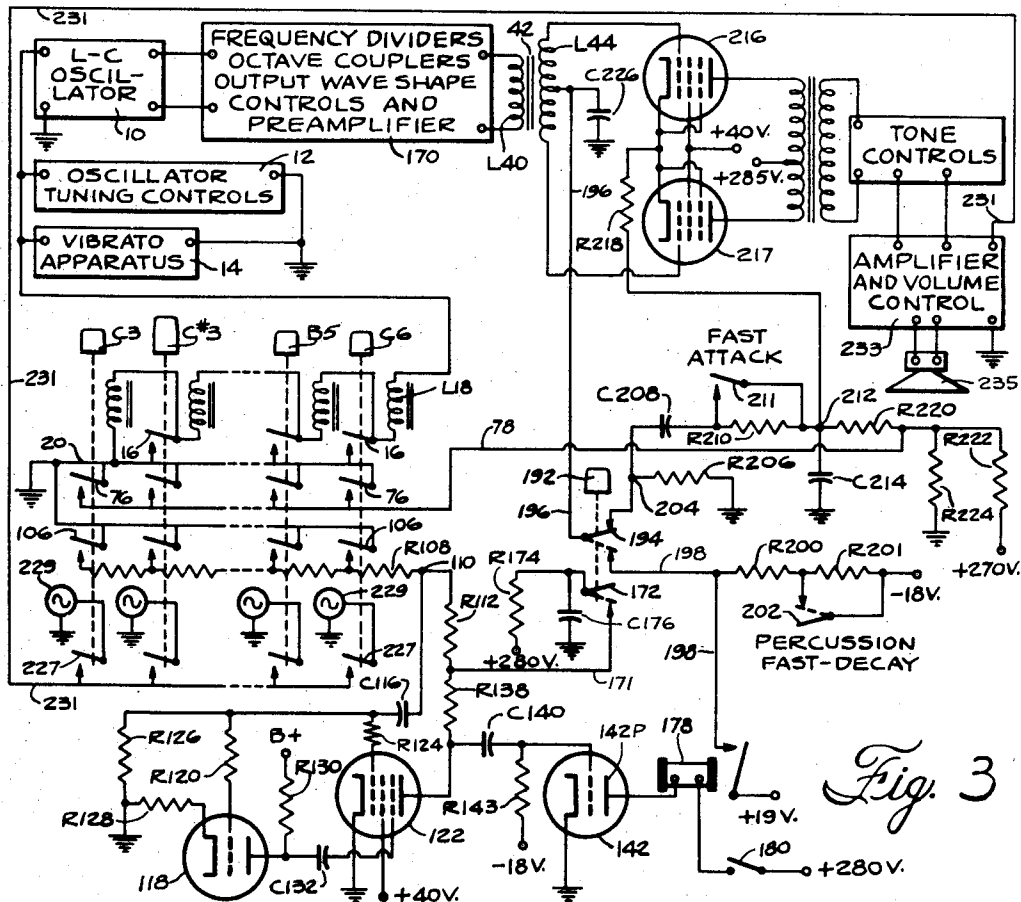


Fig. 3

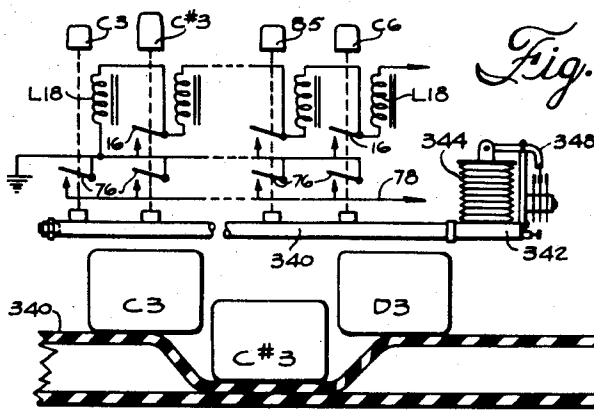


Fig. 7

Fig. 8

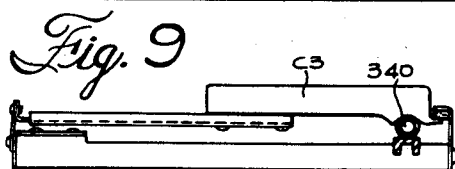


Fig. 9

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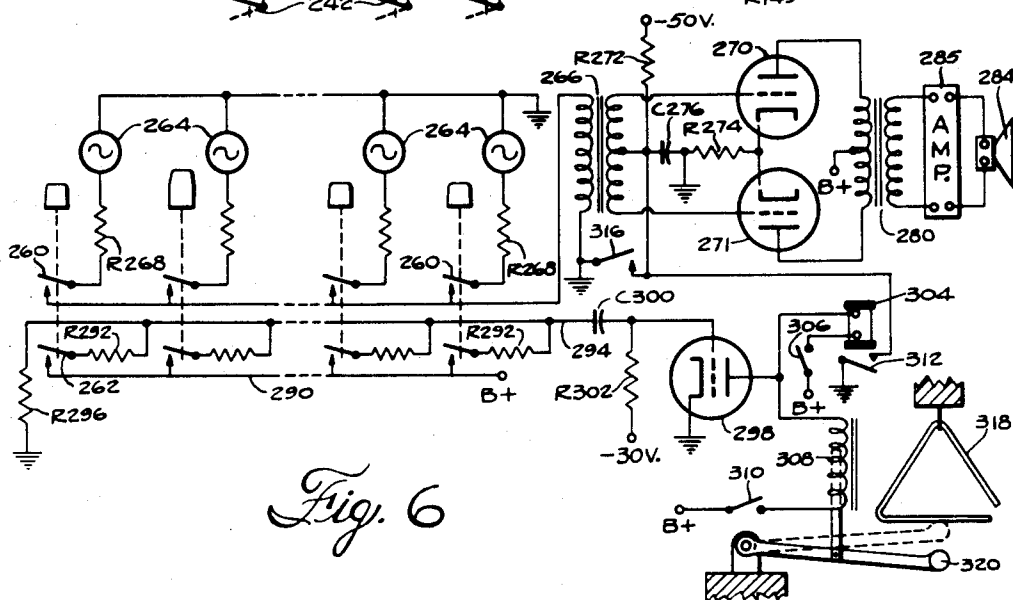
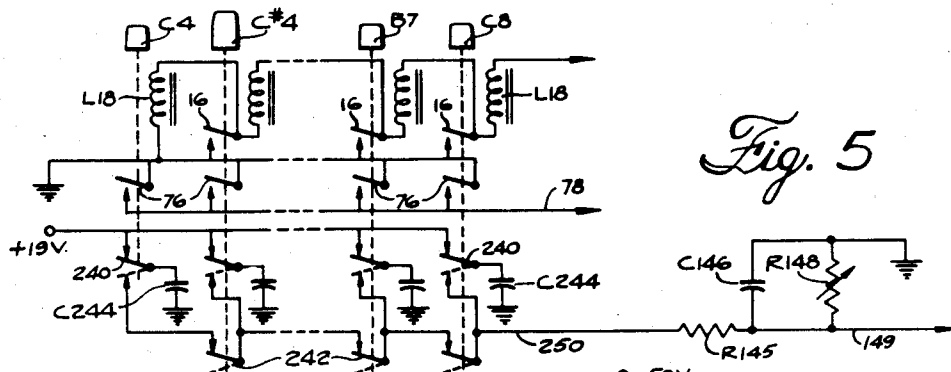
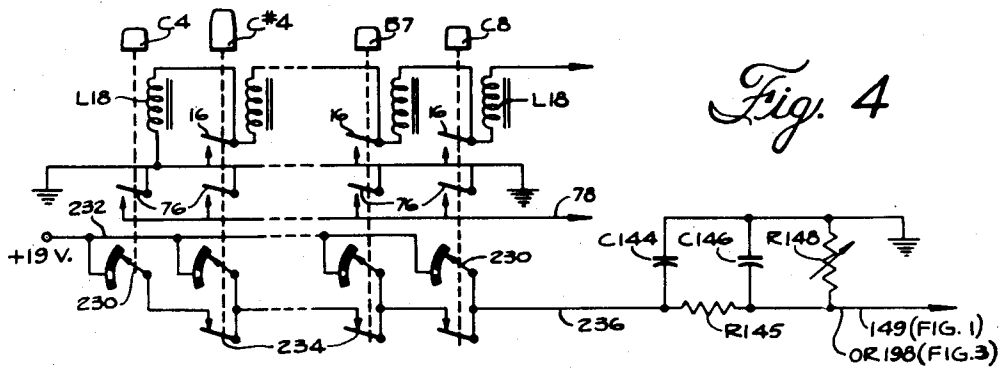
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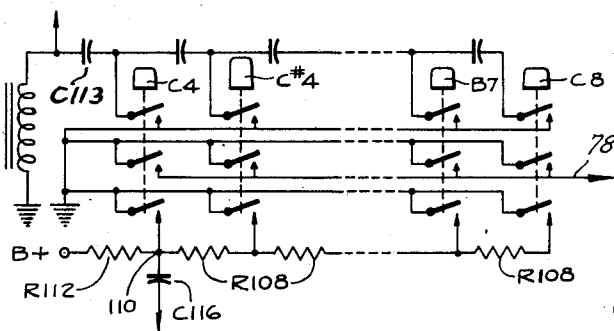


