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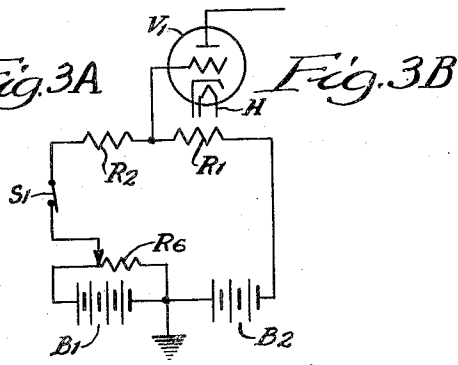
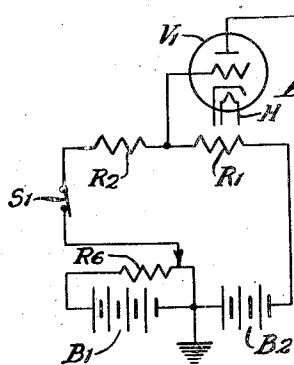
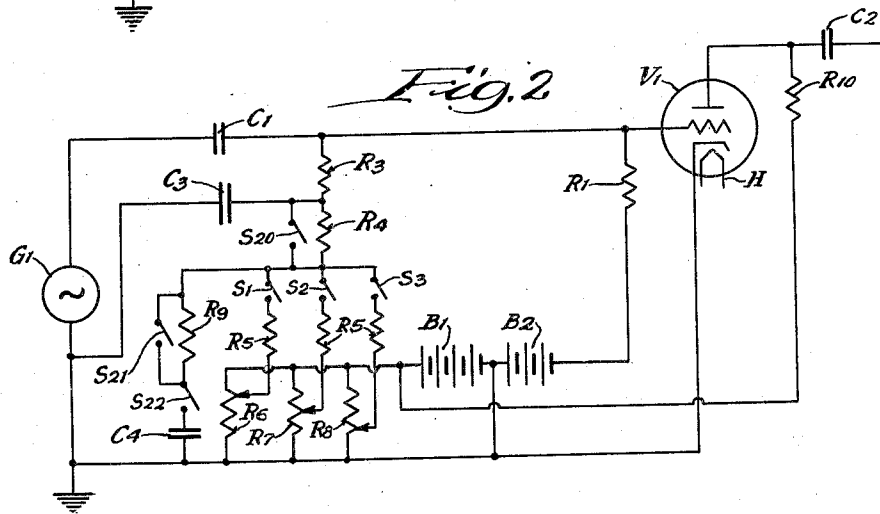
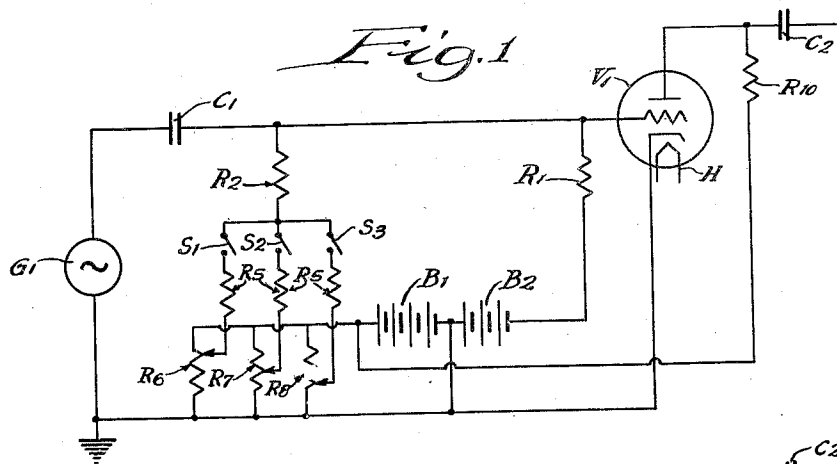
S. W. McKELLIP

2,481,608

ELECTRICAL MUSICAL INSTRUMENT

Filed Dec. 1, 1944

2 Sheets-Sheet 1



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Sept. 13, 1949.