Fig. 10

(REMAINDER OF CIRCUIT AS SHOWN IN FIG. 1)

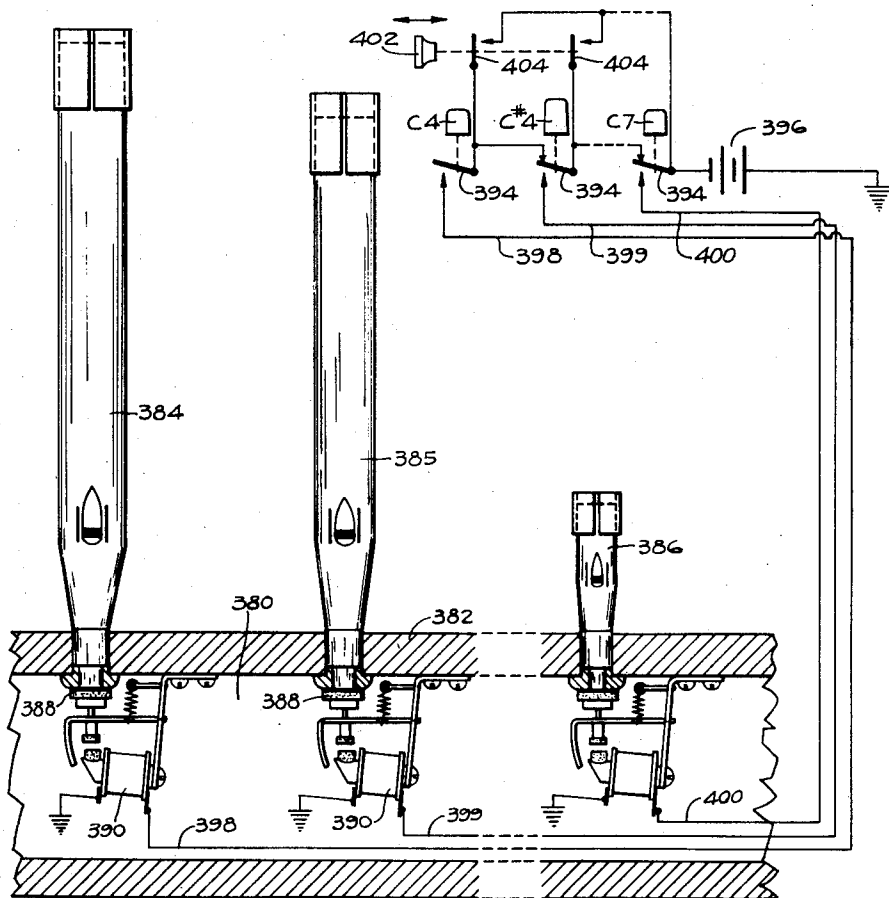
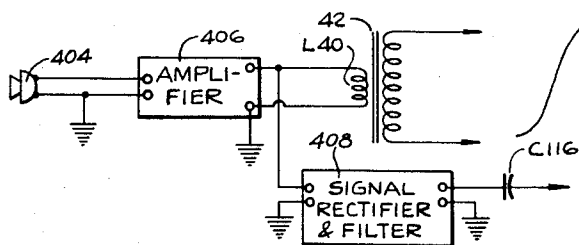


Fig. 11 (REMAINDER OF CIRCUIT AS SHOWN IN FIG. 1)



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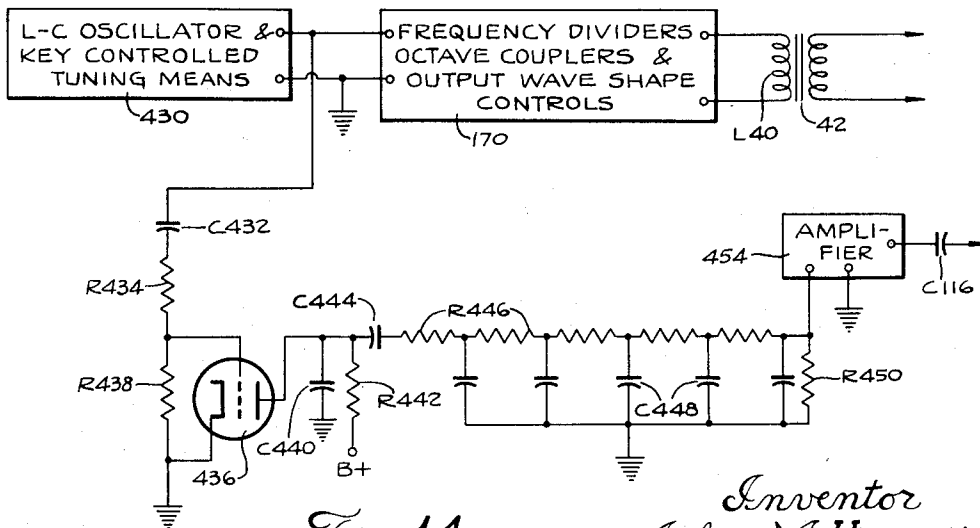
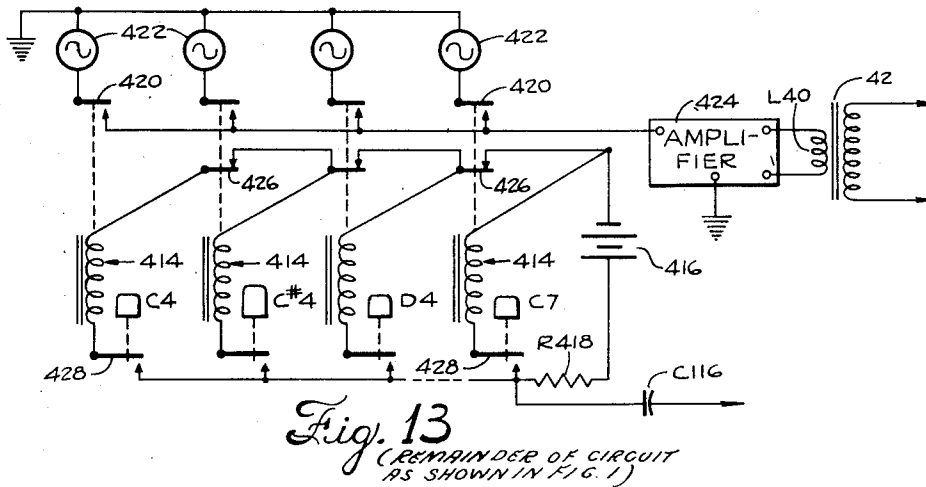
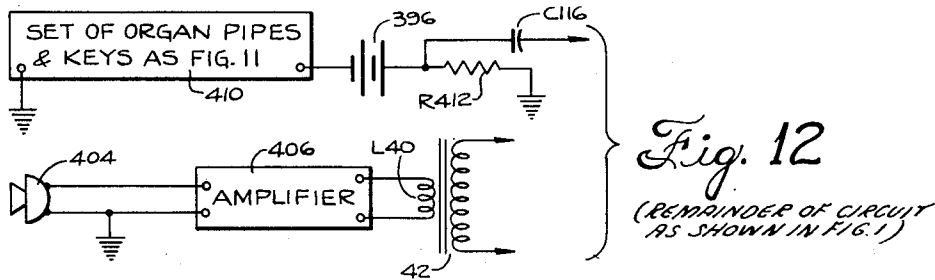
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5 Sheets-Sheet 5



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ELECTRICAL MUSICAL INSTRUMENTS

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Continuation of abandoned application Ser. No. 203,070, Dec. 28, 1950. This application Mar. 31, 1955, Ser. No. 498,163

16 Claims. (Cl. 84—1.26)

My invention relates generally to electrical musical instruments and more particularly to improvements in means for causing tones to be produced with percussive intensity envelopes, or otherwise accented, even though the keys are played in a legato manner.

In musical instruments, particularly but not restricted to those of the melody type, it is desirable to have under control of the player means to determine the character of the tone intensity envelopes, so that the melody note may be accented by causing it to be sounded with a percussive envelope, despite the fact that the player depresses the keys in a legato manner.

In instruments of the prior art this has been accomplished by providing intensity envelope control tubes in the output system of the instrument and determining the gain of these tubes by suitable resistance-capacitance networks rendered effective by the operation of the key switches. Such controls are disclosed in my prior Patent No. 2,254,284, and in the patent to Hammond et al. No. 2,233,258. With this latter type of control, tones with a percussive envelope can be produced, generally speaking, only by depressing the keys in non-legato manner and, the rendition of a selection which includes passages having a series of percussive notes to be played rapidly is very difficult, for the musician must operate the keys in a detached or non-legato manner with sufficient rapidity to produce the desired musical result.

In the instrument of the present invention, the keys may, when desired, be played in a legato manner and yet produce tones with percussive intensity envelopes.

In its broader aspects, the invention resides in the provision of means common to all of the keys and operated upon depression of any one of the keys automatically to produce an accent even though other keys are being held depressed at the time. Several embodiments of the invention are disclosed herein to show that the invention is not limited to a particular structure or circuit. In some embodiments the invention is illustrated as it may be applied to instruments such as the pipe organ, and in another embodiment, an instrument in which the accent is produced by a sound producing instrumentality other than a speaker.

More specifically, the invention resides in the provision of means common to all of the keys for production of tones with percussive intensity envelopes, or accent, even though the keys are played in a legato manner, thereby greatly facilitating the playing of rapid passages having series of notes which are to be sounded percussively.

A further object is to provide an electrical musical instrument having means to control the output thereof, whereby the tones may be produced in a percussive or non-percussive manner at the will of the player, without requiring a change in the manner in which the playing keys are operated.

Other objects will appear from the following descrip-

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tion, reference being had to the accompanying drawings in which:

Figure 1 is a schematic wiring and block diagram of an instrument incorporating the invention;

Figure 2 is a similar diagram of a modified form of the invention;

Figure 3 is a schematic wiring and block diagram showing a further modification;

Figure 4 is a schematic circuit diagram of the keying circuits;

Figure 5 shows a further variant of the switching circuits;

Figure 6 is a schematic circuit diagram showing the invention applied to a polyphonic musical instrument;

Figure 7 is a schematic representation of a form of the invention in which the keys operate the percussion envelope control switch pneumatically;

Figure 8 is a large scale sectional view of the pneumatically operated switch;

Figure 9 is a vertical sectional view through the manual showing the manner in which the keys develop pneumatic pressure;

Figure 10 is a schematic circuit diagram showing a variant of part of the instrument shown;

Figure 11 diagrammatically illustrates the invention as applied to a pipe organ;

Figure 12 diagrammatically illustrates a further modification of the invention as applied to a pipe organ;

Figure 13 is a circuit and block diagram illustrating further how the invention may be utilized in an instrument having an electrical generator for each note; and

Figure 14 is a schematic and block diagram showing a further modification of the invention.

Signal generating and control means

This application is a continuation of my copending application Serial No. 203,070, filed December 28, 1950, now abandoned, the latter being a continuation-in-part of my application Serial No. 91,325, filed May 4, 1949, now forfeited.

In Fig. 1 the invention is illustrated as embodied in an electrical musical instrument of the melody type, in which a plurality of playing keys such as the keys C4 to C7 are utilized to control the frequency of oscillation of a continuously operating master oscillator 10, which may be of any suitable type but is herein described as an oscillator having its frequency of oscillation determined by the resonant frequency of an inductance-capacitance circuit, namely an L—C oscillator. The oscillator 10 may have suitable tuning controls 12 associated therewith, whereby it may be tuned initially, and may also have a vibrato apparatus 14 associated therewith for introducing a vibrato effect, namely a frequency shift of approximately 3 percent at a periodicity of 6 or 7 cycles per second. In addition, the frequency of the oscillator 10 is controlled by the playing keys C4 to C7 each of which is adapted to close a switch 16 and thereby connect a series of one or more independent inductance coils L18 in parallel with the tuning capacitance of the resonant circuit of the oscillator which determines its frequency of oscillation. It will be noted, however, that the key C4, the lowest key, need not be provided with a switch 16 but instead, the coil associated therewith may be permanently connected to a grounded conductor 20.

Throughout this specification and in the claims the words "high" and "low" and their comparatives are intended to mean higher, or lower, in musical pitch, in the sense that a higher key or switch is used in playing a note of higher pitch. That is, the key or switch thus designated are nearer, or nearest, one end of the keyboard or manual than other keys mentioned in the context.

By operation of the various keys C4 to C7, and the

closure of their associated switches 16, the oscillator 10 is tuned to the pitch of the note represented by the key designation in the highest pitch range desired. Other lower octave ranges are obtained by connecting the output of the oscillator 10 to a plurality of cascaded frequency divider stages 22, the outputs of which may be provided with octave coupler switches and output wave shape controls, so as to provide a signal between a conductor 24 and ground which contains the desired tone signals, with respect to initial wave shape and octave coupler effects.

The conductor 24 is connected to the grid 26 of a preamplifier tube 28, the latter being self-biased by a resistor R30 and a capacitor C32 connecting the cathode 34 to ground. The grid 26 is connected to ground through a grid resistor R36. The plate 38 of the triode 28 is connected to a source of plate potential indicated as a terminal B+ through the primary winding L40 of a transformer 42. The secondary winding L44 of the transformer 42 has its end terminals connected respectively to the control grids 46G and 47G of push-pull remote cutoff control pentodes 46 and 47, while a center tap on the secondary L44 is connected to a switch 50 operable by a key or tablet 51. The cathodes 46C and 47C of pentodes 46 and 47 are connected together and to a common conductor 54 to which the heaters and suppressor grids of these pentodes may also be connected. The plates 46P and 47P of the pentodes 46 and 47 are respectively connected to the terminals of a primary winding L56 of a transformer 58, a center tap of which is connected to a source of plate current, indicated by a terminal B+. The screen grids 46S and 47S of the pentodes 46 and 47 are supplied with a suitable operating potential through a voltage divider comprising resistors R60 and R61, the opposite terminals of which are respectively connected to ground and the terminal B+, and the intermediate terminal of which is connected to the screen grids.

The secondary L62 of the transformer 58 is connected to tone controls 64, which are coupled to an amplifier 66 through a volume or expression control variable resistor R68. The amplifier is connected to a speaker 70. One terminal of the secondary winding L62 is connected to ground through a resistor R72 by which the output volume of the percussive note may be attenuated to equal those of the sustained notes.

The intensity envelopes of the tones are determined by the bias upon the control grids 46G and 47G of the remote cutoff tubes 46 and 47. When it is desired to play in the manner such that the tones are produced with a sustained envelope, the switch 50 is moved to its dotted line position, and a switch 74, mechanically coupled to switch 50, is closed to shunt the attenuation resistor R72 by connecting conductor 75 to ground. Under these circumstances, the depression of any of the keys C4 to C7, through closure of a switch 76, of which there is one operated by each of the keys, connects a conductor 78 to ground through the conductor 20. The conductor 78 is connected to the cathodes 46C and 47C of the control pentodes 46 and 47 through a mesh comprising resistors R79 and R80 in series, the junction between these resistors being connected to ground through a capacitor C82.

Conductor 54 normally has a biasing potential impressed thereon, sufficient to cut off the pentodes 46 and 47, by a voltage divider comprising a resistor R86 connected between a B+ terminal and conductor 54 and a resistor R88 connected between said conductor 54 and ground. These resistors are of relatively high value compared with the values of resistors R79 and R80 so that when conductor 78 is grounded by depression of any one of the playing keys, the potential on conductor 54, and hence on the cathodes 46C and 47C drops at a rapid rate determined by the relative values of C82, R79, R80, R86, and R88. When switch 50 is in its dotted line

position, the control grids 46G and 47G of the pentodes 46 and 47 are connected through the transformer winding L44 to a terminal 90, the potential of which is maintained at approximately 50 volts above ground potential by a mesh comprising R92, R93, and R94 connected in series between a B+ terminal and ground, and a resistor R96 connecting the junction 98 between R93 and R94 to the terminal 90. The junction point 98 is also connected to ground through a variable resistor R100 which controls the maximum volume. The junction point 90 may be connected to the conductor 54 through a capacitor C102 upon closure of a fast attack control switch 104.

Thus when the switches 50 and 74 are in their dotted line positions, depression of any key will first cause the closure of its switch 16 to tune the oscillator to the required frequency and thereafter close its switch 76 to connect conductor 78 to ground. Depending upon the values of the resistance and capacitance mesh associated with conductors 78 and 54 the potential on the cathodes 46C and 47C will decrease rapidly thereby rendering the tubes 46 and 47 conducting with prompt attack and causing the transmission of the signal from the transformer 42 through the output system of the instrument to the speaker 70 to be of a sustained organ-like character.

If it is desired to decrease the rate at which the intensity of the signals increases upon the depression of a playing key, the switch 104 may be closed which will result in decreasing the rate of change of the effective grid bias on control tubes 46 and 47, thereby to produce a slow tonal attack. This is accomplished generally in the manner more fully disclosed in the patent to Hammond and Hanert No. 2,233,252.

Percussion envelope control means

In addition to switches 16 and 76 each of the playing keys is provided with a switch 106 having one pole connected to ground. The other poles of the switches 106 are connected at the successive junctions or terminals of resistors R108 which are connected in series between a terminal 110 and the terminal of the switch 106 which is associated with the lowest key of the manual, namely the key C4. The terminal 110 is connected to a B+ terminal through resistor R112. The resistors R108, which are connected in series between the terminal 110 and ground upon the depression of a key, together with a resistor R112, form a voltage divider. It will be clear that, upon the closure of any switch 106, the potential at the terminal 110 will change suddenly. If after closing a switch such as the switch 106 associated with the key C4, a higher key is depressed, the closure of the switch 106 associated with the second or higher key will also produce a sudden change in potential at the terminal 110. The resistors R108 are of graded values so that legato playing of a given interval results in substantially equal voltage changes at the terminal 110 for all positions on the keyboard. Thus when playing up the scale in a legato manner the depression of each key will, due to the closure of its associated switch 106, cause a sudden change, in this instance, a decrease, in the voltage at the terminal 110, so that a series of negative pulses of substantially equal amplitude are transmitted through capacitor C116 connected to this terminal.

In a similar manner, if the keys are played in a legato manner progressing downwardly in the musical scale, as each successive key is released, the opening of its switch 106 will cause a sudden rise in the potential at the terminal 110 which will cause a positive pulse to be transmitted through the capacitor C116.

The capacitor C116 is connected to the grid 118G of a triode 118 through a resistor R120 and to the control grid 122G of a pentode 122 through a resistor R124. The control grids 118G and 122G of tubes 118 and 122 are connected to ground through a grid return resistor R126.