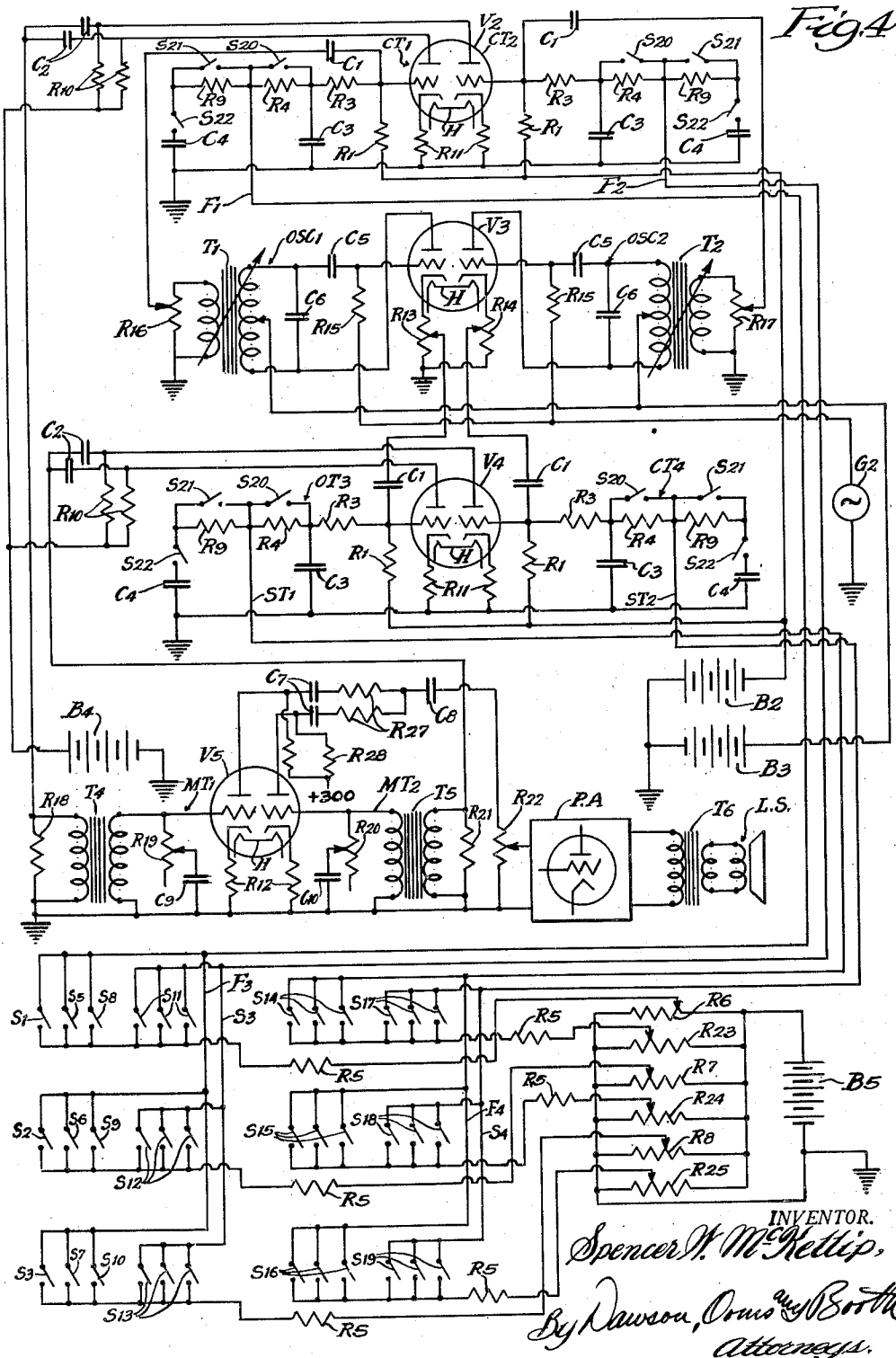
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ELECTRICAL MUSICAL INSTRUMENT

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2 Sheets-Sheet 2



UNITED STATES PATENT OFFICE

2,481,608

ELECTRICAL MUSICAL INSTRUMENT

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12 Claims. (Cl. 84—1.22)

1

My invention relates in general to electrical musical instruments and more particularly to electronic musical instruments of the organ type in which tones are produced by translating electric currents into sound.

The principal object of the invention is to provide a novel electronic organ of the multi-manual variety in which it is possible to control the different tonal signals derived from continuously operating generators from one or more points either individually or in combination.

A further object of the invention is to provide a multi-manual electric organ in which only one set of oscillators and control tubes are necessary for any number of sets of playing keys or manuals.

A still further object of the invention is to provide an instrument of the character named in which standard pipe organ designed switch mechanisms and keys can be utilized.

Another object is to provide an electrical instrument in which electrical tone currents of different characters are combined and mixed to produce a plurality of different tonal effects.

Still another object of the invention is to provide an electrical musical instrument in which the amplitude or volume of the signals produced can be controlled at will from each manual thru the keying source.

Another object of the invention is to provide an electronic organ of the multi-manual variety small and compact in physical dimensions, the over all size of which compares favorably with the average spinet piano.

Another object is to provide an electronic organ system in which control is effected in secondary nonsignal circuits.

Another object is to provide an electrical musical instrument that can be constructed economically and which lends itself readily to mass production manufacturing methods.

The above and other objects and advantages of the invention will be more readily apparent from the following description when read in connection with the accompanying drawings in which—

Figure 1 is a circuit diagram of a simplified form of part of the invention;

Figure 2 is a view similar to Figure 1 showing means of controlling the attack and decay of the signal;

Figures 3A and 3B are simplified circuit diagrams of the keying circuit shown in Figure 1; and

Figure 4 is a circuit diagram of a portion of a complete musical instrument.

2

Before proceeding with a detailed description of the circuits shown, the general arrangement and operation of an instrument embodying the invention will be briefly described. For each note of the tempered musical scale of a complete instrument, there is provided a continuously operating signal generator, preferably a vacuum tube oscillator of a type from which tone frequency currents of different characters can be derived. Such an oscillator is described in detail in U. S. Patent No. 2,340,002 in which myself and John R. Ford are the inventors. The different signals derived from each oscillator are individually controlled by the use of a keying or control vacuum tube, there being provided one such tube for each signal from each oscillator. As will be fully described hereinafter, each of these keying tubes can be keyed at will from a number of different sources either individually or in any combination and the amplitude of the signal passing thru said control tubes can be changed thru the medium of keying means.

As a practical illustration, a two manual organ type with pedal clavier may be referred to. Assuming that an instrument of this character would have a range of seventy-three notes, then in accordance with the invention, there would be seventy-three vacuum tube oscillators which would represent actually 37 tubes if twin type triode tubes were used. Still further assuming that two tone colors were obtained from each oscillator as likewise described in the patent mentioned before, then there would be a control tube for each tone color for each note or a total of 146 control tubes which represent seventy-three twin triode types. These seventy-three control tubes combined with the thirty-seven oscillator tubes and an average of fifteen miscellaneous power pack and power amplifier type tubes, make a total of one-hundred twenty-five tubes for an entire instrument.

By means of a negative and positive bias keying means that will be described in detail hereinafter, it is possible to key and regulate the amplitude or volume of the individual tone colors present on each manual either individually or in various combinations.

For example a loud flute could be played on the top manual at the 16 foot and 4 foot registers along with a soft string at the 4 foot and 2 foot registers with a medium 8 foot flute and soft 2 foot string accompaniment on the bottom manual with a 16 foot, 8 foot and 4 foot loud flute and 16 foot, 4 foot soft string pedal all from the 125 tubes mentioned. In addition

control over attack and decay can be effected and likewise a desirable controlled frequency tremolo is provided.

With an expression pedal for regulating the volume of the entire instrument and a suitable power amplifier and loud speaker there is provided a very small compact instrument about the size of the average piano that from a musical standpoint will cover a wide variety of not only well known musical sounds but many new and novel effects.

Referring to Figure 1, the signal derived from the signal source G_1 is impressed on the control grid of the control tube V_1 thru coupling condenser C_1 . This tube is preferably a high vacuum triode such as one section of a 6SN7GT. The plate of the tube is connected thru a plate load resistor R_{10} to a plus voltage source such as battery B_1 and there is a negative bias voltage on the control grid thru resistor R_1 from battery B_2 . The negative bias voltage is of such a value as to bias the grid of the tube beyond cut off so that it does not normally transmit.