The cathode 118C of triode 118 is connected to ground through a biasing resistor R128 and its plate 118P is connected to a B+ terminal through a load resistor R130. Any signal appearing on a plate 118P of the triode 118 is transmitted through a blocking capacitor C132 so as to appear across a coupling resistor R131, and is transmitted through a series resistor R134 to the suppressor grid 136 of pentode 122. The cathode 122C of the pentode 122 is connected directly to ground while the screen grid 122S is connected to a suitable source of operating potential such as a +45 v. terminal of the power supply. The plate 122P of pentode 122 is connected to a B+ terminal through a load resistor R138 and the output signal of the pentode 122 is transmitted through a blocking capacitor C140 to the control grid 142G of a triode 142. The triode 142 has its grid 142G connected to a -18 v. terminal through a resistor R143, has its plate 142P connected to a B+ terminal through load resistor R147, and has its cathode 142C connected to ground through a mesh comprising capacitors C144, and C146, a resistor R145, and a variable resistor R148. Resistor R148 is connected by conductor 149 to one of the terminals of the switch 50, which when in full line position, is connected to the center tap of the secondary L44. Thus the potential on the conductor 149 in part determines the grid bias upon the control tubes 46 and 47. It will be understood that whenever a switch 106 is closed, a switch 76 will already have been closed, so that the conductor 78 is always connected to ground at the time that any of the switches 106 is operated to closed position.

With the switches 50 and 74 in their full line positions, depression of any of the playing keys will cause a negative pulse to appear at the terminal 110. Similarly, if, while one key is held depressed, a key higher in the scale is depressed, a negative pulse will also be produced at the terminal 110. On the other hand, upon releasing the higher of two or more depressed keys, a positive pulse will be produced at the terminal 110.

When a positive pulse is transmitted through the capacitor C116 the control grids 118G and 122G of triode 118 and pentode 122 will both go positive. In the case of the pentode 122 which is operated with zero grid bias (both the cathode and common grid resistor R126 connect to ground), the series grid resistor R124 prevents the plate current from increasing when applying the positive grid signal. This is because the input impedance of the tube 122 is very low in comparison with R124 when the grid 122G is positive with respect to the cathode 122C. Consequently, most all of the positive grid signal appears across the high valued series grid resistor R124 and the plate current of pentode 122 remains substantially unaffected by the application of positive signal pulses to its grid. However, when a positive pulse is transmitted through the capacitor C116, the grid of triode 118 will go positive and this tube, being negatively biased with R128, will amplify the pulse, causing the plate to go negative. This decrease in the potential on the plate 118P of triode 118 is transmitted to the suppressor grid 136 of pentode 122. As a result the plate 122P of this pentode goes positive and this positive signal is impressed upon the grid 142G of triode 142 to overcome the -18 volt cutoff bias and causing plate current flow which rapidly charges capacitor C144. This rapid increase in charge on the capacitor C144 causes the potential on the conductor 149 to increase at a rate determined in part by the attack controlling resistor R145 and capacitor C146. Such increase of the potential on this conductor 149, and hence on the control grids of the control pentodes 46 and 47, is in the nature of a triggering pulse and causes the latter to conduct the signal with a prompt but transientless attack.

As soon as the grid of triode 118 again goes negative, after the termination of a positive pulse of short duration (the length of which is determined mainly by the

value of C116) the voltage at the plate 118P of this tube returns positive, causing the suppressor grid 136 likewise to return to its normal ground potential, and the voltage across the load resistor R138 drops to allow the grid 142G to return to its negative value to cut off the flow of plate current in tube 142. However, due to the provision of capacitors C144 and C146, the potential on the conductor 149 decreases only gradually, and the rate at which it decreases may be adjusted by means of the variable decay resistor R148, because the latter is in parallel with capacitor C146 and substantially in parallel with capacitor C144. Thus the intensity envelope of a signal transmitted through the control tubes 46 and 47 will be one typical of a percussive tone such as the envelope of a tone produced by a piano, banjo, or chime.

If, on the other hand, the pulse produced at the terminal 110 is negative (as, will be caused, for instance, by depressing higher pitched keys while holding a lower pitched key depressed), both control grids 118G and 122G will go negative. The plate 118P of triode 118 will go positive. This positive pulse is transmitted through C132 and the series suppressor grid resistor R134. Resistor R134 functions in a manner similar to R124 and prevents the flow of suppressor current as well as preventing appreciable change in the plate current of pentode 122 due to positive signals being applied to its suppressor grid 136. However, when the negative signal pulse is applied to the control grid of pentode 122, the input grid impedance rises to an extremely high value and substantially all of the negative pulse appears at the grid 122G which results in the plate 122P going positive. As before, this positive signal is impressed upon the grid 142G of triode 142 to overcome the -18 volt cutoff bias, and to cause plate current flow which rapidly charges capacitors C144 and C146. As explained above, a percussive envelope ensues, the rate of decay of which may be adjusted by means of the resistor R148. Thus, it is seen that both positive and negative pulses produced at the terminal 110 have substantially the same effect of rapidly charging capacitors C144 and C146 which, in turn, results in imparting a percussive envelope to the tone signals transmitted by control tubes 46 and 47.

In playing the instrument, during the rendition of smooth melodic passages, the switches 50 and 74 are preferably in their dotted line positions and when in these positions the effective envelope controlling circuit is comparable to those of the prior art, as exemplified by the aforesaid patents. However, when the musical selection is such that a series of percussive piano-like notes are to be rendered, the switches 50 and 74 are moved to their full line positions, and under these circumstances the keys may, for ease in playing, be depressed in a legato manner. Under these circumstances, the depression of a key higher than any key then depressed will cause the sounding of the note controlled by that key with a sharp percussive intensity envelope, that is, one with fast attack and rapid decay. It will be understood that the highest of any of the depressed keys C4 to C7 will determine the frequency of oscillation of the oscillator 10 and thus whenever a key higher than those which have previously been depressed is operated, the oscillator will immediately be tuned to the new frequency and the percussion intensity envelope controlling means will operate to cause the sounding of the new note with the percussive envelope.

On the other hand, the percussive envelope determining means will also be operated upon release of the highest of several simultaneously depressed keys. Thus, the new note will sound only after the previously depressed key has been released. In playing in the downward direction in a legato manner, depression of the lower key, while holding the upper one depressed, will not change the tuning of the oscillator nor will it effect the operation of a percussive control apparatus because the potential on the terminal 110 will not change nor will there be a change in the number of inductances L18 effective in the

tuning circuit of the oscillator 10. But upon release of the highest of several depressed keys, the oscillator will be tuned to the frequency represented by the highest of the remaining depressed keys, and at the same time a positive pulse will be transmitted across the capacitor C116 and, in the manner previously described, cause the control tubes to transmit the signal to the output system and speaker with a percussive intensity envelope.

When any playing key is released while not holding down any other playing key, it is to be noted that a positive pulse is generated thereby at the terminal 110. This positive pulse charges capacitors C144 and C146 as explained heretofore. The percussion envelope in the signal is not heard however, because the conductor 78 has been disconnected from ground by opening switch 76 prior to opening the switch 106. Disconnection of conductor 78 from ground results in the potential on the cathodes of tubes 46 and 47 rising rapidly thus cutting off their plate currents and preventing the signal from being transmitted to the amplifiers 66 and speaker 70. The subsequent charging of capacitors C144 and C146 to a positive potential is of a magnitude insufficient to overcome the high cutoff bias effective on the control grids 46G and 47G of tubes 46 and 47 due to their increased cathode potentials, and thus the charging of capacitors C144 and C146 has no audible effect.

Exemplary values of the number of components of the circuit will be given, although it will be understood that in many respects these values are not critical and may be varied considerably without affecting the manner of operation of the instrument. Changes in values of most of the components may be made, especially if compensatory changes are made in the values of other circuit elements. The values, in ohms, in thousands of ohms (K), megohms (M), and microfarads, may be as follows:

R78	-----	.5K
R80	-----	.85K
C82	-----	.1
R86	-----	5K
R88	-----	6K
R92	-----	.13M
R93	-----	.18M
R94	-----	.13M
R96	-----	.68K
R100	-----	130K
R112	-----	100K
C116	-----	.102
R120	-----	2M
R124	-----	2M
R126	-----	1M
R128	-----	2K
C132	-----	.02
R134	-----	2M
R138	-----	250K
C140	-----	.02
R141	-----	1M
R143	-----	50K
C144	-----	.25
R145	-----	50K
C146	-----	.25
R148	-----	5M

The values of resistors R108 may range from 2.8K to 600K, the resistors nearer the lower end of the keyboard having progressively greater values than those nearer the upper end of the keyboard.

In the particular embodiment disclosed in Fig. 1 the pitch of the oscillator is determined by the highest of several depressed keys, but it will be understood that the oscillator and its key controlled pitch determining circuits might be of the type in which the lowest of several depressed keys determines the pitch. In the latter type, as shown in Fig. 10 the terminal 110, resistor R112 and the B+ terminal would be located at the lower end of the series of resistors R108. The oscillator would then

preferably be of the L-C type in which the semitone tuning of the oscillator is effected by connecting capacitors C113 in series in the tuning circuit under the control of the playing keys. Such oscillator and tuning means are disclosed in my prior Patent No. 2,254,284. It is intended that the claims be construed to include this reciprocal arrangement.