The tube is controlled thru keying means which provides control circuits separated from the signal circuit. The battery B_1 is connected to a series of potentiometers R_6 , R_7 , R_8 having adjustable contacts thereon connected to switches S_1 , S_2 and S_3 thru resistors R_5 . The switches S_1 , S_2 and S_3 are connected to a common resistor R_2 which in turn is connected to the control grid of the tube.

The switch S_1 might represent a note played from the top manual of a two manual organ, switch S_2 the bottom manual and switch S_3 the foot pedals. When one of these switches, for example switch S_1 , is closed the control grid of the tube will be supplied with positive voltage, the value of which will depend on the setting of potentiometer R_6 . This positive voltage raises the grid potential to a point where the tube will transmit, the amplitude of the signal transmitted through the tube being directly controlled by the said positive voltage potential.

Figures 3A and 3B are so arranged that a quick analysis of the amplitude controlling action of the positive voltage through the key switch S_1 to the tube control grid can be made. It might be assumed that the tube transmits full signal with a grid voltage of minus 6 volts and is completely cut off and ceases to transmit signals at minus 10 volts.

Referring to Figure 3A, if the value of R_1 is 1 meg., R_2 10 megs., B_1 52 volts positive from ground, and B_2 eleven volts negative from ground, it can be readily seen that the current flowing through resistors R_2 and R_1 will be 1 microampere; that is, 11 meg. divided into 11 volts. The voltage drop across the resistor R_1 is one volt so the grid voltage to ground is 10 volts. The tube is cut off and does not transmit. The potentiometer volume control R_6 is shown turned in the off position so that the battery B_1 might just as well be out of the circuit as it is supplying no voltage to switch S_1 .

Referring to Figure 3B, with all values the same for all components as 3A except the slider of potentiometer R_6 which now has been shifted over to full positive voltage or the full signal position, the current flowing through resistors R_2 and R_1 is 5.7 microamperes. That is 11 megs. divided into 63 volts, the total voltage of batteries B_1 and B_2 as they are connected in series. The grid voltage to ground on the tube is now -5.3 volts as the voltage drop across re-

sistor R_1 is 5.7 microamperes $\times$ 1 meg. = 5.7 volts and this from -11 volts negative = -5.3. The control grid potential now has been raised to the maximum operating range and the tube transmits full signal.

From the foregoing it can readily be seen that the amplitude of the signal transmitted by the tube V_1 can be controlled by adjustment of the potentiometer R_6 .

Referring back to Figure 1 and keeping in mind the fact that the current flowing through the switches S_1 , S_2 and S_3 will vary from 1 microampere to 5.7 microamperes as heretofore pointed out and also that the maximum voltage to be broken by any of the switches is approximately 52 volts, it will be seen that the control of clicks and thumps set up by the closing and opening of the switches S_1 , S_2 and S_3 can be accomplished relatively easily. From past experience, I have found that the extent of the clicks and plops present is, to a large degree, a function of the voltage and current at the keying point in ratio to the signal controlled by the key. However, it takes a very small amount of click particularly to ruin a soft flute type tone in view of the extreme contrast between the flute tone which has few higher harmonics and the click voltage which is extremely rich in higher harmonics.

By proper selection of condenser C_1 and resistor R_2 a satisfactory attack and decay condition can be effected when the switches S_1 , S_2 or S_3 are opened or closed. It must be borne in mind however that the value of R_2 has to be high enough so that the control grid of the tube is biased beyond cut off so that the tube will not transmit when the switches S_1 , S_2 and S_3 are open. A value of 10 meg. for R_2 will accomplish this.

Resistors R_5 are in series with the sliders of the potentiometers R_6 , R_7 and R_8 to prevent shorting of the battery B_1 in the event that two or more of the switches are closed simultaneously when one potentiometer slider is at ground potential and the other at plus 52 volts. As the resistance of these resistors R_5 is extremely low compared with the values of R_1 and R_2 , the effect on the keying or amplitude controlling feature of the circuit is negligible. More will be said regarding these resistors hereinafter.

Figure 2 is the same as Figure 1 except that a means of controlling the attack and decay of the signal has been added.