Modification employing multiple generators shown in Figure 2

The invention may be used in an instrument which includes a polyphonic generating system employing a generator for each semitone or for a few adjacent semitones, in which case the key operated switches are effective not only to transmit the signal from the desired generator to the output system but also cut off all other generators nearer either end of the keyboard, and thus, in effect, to provide a monophonic instrument from a polyphonic generating system. Such modification is shown in Fig. 2 as comprising a plurality of generators 160, of which three are illustrated as typical, and which are adapted to be selectively connected to the output system 162 by operation of keys C4 to C7. Each of these keys operates three switches 76, 164 and 166. The switches 164 are single-pole double-throw switches arranged so that the highest of a plurality of simultaneously depressed keys will be effective in causing the signal provided by the generator 160 associated with said key to be transmitted to the output system. The switches 166 correspond to the switches 106 in the previously described embodiment of the invention and are adapted to connect the terminals between series connected resistors R108 to ground, in the same manner as previously described, and thereby to control the tone intensity envelope of the signals produced by the generators 160.

The generators 160 may be phonic wheel electromagnetic generators, photoelectric signal generators, individual vacuum tube oscillators, phonographic or other recordings, or any other suitable type of electrical tone signal sources of different pitch. The switches 76 of Fig. 2 function in the same manner as the correspondingly numbered switches in the embodiment of Fig. 1, but, if desired, they may be omitted together with their associated circuits in the output system 162.

Combined monophonic and polyphonic instrument shown in Figure 3

The invention as shown in Fig. 3 is in a simplified and preferred form, as compared with that of Fig. 1. However, because it has many features of similarity some of the reference characters used in Fig. 1 have been applied to the corresponding parts shown in Fig. 3, and a further description thereof is therefore unnecessary.

In Fig. 3, the preamplifier tube (corresponding to the triode 28 of Fig. 1) is not shown in detail, it being assumed that the preamplifier is enclosed in the block 170 which, in addition to representing the preamplifier, is intended to include the frequency dividers, octave couplers, and output wave shape controls. For the sake of simplicity, but four keys C3, C#3, B5, and C6 are shown, these keys operating switches 16, 76, and 106 in the manner previously described, that is, switches 16 and 106 closing before switch 76 on the downstroke and opening after switch 76 on the upstroke. The closure of any switch 106 higher than any other switch 106 which is closed, or the opening of the switch 106 associated with the highest key of a number which may be depressed, produces a pulse in the same manner previously described with respect to Fig. 1, but it will be noted that instead of connecting resistor R112 directly to the B+ terminal it is shown in Fig. 3 as being capable of being connected to a +280 v. terminal by a conductor 171, a switch 172, and a resistor R174. One pole of switch 172 is connected to ground through a capacitor C176. Conduc-

tor 171 is also utilized to supply plate current for pentode 122 through plate load resistor R138. Thus, whenever the switch 172 is open, as it is when it is not desired to utilize the percussive effect, the pentode 122 does not draw plate current nor are the switches 106 subjected to useless wear by sparking, because when switch 172 is open there is no voltage applied across the series of resistor R108.

The circuit for supplying plate current to the triode 142 includes a relay 178, one terminal of which is connected to the plate 142P and the other terminal of which is adapted to be connected to a plate voltage source, indicated as a terminal +280 v., upon closure of a switch 180 which may be mechanically connected with switch 194 to open and close therewith.

The switch 172 is operated by a suitable stop tablet 192 which also operates a switch 194. One pole of switch 194 is connected by a conductor 196 to the center tap on the secondary L44 of transformer 42. The other pole of switch 194 is connected by a conductor 198 to a +19 v. terminal whenever relay 178 is energized. Conductor 198 is also connected by resistors R200 and R201 to a -18 v. terminal, resistor R201 being adapted to be shunted out of this circuit upon closure of a switch 202. This switch is closed whenever a very fast decay of the percussive tone signals is desired.

Upon energization, the relay 178 is effective to connect capacitor C226 to a source of voltage indicated as +19 v. Actually, this source is derived from a power supply which has sufficient internal resistance to suppress the spark incident to the closure of the relay contacts. However, this internal impedance is sufficiently small so that any residual charge on capacitor C226 due to a previously played note is irrelevant in determining the potential to which the capacitor C226 rises upon closure of the relay contacts. In other words, there is no "building up" of potential upon this capacitor due to playing rapidly occurring notes in the music. This of course, is desirable as the intensity of a percussion note should in no way be related to the intensity of a preceding percussion note at the time that the following note was played.

In the embodiment shown in Fig. 1 the function of the relay 178 is performed by the electronic relay 142 in that the capacitor C144 is charged to a suitable positive potential when a key is depressed. The potential is determined by the duration of the percussion pulse, the plate load resistor R147, and the internal plate to cathode resistance of the triode 142. These resistances are sufficiently small so that capacitor C144 is rapidly charged and while its charging is not as instantaneous as that accomplished by the contacts of the relay 178 shown in Fig. 3, it, nevertheless, is sufficient for most musical purposes.

When the switch 194 is in its full line position, as when sustained organ type tones are desired, it connects conductor 196, and hence the center tap of the secondary L44, to a terminal 204. This terminal is connected to ground through resistor R206. A capacitor C208 and resistor R210 are connected between terminal 204 and a terminal 212, the latter being connected to ground through a capacitor C214 and connected to the cathodes of control pentodes 216 and 217 through a resistor R218. Conductor 78 is connected to terminal 212 through a resistor R220 and is connected to a voltage divider comprising resistors R222 and R224 which are connected in series between a +270 v. terminal and ground. A capacitor C226 is connected between the center tap of secondary winding L44 and ground.

In addition to controlling the operation of the melody instrument, the keys operate switches 227 by which signal sources 229 are connected to a conductor 231 and are thus transmitted to an amplifier and volume control 233, and translated into sound by speaker 235.

When the percussive effect is desired, the tablet 192 is operated to move switches 194 and 172 to their dotted line positions. Under these circumstances the series of resistors R108 is connected to the +280 v. terminal source through R112 and the pentode 122 is supplied with plate current so that this portion of the circuit is effective to produce a pulse to energize relay 178 whenever a key higher than any depressed key is depressed, or whenever the highest of a plurality of depressed keys is released. The relay 178 is energized for but an instant, and the potential of +19 volts is impressed directly on the grids of the pentodes 216, 217 and also charges capacitor C226. Since the potential of the cathodes is at this time fairly low (because one of the switches 17 has previously been closed to connect the conductor 78 to ground) the pentodes 216 and 217 commence to transmit the signal at a very high amplitude. Since the closure of the switch of relay 178 is of exceedingly short duration, the high intensity signal is likewise of extremely short duration but the decay from its highest intensity is made gradual, but nevertheless very rapid, as the capacitor C226 discharges mainly through the flow of grid current in the pentodes 216 and 217, and thereafter mainly through resistors R200 and R201.

If it is desired that the decay be extremely rapid, the switch 202 may be closed thus permitting the capacitor C226 to drop more rapidly to the -18 v. potential.

It will be recalled that switches 16 and 106 close before switch 17 is closed on the downstroke and that switch 17 opens before switches 16 and 106 open on the upstroke. Therefore, if but one key is depressed and released, the pentodes 216 and 217 will be biased beyond cutoff by making their cathodes highly positive before the positive pulse resultant from the opening of the switch 106 is impressed upon their control grids, and that such positive pulse will thus have no effect.

However, if only the higher of several depressed keys is released (that is, at least one key remains depressed) the potential on the cathodes of the pentodes 216 and 217 will be maintained at a relatively low value because of the fact that one of the switches 17 associated with a key still held depressed is still closed.

If a fast attack, but no percussive tone intensity envelope, is desired the switch 211 is opened whereupon the drop in voltage at the terminal 212 (due to the closing of a switch 76) is not transmitted to the control grids (because R210 is of very high value) thereby increasing the rate of attack.

The instrument shown in Fig. 3 is played in substantially the same manner as that shown in Fig. 1 and the musical results attainable are likewise comparable, with the important exception that the sustained tone signals supplied by the generators 229 are produced when chords are played as well as when a single key is depressed. This result greatly improves the possible musical output of the instrument as compared with the musical results attainable by the instrument shown in Fig. 1. For example, the player may hold a two, three, or four note chord, and with the remaining finger of one hand (usually the little finger) produce alternating percussion tones merely by operating a key with the fifth finger. For example, the player may with three fingers hold a chord such as C, E, G and with the little finger play the octave note C intermittently whereupon the chord C, E, G, will sound continuously but when the octave higher C key is depressed that note will sound with percussion and upon release of the high C key the note G, in addition to being sounded as a component of the sustained chord, will be sounded as a percussion tone. Thus, it is possible with the player's right hand only to produce both a percussion melody leading voice as well as a smooth legato accompanying chord.

It will be understood that in this embodiment of the invention, as well as in most of the others disclosed herein, the melody section of the instrument, especially if

used in the bass register, may be arranged to select the lowest of a number of keys depressed at the same time as the control for the percussion circuits, as in the manner illustrated in Fig. 10.

Modification shown in Figure 4

In Fig. 4 there is shown a simplified key operated switch circuit by which substantially the results of the previously described keying circuits may be obtained. Again, parts and circuits corresponding to those previously described have been given corresponding reference characters and their description will not be repeated. Each of the keys, in addition to operating the tuning switch 16 and the control tube keying switch 76, operates a wipe switch 230 during the course of its downward movement, this switch making a contact of short duration after the associated switch 16 has been closed but slightly before the associated switch 76 has been closed. One pole of each of the switches 230 is connected to a conductor 232 which is maintained at a positive potential by connection to a terminal +19 v. All except the lowermost of the playing keys, in addition to operating switches 16, 76, and 230, also opens a switch 234. It will be noted that one pole of each of the switches 230 and 234 are connected together and to the opposite pole of the switch 234 of the next higher key in the scale, and that the highest of the switches 230 and 234 are connected to a conductor 236. Conductor 236 is coupled to conductor 149 (which corresponds to the conductor 236 shown in Fig. 1) through a mesh comprising capacitor C144 and C146 and resistors R145 and R148 previously described. Upon depression and release of a key its switch 234 opens before and closes after the switches 16, 17, and 230.

As an alternative the conductor 236 could be connected to the conductor 198 of Fig. 3 to provide the pulse for the percussive effect.

Due to the series connection of the switches 234, and the fact that each of the switches 234 is also in series with the switch 230 of the next lower key, it will be clear that a pulse of 19 volts will be impressed upon conductor 236 every time a single key is depressed and every time that a key higher than one or more depressed keys is operated. It will also be clear that, while holding one key depressed, operation of any lower key cannot result in the production of a pulse on the conductor 236. The switch 76 opens before the switch 230 makes a contact upon the upstroke of the key, so that if only one key is depressed and released the pulse produced on the conductor 236, during the return stroke of the key, will not produce the percussion effect because at this time the control pentodes are cut off by the increase in the potential on their cathodes due to the opening of switch 76.

An instrument such as shown in Fig. 1 or in Fig. 3, but having the solo key switching means of Fig. 4, is played in the same manner as the previously described instruments with comparable musical results.

Modification shown in Figure 5

A further modification of the invention is shown in Fig. 5 wherein each key, in addition to operating switches 16 and 76, operates a single-pole double-throw switch 240 and each key, except the lowermost key, operates a fourth switch 242. One fixed pole of each of the switches 240 is connected to a +19 v. terminal while the moving contactor of each of these switches is connected to a grounded capacitor C244. The other fixed pole of each of the switches 240 is connected to one of the poles of the switch 142 next higher in the scale and the switches 242 are connected in series. The highest switch 242 is connected to a conductor 250 which is connected to conductor 149 of Fig. 1 or to conductor 198 of Fig. 3, through the resistor R145. The capacitor C146 and the

adjustable resistor R148 connect the conductor 149 to ground as in Fig. 1.

From the foregoing it will appear that the capacitors C244 are normally charged to a +19 v. potential because the switches are normally in the positions shown in full lines in Fig. 5. Whenever a key is depressed the charge on the associated capacitor C244 is transferred to the conductor 250 and hence is impressed upon the grids of the control pentodes to render them rapidly conductive so that the tone will have a percussive intensity envelope. Because of the series connections of the switches 242 it will be noted that depression of a higher key than that previously depressed will cause transference of a charge from its capacitor C244 to the conductor 250, and that when the highest of several depressed keys is released, as when playing down the scale in a legato manner, the charge from the capacitor C244 associated with the lower key will be transmitted to the conductor 250 through closure of the switch 242 associated with the higher key. It will be clear that in other respects the switching and circuit arrangement of Fig. 5, when used in conjunction with the remaining circuits either of Fig. 1 or Fig. 3, will operate to produce the same results as are obtainable by the use of the previously described embodiments.

Modification having mechanical percussion tone producing means (Fig. 6)

A further modification of the invention is shown in Fig. 6 wherein it is applied to a polyphonic musical instrument as distinguished from the previous applications to instruments of the solo or melody type. In Fig. 6 each of the keys, upon depression, closes two switches 260 and 262 in the order named. Switch 260 is effective to connect a musical tone signal generator 264 to a matching transformer 266 through a decoupling resistor R268. The signal is thus transmitted to the control grids of triodes 270 and 271. The center tap of the secondary of transformer 266 is connected to a terminal -50 v. through a resistor R272 so that these triodes are normally biased beyond cutoff because their cathodes are connected to ground through a common self-bias resistor R274. The center tap of the transformer secondary winding is also connected to ground through a capacitor C276 which corresponds generally to the capacitor C226 in the previously described embodiment shown in Fig. 3. The plates of triodes 270 and 271 are connected in push-pull to the primary of a transformer 280 the center tap of which is connected to a +B source of voltage. The secondary winding of transformer 280 is connected to a speaker 284 through an additional amplifier 285 provided with the usual controls.

Each of the switches 262 has one pole connected to a conductor 290 which is connected to a B+ terminal of the power supply while the other terminal of each of these switches is connected through a resistor R292 to a conductor 294. The conductor 294 is connected to ground through a resistor R296 which is of high value relative to that of each of the resistors R292. Conductor 294 is connected to the grid of a triode 298 through a blocking capacitor C300. The triode 298 is normally biased beyond cutoff by connection to a -30 v. terminal through a grid resistor R302. Plate current for the triode 298 may be supplied either through a relay coil 304 upon closure of a switch 306 or may be supplied through the winding of the solenoid 308 upon closure of a switch 310, through switches 306 and 310 each having one pole connected to a B+ terminal. One contact of the switch 312, which is part of the relay 304, is connected to ground while the other pole thereof is connected to the center tap of the secondary of transformer 266.

With switch 306 closed, when any of the keys is depressed the closure of its associated switch 260 results in impressing a tone signal across the primary of transformer 266. In addition, a positive pulse is transmitted

through capacitor C300. The time constant of the mesh comprising capacitor C300 and resistor R302 is very short so that the triode 293 conducts but momentarily and the relay switch 312 is likewise closed briefly, placing the grids of the control triodes 270, 271 at ground potential. Thus the triodes 270, 271 are rendered conductive of the signal at high amplitude to produce a percussive attack. The charge on capacitor C276 is removed and therefore the pentodes 270, 271 will continue to conduct the signal at decreasing amplitude as the capacitor C276 is recharged from the negative bias terminal -50 v. through resistor R272. Therefore, the operation of any one of the keys, irrespective of whether other keys are depressed at that time, will cause the tone to sound with a percussive envelope.

If desired, a switch 316 may be provided which, when closed, maintains the grids of the triodes 270 and 271 at ground potential. Under these conditions the tones will sound in a customary sustained manner at a sustained intensity determined by the usual volume control. Also, whenever desired, the switch 310 may be closed to cause operation of the solenoid 308, the plunger of which may be connected to the hammer of any percussive instrument, such as the musical steel triangle 318, which is suitably suspended above a hammer 320 connected to be operated by the plunger of the solenoid.

The time constant of C300 and R302 is made very short in order to resolve the pulses due to opening one of the contacts 262 and closing of another of these contacts when playing from one key to another in a legato manner. Theoretically, the positive and negative pulses generated thereby might cancel each other to produce no transient if the closing and opening of these switches occurred at exactly the same instant of time. By the use of a very short time constant, and also due to the momentary unavoidable wiping effects of the contacts, a usable pulse is usually obtained.

It is to be noted that whenever a playing key is released, a negative pulse will be generated, but this pulse will have no effect upon triode 298 because its grid is already maintained at plate current cutoff. Thus the percussive effect is obtained only by the depression of a playing key. This effect, however, will be obtained even though other keys are being held depressed. Thus the musician can obtain a series of percussive tones even though he employs a legato playing technique.

In playing the instrument of the kind shown in Fig. 6 the musician has means available for producing a variety of musical effects by operating the switches 306, 310, and 316 in various combinations. For example, assuming those of these three switches not mentioned as closed, are open, the following effects may be obtained:

(1) With switch 316 closed the instrument is played, and will perform in the manner of a customary organ;

(2) With switches 310 and 316 closed the instrument will produce the customary organ tones accompanied by the percussive mechanical instrument tone of the steel triangle or the like;

(3) With switches 306 and 316 closed the instrument will perform as in customary organ because the center tap on the secondary transformer being already connected to ground by the switch 316, closure of the relay switch 312 will not change the performance;

(4) With all three switches closed the instrument will perform as in (2) above, the customary organ tones and the mechanical percussive tones will be produced;

(5) If all three switches are open no sound will be produced upon playing the keys because the control tubes 270, 271 are biased beyond cutoff by their connection to the -50 v. terminal of the power supply;

(6) If only switch 310 is closed only the mechanical percussive tone from the steel triangle 318 will be sounded;

(7) If only the switch 306 is closed the tone produced will be a percussive tone of organ quality;

(8) If the switches 306 and 310 are closed the organ percussive tone will be sounded together with the percussive tone from the steel triangle.

The musician thus has available the ability to employ these various effects in the rendition of a selection so as to add variety and interest to the music.

The modification shown in Figs. 7, 8, and 9

The means for producing a short positive pulse on the grids of the control tubes may be partly pneumatic, as illustrated in Figs. 7, 8, and 9. In Fig. 7 the keys operate switches 16 and 76 in the manner and for the purposes previously described. Arranged below the row of keys C3 to C6 is a flexible elastic tube 340. The left-hand end of the tube 340 is plugged while the right-hand end of this tube is connected to a casing 342 which has a thin walled expansible bellows 344 sealed around an opening 346 in its top. The bellows 342 is preferably resilient so as to be self supporting in an intermediate position. A bell crank 348 is pivoted on a bracket 350 which is secured to the casing 342. One arm of the bell crank has a pin and slot connection with a lug 352 secured to the top of the bellows 344 and the other arm thereof is connected to the center blade 354 of a single-pole double-throw switch which is suitably secured to and insulated from the bracket 350. The center blade 354 is connected to a conductor 149 corresponding to the conductor 149 of Fig. 1, or corresponding to the conductor 198 of Fig. 3. The outer blades 356 and 357 of the switch are connected to a positive potential source such as a +19 v. terminal. The interior of the casing 342 is vented to atmosphere through a port 358, the effective size of which may be adjusted by means of a needle valve 360.