It will be noted that instead of the single resistor R_2 shown in Fig. 1 two resistors R_3 and R_4 are used in the keying circuit. The combined value of both of these resistors R_3 and R_4 should approximate that of resistor R_2 shown in Figure 1. In addition a condenser C_3 has been added to control attack clicks. Switch S_{20} controls the attack by shorting out resistor R_4 , the attack being sharp or abrupt with R_4 shorted out. A resistor R_9 with an associated shunt switch S_{21} controls the initial rate of discharge of condenser C_4 . The effect of R_9 cooperating with C_4 in the circuit is to cause the signal to decay very rapidly for part of the decay cycle, then taper off gradually for the balance of the decay time. A piano type of decay can be approximated by the proper selection of R_9 and C_4 . This effect is brought about by the voltage drop across resistor R_9 when condenser C_4 discharges back thru it to sustain the signal when the playing key is released and the keying switch is opened. As the voltage derived from the condenser C_4 thru resistor R_9 is lowered by the voltage drop across the resistor, the signal diminishes very rapidly

when the keying switch is first opened then decays slowly depending upon the value of C_4 . Variable R_9 resistors instead of fixed resistors and accompanying shunt switches might be used to control the decay where greater flexibility of control is desired. Condenser C_4 and associated switch S_{22} control to a large degree the total length of the decay time.

To illustrate the sustain action when one of the keys S_1 , S_2 or S_3 whichever one it might be, is released, the condenser C_4 discharges back into the circuit thru resistor R_9 or the shunt switch S_{21} supplying the necessary positive voltage thru R_4 and R_3 to maintain the grid of the tube V_1 at a high enough potential to transmit. As the condenser continues to discharge the voltage diminishes and the strength of the signal becomes weaker in proportion to the condenser discharge voltage.

It must be borne in mind that an adjustment of the battery voltages B_1 and B_2 will become necessary in carrying out the attack and decay features of Fig. 2 to cause the grid of the tube to function as desired. As this change will be minor in nature the keying condition with respect to clicks and plops is not appreciably changed.

Fig. 4 is a schematic diagram representing a portion of a complete two manual organ with associated pedal clavier or pedal board. For simplicity only two of the signal sources or oscillators are shown and as only two different tone frequency currents are derived from each of the oscillators, four keying or control tubes are shown.

V_3 is a twin triode, preferably type 6SN7GT, in which the lefthand tube section is part of the oscillator OSC1 and the righthand tube section is part of oscillator OSC2. The oscillators OSC1 and OSC2 are described in detail in my U. S. Patent No. 2,340,001 and in the joint patent of myself and John R. Ford No. 2,340,002. While the oscillators described in both of these patents utilize keyed screen grid type tubes, as is pointed out particularly in Patent No. 2,340,001 the oscillator is started and stopped in the screen grid circuit. In this present invention the oscillator oscillates continuously so a triode type tube has been substituted in place of the screen grid type. The triode oscillators OSC1 and OSC2 function in practically every respect the same as the screen grid oscillators described in the mentioned patents.

The oscillator tube V_3 includes two cathodes, two control grids and two plates. The cathodes are connected to ground through cathode resistors R_{13} and R_{14} and the plates are connected through feed back circuits including transformers T_1 and T_2 having condensers C_6 connected across their primaries. The transformers T_1 and T_2 are variable to provide inductance to enable the final tuning of the oscillatory circuits to the tempered musical scale as described in detail in the aforementioned patents. Grid resistors R_{15} are connected across the grid plate circuits and as shown are connected to the source of tremolo voltage G_2 . Reference is made to the aforementioned patents for further information regarding the tremolo voltage generator. As also described in the mentioned patents, a signal that is substantially of a flute variety is derived from the secondaries of transformers T_1 and T_2 while a signal having a string character is derived from the cathode circuits of both sections of the tube V_3 .

The volume of the flute signals derived from the secondaries of transformers T_1 and T_2 is controlled by potentiometers R_{16} and R_{17} which

are shunted across the transformer secondaries. The sliders of the potentiometers R_{16} and R_{17} are connected to the control grids of the two tube sections of control tube V_2 through coupling condensers C_1 which allow the signal to pass through but block the control tube D. C. bias voltage path to ground.