Whenever any of the keys C3 to C6 is depressed the air within the tube 340 is compressed slightly so as to cause the bellows 344 to expand, causing the switch blade 354 to contact the switch blade 356. This contact is of short duration because the air will rapidly bleed through the port 358 and the bellows will then rapidly return to its intermediate position. If one key, such as the C#3 key shown in Fig. 7, is held depressed, no pressure changes will result from the depression of any lower keys because the key C#3 fully collapses the tube 340 and causes it to disconnect the portion of the tube to the right of the depressed key from that to the left thereof. The tube 340 has sufficient elasticity that several keys to the left of a fully depressed key may be depressed without applying undue pressure and without danger of rupturing the tube. Whenever a key higher than a depressed key is operated the bellows will again expand temporarily and close the switch 354, 356. Also upon release of a higher depressed key a slight vacuum will be formed within the bellows 344 and the bellows will contract, swinging the bell crank 346 counterclockwise and closing the switch 354, 357 and again producing a pulse thereby causing the highest of the remaining depressed keys to sound its note with a percussive envelope. When a single key is depressed and released the switch 354, 356 will close on the down stroke and the switch 354, 357 will close on the up stroke of the key but the completion of the circuit on the up stroke will not have any effect because at the time this occurs the switch 76 associated with the key will have been opened to render the control pentodes 46, 47 (Fig. 1), or 216, 217 (Fig. 3), incapable of transmitting the signal.

It will be clear that the pneumatic means for operating the switch to change the bias on the control tubes is the equivalent of the switches and electronic circuits employed for this purpose in the previously described embodiments.

The invention applied to a pipe organ shown in Figure 11

Fig. 11 shows how the invention may be applied to cause percussive effects to be added to the music of a pipe organ. A portion of a wind chest 380 is illustrated

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as including a top board 382 appertured to receive the reduced diameter lower ends of pipes 384, 385, and 386 which, for purposes of this description, may be assumed to produce tones at the pitches of C4, C#4, and C7 respectively. The valves 388 for controlling the speaking of the pipes are shown as to be opened by energization of electromagnets 390 of well-known construction. Keys C4, C#4, and C7 operate switches 394 which are connected in series to one terminal of a source of power illustrated as a battery 396. The lower stationary contacts of the switches 394 are connected by conductors 398, 399, and 400 to the electromagnets for the pipes 384, 385, and 386 respectively. Due to the series arrangement of the switches 394, when several of the keys are depressed at the same time the electromagnet for the highest of the depressed keys will be the only one which will be energized. However when such high note selection is not desired but, instead, the organ is to be played in the normal manner, a control knob 402 is operated to close switches 404. It will be clear that closure of these switches effectively connects the switches 394 in parallel.

Associated with the pipe organ, either in the pipe loft or in a position close thereto, there is a microphone 404 the output of which is supplied to an amplifier 406. The output of the amplifier 406 is supplied to the input of a transformer 42 which corresponds to the similar numbered transformer shown in Fig. 1. The remainder of the output system is likewise the same as that shown in Fig. 1 except for the manner in which the signal is supplied for causing the percussion or accent to take place. In the instrument of Fig. 11 the output of the amplifier 406 is also supplied to a signal rectifier and filter 408, which may also include amplification means and which operates to produce a pulse each time the pitch of the tone signal at the output amplifier changes materially. The filter should preferably be of a type which is highly responsive to frequency changes but should not be so finely tuned as to be affected by the minor frequency modulation present when the vibrato is employed. An exemplary filter suitable for this use is shown in Fig. 14 and will hereinafter be described.

The output of the rectifier and filter 408 (such as are well-known in the art and as shown, for example, in the circuit for operating relays 72, 74, etc., in my prior Patent No. 2,514,490—Fig. 1) is connected between ground and a capacitor C116 which is connected in the same manner as shown in Fig. 1 to the percussion controlling circuits by which the envelope of the tone supplied is caused to be of a percussive nature, all as shown and described with reference to Fig. 1.

As an alternative the output of the rectifier and filter 408 may be used to operate the mechanical percussion instrumentality such as the musical triangle above described with reference to Fig. 6. The knob 402 may for convenience also operate switches 50 and 74 (Fig. 1), moving the latter to their dotted line positions whenever switches 404 are closed by operation of the knob. The instrument of Fig. 11 is played in the same manner as the previously described embodiments of the invention, and it will be clear that with the switches 404 open, and the switches 50 and 74 in their dotted line positions (Fig. 1), the playing of the keys in a legato manner going up the scale will cause the percussion or accent means to operate upon playing each successive note so that the musician may play rapidly up the scale without the necessity of having to depress the keys in a detached manner. Likewise, as in the previously described embodiments of the invention, whenever the highest of several depressed keys is released the tone of the next lower of the originally depressed keys will cause its associated pipe to speak and at the same time the signal rectifier and filter 408 will supply a pulse to cause the percussion section of the instrument to be sounded with an accent. If amplification of the tones of the pipes is not required the out-

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put of the amplifier 406 need not, of course, be supplied to the transformer 42, but instead, need be supplied only to the signal rectifier and filter 408.

The modification shown in Figure 12

The pulse required for the initiation of the percussion or accent effect may be obtained in the manner indicated in Fig. 12 in which a set of organ pipes, keys, and switches as shown in Fig. 11 are represented by a block 410. In this form of the invention a resistor R412 is connected between ground and the terminal of the battery 396 which in Fig. 11 is shown as connected directly to ground. This resistor is of sufficient value that when one of the switches such as 394 (Fig. 11) is closed, assuming no higher key is then depressed, there will be a voltage drop across the resistor R412 resulting in a pulse being transmitted to the capacitor C116 (as in Fig. 1) which is connected to the junction between the resistor R412 and battery 396. If amplification of the tones produced by the pipes is not desired, the microphone 404, amplifier 406, and the remainder of the output system need not be provided. It will be clear that the instrument diagrammatically shown in Fig. 12 would be played in the same manner as that shown in Fig. 11 is played and that the musical results will likewise be the same.

The modification shown in Figure 13

Fig. 13 diagrammatically illustrates a further modification of the invention in which relays 414 are energized from a battery 416 each through a circuit including a common resistor R418. Each of the relays 414 when energized closes its contactor 420 to connect the ungrounded terminal of its associated electrical tone signal generator 422 to an amplifier 424 which is connected to the output system such as shown in Fig. 1 through the output transformer 42. In addition, each of the relays 414, except that for the lowermost key of the manual, also operates to open a contactor 426. The contactors 426 are connected in series and, in addition, the moving part is connected to the coil of the relays 414 for the next lower semitone. Thus energization of the relay 414 for the highest notes prevents energization of all relays associated with lower keys. It will be noted that the fixed contact 426 for the highest key is connected to the battery 416 as is the coil of relay 414 for the highest key.

Each time a key higher than any others depressed at that time is operated to close its switches 428 a sudden voltage drop will occur across resistor R418, with the result that a pulse will be supplied to capacitor C116 to the percussion or accent control portion of the instrument in the same manner as shown in Fig. 1. As in most of the other embodiments of the invention, depression or release of the highest key of a group depressed at one time will render effective the percussion accent instrumentalities.

The modification shown in Figure 14

Portions of the instrument shown in Fig. 14, are similar to those shown in Fig. 1 in that it is of a melody type, and it is similar to the embodiments shown in Fig. 11 with respect to the manner in which the initiation of the accent or percussion means is controlled by the tone signal output of the generator, that is, it is responsive to changes in frequency.

In this figure a block 430 is intended to represent an L-C oscillator and associated frequency controls including the keyboard and oscillator tuning means. This oscillator etc., as in Fig. 1, has its output coupled to frequency dividers, octave couplers, octave wave shape controls, and a preamplifier collectively numbered 170, as in Fig. 1. The output of the amplifier included in the block 170 is transmitted to the output system in the same manner as in Fig. 1. However, the output of the oscillator is supplied through a capacitor C432 and a resistor

R434 to the control grid of a rectifier triode 436. This grid is also connected to ground through a grid resistor R438. The plate of the triode 436 is connected to ground through a high frequency filtering capacitor C440, and is connected to a source of plate current, indicated as terminal B+, through a load resistor R442. The rectified output of the triode 436 is supplied through a blocking capacitor C444 to a filter comprising a plurality of series connected resistors R446 and shunt-connected capacitors C448. The filter mesh has a terminating impedance in the form of resistor R450. The voltage across this resistor is supplied to an amplifier 454, which will result in transmission of a pulse to capacitor C116. This capacitor, as in the embodiments shown in Fig. 1, controls the initiation of the operation of the accent or percussion instrumentalities of the instrument. The remainder of the output system may be identical with that shown and described with reference to Fig. 1 or that of Fig. 6.

The invention in general

From the foregoing it will appear that the basic or underlying concept of the invention may be embodied in a large number of different forms, that the control of the sounding of the tone may be accomplished through a variety of electrical and mechanical means which are responsive either to the depression and the release of the keys or to changes in voltage or frequency in circuits directly or indirectly controlled by the depression of the keys, or by the depression and release of the keys. For example, in the circuit shown in my prior Patent 2,254,284 a direct current voltage divider is utilized to provide different bias on various oscillators. Pulses appear in this divider circuit whenever there is a change in the master oscillator frequency so that this pulse, or the change of frequency in the master oscillator, may be used as means for controlling the operation of a triode such as the triode 142 in Figs. 1 and 3. In this way the number of switches operated by the keys may be reduced. I therefore desire, by the following claims, to include within the scope of my invention all such similar and modified forms of the circuits and apparatus disclosed herein, by which substantially the results of the invention may be obtained, using substantially the same or equivalent means.

I claim:

1. For use in an electrical musical instrument having an output system including a control terminal the potential of which determines the intensity of the signal transmitted through the output system, the instrument having a keyboard comprising a plurality of playing keys, the combination of a plurality of switches respectively operable by the playing keys, each of said switches having a grounded pole, a source of direct current potential having a grounded terminal, a plurality of impedances, a number of which are connectable in series between ground and the ungrounded terminal of said source by the closing of one of said switches, connections, respectively between junctions of the series of impedances and the ungrounded poles of said switches, a coupling to the series of impedances operable to transmit an electrical pulse whenever the aggregate effective impedance of the series of impedances is changed by the operation of the key switches, a resistance-capacitance circuit including said control terminal for determining the potential on the latter, and means responsive to the pulses transmitted by said coupling rapidly to apply an operating potential to said resistance-capacitance circuit and thereby rapidly change the potential on said control terminal to cause transmission of the signal through the output system with a percussive intensity envelope.

2. In an electronic musical instrument having a tone signal generating means, an output system, and a keyboard having a plurality of playing keys operative to connect said tone signal generating means to said out-

put system, the combination therewith of a pulse producing means operatively connected to said playing keys for actuation thereby and adapted to produce a pulse whenever a key farthest toward one end of the keyboard with respect to a held key is played or released but not to produce a pulse when a key toward the opposite end of the keyboard with respect to any held key is played or released, and a pulse responsive variable gain control percussion circuit forming a portion of said output system connected to respond to said pulse producing means, whereby upon reception of a pulse by said percussion circuit the output system will render the signal with a percussive envelope.

3. In an electronic musical instrument having a tone signal generating means, an output system, and a keyboard having a plurality of playing keys operative to connect said tone signal generating means to said output system, said generating means and keyboard connections being of the monophonic type which selects and sounds only the tone signal corresponding to the played key nearest one end of the keyboard when several keys are played together, the combination therewith of a pulse producing means operatively connected to said playing keys for actuation thereby and adapted to produce a pulse whenever a key farthest in one direction of the keyboard with respect to a held key is played or released but not to produce a pulse when a key in the opposite direction of the keyboard with respect to any held key is played or released, and a pulse responsive variable gain control percussion circuit forming a portion of said output system connected to respond to said pulse producing means, whereby upon reception of a pulse by said percussion circuit the output system will render a selected tone signal with a percussive envelope.

4. In an electronic musical instrument having a tone signal generating means, an output system, and a keyboard having a plurality of playing keys operative to connect said tone signal generating means to said output system, said generating means and keyboard connections being of the monophonic type which selects and sounds only the tone signal corresponding to the played key nearest the higher pitched end of the keyboard when several keys are played together, the combination therewith of a pulse producing means operatively connected to said playing keys for actuation thereby and adapted to produce a pulse whenever a key farthest toward one end of the keyboard with respect to a held key is played or released but not to produce a pulse when a key toward the opposite end of the keyboard with respect to any held key is played or released, and a pulse responsive variable gain control percussion circuit forming a portion of said output system connected to respond to said pulse producing means, whereby upon reception of a pulse by said percussion circuit the output system will render a selected tone signal with a percussive envelope.

5. In an electronic musical instrument having a tone signal generating means, an output system, and a keyboard having a plurality of playing keys operative to connect said tone signal generating means to said output system, said generating means and keyboard connections being of the monophonic type which selects and sounds only the tone signal corresponding to the played key nearest the higher pitched end of the keyboard when several keys are played together, the combination therewith of a pulse producing means operatively connected to said playing keys for actuation thereby and adapted to produce a pulse whenever a key farthest toward said higher pitched end of the keyboard with respect to a held key is played or released but not to produce a pulse when a key toward the lower pitched end of the keyboard with respect to any held key is played or released, and a pulse responsive variable gain control percussion circuit forming a portion of said output system connected to respond to said pulse producing means, whereby upon reception of a pulse by said percussion circuit

the output system will render a selected tone signal with a percussive envelope.

6. In an electronic musical instrument having a tone signal generating means, an output system, and a keyboard having a plurality of playing keys operative to connect said tone signal generating means to said output system, said generating means and keyboard connections being of the monophonic type which selects and sounds only the tone signal corresponding to the played key nearest the lower pitched end of the keyboard when several keys are played together, the combination therewith of a pulse producing means operatively connected to said playing keys for actuation thereby and adapted to produce a pulse whenever a key farthest toward one end of the keyboard with respect to a held key is played or released but not to produce a pulse when a key toward the opposite end of the keyboard with respect to any held key is played or released, and a pulse responsive variable gain control percussion circuit forming a portion of said output system connected to respond to said pulse producing means, whereby upon reception of a pulse by said percussion circuit the output system will render a selected tone signal with a percussive envelope.

7. The combination called for in claim 2 in which said pulse producing means actuated by said keys comprises a circuit adapted to produce a pulse when the value of an impedance element therein is abruptly changed, an impedance element in said circuit formed of a connection of a plurality of discrete impedance portions, a plurality of switches each actuated by one of the playing keys, and connections between said switches and said portions such that the number of said portions connected to form said impedance element is determined by the depressed key closest to one end of the keyboard.

8. The combination called for in claim 3 in which said pulse producing means actuated by said keys comprises a circuit adapted to produce a pulse when the value of an impedance element therein is abruptly changed, an impedance element in said circuit formed of a connection of a plurality of discrete impedance portions, a plurality of switches each actuated by one of the playing keys, and connections between said switches and said portions such that the number of said portions connected to form said impedance element is determined by the depressed key closest to one end of the keyboard.

9. The combination called for in claim 2 in which the pulse producing means includes a circuit for producing pulses of a single polarity from mixed pulses of either polarity comprising means providing a first and a second electrical path, circuit means connected for feeding mixed pulses to both of said paths, said first path including rectifying means for suppressing input pulses of one polarity and for passing input pulses of the other polarity, said second path including rectifying means and polarity reversal means for passing input pulses of said one polarity but with reversed polarity and for suppressing input pulses of said other polarity, and a common output circuit connected to receive pulses from both of said circuits.

10. The combination called for in claim 3 in which the pulse producing means includes a circuit for producing pulses of a single polarity from mixed pulses of either polarity comprising means providing a first and a second electrical path, circuit means connected for feeding mixed pulses to both of said paths, said first path including rectifying means for suppressing input pulses of one polarity and for passing input pulses of the other polarity, said second path including rectifying means and polarity reversal means for passing input pulses of said one polarity

but with reversed polarity and for suppressing input pulses of said other polarity, and a common output circuit connected to receive pulses from both of said circuits.

11. The combination called for in claim 2 in which the pulse producing means includes means for rectifying and filtering the tone signals supplied by the generating means under the control of the playing keys.

12. The combination called for in claim 2 in which the tone signal generating means includes acoustical tone generators and the output system includes a microphone receiving the acoustical output of the generators and an amplifier and speaker coupled to the microphone.

13. The combination called for in claim 2 in which the pulse producing means includes a plurality of momentary contact wipe switches actuated each by one of the playing keys.

14. The combination called for in claim 2 in which the pulse producing means includes a source of electrical potential, a pulse output system, a plurality of capacitors, a plurality of switches actuated by the playing keys and circuit means connecting said switches between said source, said capacitors and said output system so that said switches connect the capacitors to the source when the keys are in repose and disconnect the capacitors from the source and connect the capacitors to the output system when the keys are played.

15. In an electrical musical instrument having tone signal generating means, an output system having a signal input, and a keyboard having a first and a second playing key connected to cause appropriate tone signals from said generating means to appear at the input of said output system, the combination therewith of means individual to each of said playing keys and operatively connected to said playing keys for actuation thereby and adapted to produce a pulse whenever either of said keys is played individually and whenever said first key is played while said second key is held in playing position, and a pulse responsive variable gain control percussion means forming a portion of said output system connected to respond to both of said pulse producing means, whereby upon reception of a pulse by said percussion means the output system will render the signal with a percussive envelope.

16. In an electrical musical instrument having tone signal generating means, an output system having a signal input, and a keyboard having a plurality of playing keys connected to cause selected tone signals from said generating means to appear at the input of said output system, the combination therewith of pulse producing means including means individual to each of said playing keys and operatively connected to said playing keys for actuation thereby and adapted to produce a pulse whenever any of said keys is played without regard to the playing position of any other key, and a pulse responsive variable gain control percussion means forming a portion of said output system connected to respond to said pulse producing means, whereby upon reception of a pulse by said percussion means the output system will render the signal with a percussive envelope.

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