The string signals derived from the cathode circuit of the tube V_3 are controlled in amplitude by the cathode potentiometers R_{13} and R_{14} . The sliders of these potentiometers are connected to the control grids of both tube sections of control tube V_4 through coupling condensers C_1 which also block the control tube D. C. grid bias voltage path to ground. The plates of the control tube V_2 receive positive voltage from battery B_4 , through plate load resistors R_{10} and the signals derived from said plates are impressed on the primary of mixing transformer T_4 through coupling condensers C_2 . The plates of the control tube V_4 receive positive voltage in a similar manner from battery B_4 through plate load resistors R_{10} . The signals derived from said plates are impressed on the primary of mixing transformer T_5 through coupling condensers C_2 . The primaries of transformers T_4 and T_5 are of extremely low impedance and are loaded with 100 ohm resistors R_{18} and R_{21} which are shunted across said primaries.

Due to the extreme low impedance of the mixing transformer primaries all of the necessary control tube plates can be parallel mixed to these primaries without appreciable cross modulation or distortion occurring. Also even taking into consideration that with liberal "coupling," which will be described hereinafter, the losses incurred by virtue of the parallel mixing can easily be made up in the first audio amplification stage.

Shunted across the secondaries of the mixing transformers T_4 and T_5 are tone variable controls for attenuating the higher harmonics of the signals. These tone controls are made up of potentiometers R_{19} , R_{20} and condensers C_9 and C_{10} .

The secondaries of transformers T_4 and T_5 are connected to the control grids of mixer or first audio stage tube V_5 . The cathodes of this tube are connected to ground through cathode resistors R_{12} and the plates of the tube are connected to a positive voltage source through plate load resistors R_{23} . The signals derived from the plates of the tube are mixed together through condensers C_7 and high impedance resistors R_{27} and are impressed upon the high side of potentiometer R_{22} , the lower side of this potentiometer being tied to ground. This potentiometer R_{22} might represent the swell pedal for regulating the volume level of the entire instrument. It can be foot controlled in the usual organ manner and also used as an expression pedal. The slider of potentiometer or swell pedal resistor R_{22} is fed directly into a suitable power amplifier indicated at PA the output of which terminates into a loud speaker LS for translating the electrical energy into sound.

With the exception of tone controls R_{19} and R_{20} and the swell pedal potentiometer R_{22} , the control of the entire instrument with respect to keying, selection of various tone colors and regulating of the volume level of the tone color in question is entirely separated from the signal and is effected in secondary D. C. controlled circuits.

Referring back to Figure 4, control tubes V_2 and V_4 , the control grids of these tubes are biased beyond cut off by the negative voltage derived

from battery B₂ thru resistors R₁ so the tubes will not normally transmit. The control tubes V₂ and V₄ are connected in every respect the same as set forth in Figure 2 except the positive bias voltage is applied thru resistors R₃ and R₄ from a series of unit coupler key switches shown in the lower left corner of Figure 4. In turn as in Figure 2, the common sides of the switches receive positive voltage thru resistors R₅ from the potentiometers R₆, R₂₃, R₇, R₂₄, R₈, R₂₅ which are connected in parallel across battery B₅. As described heretofore, the amplitude of the signals of the control tubes are regulated by the position of the sliders on the potentiometers R₆, R₂₃, etc. Also the resistors R₅ exclude the possibility of shorting the battery B₃.

The six groups of switches shown in the lower left corner of Figure 4, are shown to represent three unit coupler switch key actions similar to the ones used in connection with pipe organs.

These switches may form parts of any desired type of unit coupler key actions such, for example, as the Austin type key action described in Chapter 19 of the second edition of the book "The Contemporary American Organ" by William H. Barnes and published in 1933 by J. Fischer & Bros. of New York. As shown the group in which switches S₁ and S₁₄ appear may be the top manual key action, the groups in which switches S₂ and S₁₅ appear may be the bottom manual key action and the groups including switches S₃ and S₁₆ may be the pedal clavier key action.

So that a better understanding of the keying circuits might be had it will be assumed that the left half of tube V₂ is assigned to control the signals of flute note 37 of the completed instrument. By following conductor F₁ from the junction of resistors R₃ and R₄ it will be found that the three key switches S₁, S₅ and S₈ of the top manual coupler action are connected to this conductor. Of these switches, switch S₅ could be actuated when playing key 37 is struck causing the organ to speak in the 8 foot register as note 37 is played from key 37. Switch S₁ could be actuated by playing key 25 and as note 37 is now being played from an octave lower the organ speaks in the four foot register. Switch S₈ could be actuated by playing key 49 and as note 37 is now being played from a point one octave above note 37 the organ speaks in the 16 foot register. In an arrangement of this character where the 16 foot, 8 foot and 4 foot registers are present, there would in effect be three switches per playing key for each tone where the said registers appear or in other words, an individual switch per register per tone color.

As is shown on pages 313 and 314 of the aforementioned Barnes book, each individual key switch is composed of a contact that makes with a roller coupler bar that is common to all contacts of a like character and the said rollers can be selectively brought into contact position each individually or in any combination. When a playing key is depressed, the contacts are flexed to make with the desired roller coupler bar.

While I prefer the so called Austin type of key coupler action as described above, and also in the Barnes book, it might be pointed out that other types of key actions, switching combinations and the like may be utilized to provide octave coupling or other desired effects.

For simplicity only three coupler switches are shown for each of the two tone colors for each manual and pedal clavier. It is understood that

the number of switches that can be used in connection with each coupler is only limited by the mechanics of the situations and the space available. There is no limit from an electrical standpoint. The usual practice in smaller organs would be for the switches of the coupler action to be mechanically actuated by the pressure the organist exerts on the playing keys. Naturally there is a limit to the practical number of switches that could be actuated in this manner. In larger organs the key actions could be remotely actuated by relays also described in the Barnes book.

It will be noted that conductor F₃ connects the other two unit coupler actions in parallel with the top one, making it possible to key the corresponding switches from the same key numbers on the bottom manual and pedal board. In other words, flute tone 37 can be keyed from any one of nine key switches.

It will also be noted that for each tone color group of switches on each manual there is an individual volume control potentiometer which is connected to a plus voltage source B₅ thru protective resistors R₅. The resistors R₅ are to protect the battery B₅ from being shorted if part of the volume control potentiometers are at ground potential and the rest at a higher positive above ground.

In the event that more than one key switch is closed at the same time on one of the keying tubes, the keying switch supplying the highest voltage will be the one that causes the tube to transmit.

The key switch supplying lower voltages will contribute nothing towards the tube transmitting as the lower voltage switches are directly in parallel with the high voltage switch. While the present invention provides a non-additive type of control, I have found that as long as there is no "robbing effect" when a note is keyed from more than one source at the same time, there is no substantial difference in effect between the additive type of system and the non-additive type. In fact with the ensuing complications, that are run into with additive type systems, and this is particularly true where quite a number of circuits are keyed to the same tube, any advantage gained is more than lost by said complications.

With an organ system as described it is possible to have a complete multi-manual instrument in which a number of different foundation tone colors can be keyed from each manual and the pedal board. It is possible for the organist to select these tone colors at will at various volume levels and at various registrations. In addition means are provided to effect changes of attack and decay conditions. The tones can also be regulated with respect to higher harmonics by the tone control heretofore described. All of this along, with a suitable tremolo, that can be turned on or off at will and regulated with respect to amplitude and volume, an expression or swell pedal and a suitable power amplifier and loud speaker go to make up a small and compact instrument that can be played in the conventional manner and is capable of being conditioned by the organist to cover a wide variety of not only well known musical sounds but many new and interesting ones.

While one embodiment of the invention has been shown and described in detail herein it will be understood that this is illustrative only and is not intended as a definition of the scope of the

invention, reference being had for this purpose to the appended claims.

What is claimed is:

1. In an electrical musical instrument including a source of tone frequency current and a tone producing means, control means comprising a tube having a grid connected to said source, means to supply a substantially constant negative bias to the grid sufficient to bias the tube past cut off, a source of positive direct current, a keying switch for connecting the source to the grid, a resistor in series with the switch, a condenser in shunt with the resistor, and a shunt circuit around the resistor having a switch therein to vary the attack of the tone produced.

2. In an electrical musical instrument including a source of tone frequency current and a tone producing means, control means comprising a tube having a grid connected to said source, means to supply a substantially constant negative bias to the grid sufficient to bias the tube past cut off, a source of positive direct current, a keying switch for connecting the source to the grid, a resistor in series with the switch, a condenser in shunt with the resistor, a second condenser connected between the source and the resistor to ground, and a switch in series with the second condenser to vary the decay of the tone produced.

3. In an electrical musical instrument including a source of tone frequency current and a tone producing means, control means comprising a tube having a grid connected to said source, means to supply a substantially constant negative bias to the grid sufficient to bias the tube past cut off, a source of positive direct current, a keying switch for connecting the source to the grid, a resistor in series with the switch, a condenser in shunt with the resistor, a second condenser connected between the source and the resistor to ground, a shunt circuit including a switch around the resistor to vary the attack of the tone produced, and a switch in circuit with the second condenser to vary the decay of the tone.

4. In an electrical musical instrument including a source of tone frequency current and a tone producing means, control means comprising a tube having a grid connected to said source, means to supply a substantially constant negative bias to the grid sufficient to bias the tube past cut off, a source of positive direct current, a keying switch for connecting the source to the grid, a resistor in series with the switch, a condenser in shunt with the resistor, a second condenser connected between the source and the resistor to ground, a second resistor in series with the second condenser, a shunt circuit including a switch around the second resistor, and a switch in series with the second condenser.

5. An electrical musical instrument comprising an oscillator circuit including an electron discharge tube having a plate circuit and a cathode circuit, the plate and cathode circuits providing tone frequency currents of different character, a pair of control tubes having control grids connected respectively to the plate and cathode circuits of the oscillator, means to supply a substantially constant negative bias to the grids of the control tubes, and keying means for each of the control tubes including a plurality of switches in parallel for connecting the tube grid to separate sources of positive potential, and resistors between the switches and the sources to prevent cross feeding between the switch circuits when a

plurality of the switches are closed simultaneously.

6. In an electrical musical instrument including a plurality of sources of tone frequency current of different frequencies and tone producing means, control means comprising a plurality of control tubes connected to the sources respectively to control connection thereof to the tone producing means, and a plurality of keying means each including a plurality of switches connected to different ones of the control tubes, there being a plurality of switches associated with different keying means connected to each of the control tubes, resistors in series with the switches, condensers in parallel with the resistors, and shunt switches around the resistors to control the attack of a tone.

7. In an electrical musical instrument including a plurality of sources of tone frequency current of different frequencies and tone producing means, control means comprising a plurality of control tubes connected to the sources respectively to control connection thereof to the tone producing means, a plurality of keying means each including a plurality of switches connected to different ones of the control tubes, there being a plurality of switches associated with different keying means connected to each of the control tubes, resistors in series with the switches, condensers in parallel with the resistors, a second set of condensers connected respectively from points ahead of the resistors to ground, and switches in circuit with the condensers of the second set to control the decay of a tone.

8. An electrical musical instrument comprising sources of tone frequency currents of different characters and of the same fundamental frequency, a control tube connected to each of the sources to control the transmitted amplitude thereof, means for combining the outputs of the control tubes, and translating means connected to the last named means for translating the combined outputs into sound.

9. An electrical musical instrument comprising a plurality of sources of tone currents of different frequency of one character, a plurality of sources of tone currents of different frequency of a different character, keying means to control the transmission of signal currents from said sources, means for combining the tone currents of said one character, means for combining the tone currents of said different character, means for combining the outputs of the two last named means, and translating means for translating the combined outputs of the last named means into sound.

10. An electrical musical instrument comprising a plurality of sources of tone currents of different frequency of one character, a plurality of sources of tone currents of different frequency of a different character, keying means to control the transmission of signal currents from said sources, a low impedance transformer for combining the tone currents of said one character, a low impedance transformer for combining the tone currents of said different frequency, and translating means connected to both of the transformers to translate the combined outputs thereof into sound.

11. An electrical musical instrument comprising a plurality of oscillator circuits each including an electron discharge tube having a plate circuit and a cathode circuit, control tubes associated with the plate and cathode circuits of the oscillators respectively, means for combining

the outputs of the control tubes, and translating means responsive to the last named means to translate the combined outputs into sound.

12. An electrical musical instrument comprising a plurality of oscillator circuits each including an electron discharge tube having a plate circuit and a cathode circuit, control tubes associated with the plate and cathode circuits of the oscillators respectively, keying means to control the transmission of the control tubes, means for combining the outputs of the control tubes associated with the oscillator plate circuits, means for combining the outputs of the control tubes associated with the oscillator cathode circuits, and translating means responsive to both of the combining means to translate the outputs thereof into sound.

SPENCER W. McKELLIP.

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