A monophonic electronic musical instrument of an equal tempered scale is disclosed in which a note voltage generator circuit includes a plurality of first resistors connected in series between first and second terminals, a plurality of second resistors each connected between the connection point of adjacent ones of the plurality of first resistors and a third terminal common to the first and second resistors and third and fourth resistors connected between the first and third terminals and the second and third terminals, respectively; at least the connection points of adjacent ones of the plurality of first resistors are connected through the keyboard switches to the one end of a DC power source connected at the other end to the third terminal; out put terminals are led out from the first and third terminals or the mid point of the third resistor and said third terminal; and the values of the first and second resistors and the values of the third and fourth resistors are determined by the diminishing ratio between adjacent notes of the equal tempered scale.

3 Claims, 4 Drawing Figures
1. Field of the Invention

This invention relates to improvements in a monophonic electronic musical instrument of an equal tempered scale which has keyboard switches corresponding to notes of the equal tempered scale, a note voltage generator circuit from which a note voltage corresponding to each of the keyboard switches can be obtained by depressing each of the keyboard switches, an oscillator for producing a tone signal having a frequency corresponding to the note voltage, an amplifier for amplifying the tone signal and a speaker connected to the amplifier.

2. Description of the Prior Art

In conventional note voltage generator circuits for monophonic electronic musical instrument of the above type, a corresponding number of resistance circuits to that of notes of the equal tempered scale are connected to a DC power source and the resistance values of the resistance circuits are adjusted in the manner of trial and error, by which signals having frequencies corresponding to the notes of the equal tempered scale are derived from a voltage control oscillator. This is based on such a concept that it is sufficient only to obtain monotones corresponding to the notes of the equal tempered scale by selectively depressing keyboard switches one after another.

Accordingly, the note voltage generator circuit herebefore employed in this kind of monophonic electronic musical instruments is constructed to include a variable resistor for each of the resistance circuits corresponding to the notes, and hence is complicated, bulky and expensive in its overall circuit construction and, in addition, involves troublesome adjustment of the resistance values of the individual resistance circuits corresponding to the notes.

SUMMARY OF THE INVENTION

Accordingly, the present invention has for its object to provide a monophonic electronic musical instrument which is free from the aforesaid defects experienced in the prior art.

Other objects, features and advantages of this invention will become apparent from the following description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram showing one example of a monophonic electronic musical instrument of the equal tempered scale according to this invention;

FIG. 2 is a graph showing the relationships of voltages and frequencies of signals corresponding to notes to selection switches, for explaining this invention; and

FIGS. 3 and 4 are block diagrams illustrating other examples of this invention, respectively.

DESCRIPTION OF PREFERRED EMBODIMENTS

In FIG. 1, reference numeral 1 indicates generally a note voltage generator circuit according to this invention. Between terminals 2 and 3 are sequentially connected in series (n−1)3 resistors X1, X2, . . . and Xn−1 where n indicates the last term or the number of terms in a series of similar terms. Resistors Y1, Y2, . . . and Yn are connected between a common line shown extending between terminals 4 and the junctions P between the resistors X to the end junctions P1 and Pn connected to terminals 2 and 3 respectively. In addition terminating resistors keyboard switches S1, S2, . . . and Sn to the one end of a DC power source 7 connected at the other end to the terminal 4. Further, a pair of output terminals 8a and 8b are connected to the terminals 2 and 4, respectively. In this case, the resistors X1 to Xn−1 have the same resistance value r and the resistors Y1 to Yn have also the same resistance value R. Further, the resistance values of the resistors 5 and 6 are selected to be those R1 and R2 which are substantially equal to image impedances viewed from the terminals 2 and 4, and 3 and 4 to the sides of the terminals 3 and 4, and 2 and 4, respectively. (In this case, since R1=R2, these values will hereinafter be referred to as Rz.) Accordingly, if voltages which are obtained between output terminals 8a and 8b by sequentially depressing the switches S1, S2 . . . and Sn are taken as e1, e2, . . . and en and if K is taken as a constant, output voltages e1, e2, . . . and en (where e1>e2>. . . >en) bearing the following relationships are derived from between the output terminals 8a and 8b,

\[
\frac{e_1}{e_1} - \frac{e_2}{e_2} = \frac{e_3}{e_3} = \cdots = \frac{e_n}{e_n} - K
\]

By sequential depression of the keyboard switches S1, S2, . . . , Sn in such a note voltage generator circuit 1, the voltages e1, e2, . . . and en are sequentially obtained between the output terminals 8a and 8b and supplied to an oscillator 9, from which are sequentially derived tone signals F1, F2, . . . and Fn, having frequencies f1, f2, . . . and fn respectively. In this case, the oscillator 9 is one that its input voltage versus frequency characteristic is linear, so that the frequencies f1, f2, . . . and fn of the tone signals F1, F2, . . . and Fn derived from the oscillator 9 bear the following relationships:

\[
\frac{f_1}{f_1} = \frac{f_1}{f_1} = \frac{f_1}{f_1} = \cdots = K
\]

With such an arrangement as set forth above, in the note voltage generator circuit 1, the tone signals of the frequencies f1, f2, . . . and fn sequentially derived from the oscillator 9 by sequential depression of the switches S1, S2, . . . and Sn are supplied through an amplifier 10 to a speaker 11. Accordingly, if the switches S1, S2, . . . and Sn are selectively depressed one after another, notes of the frequencies f1, f2, . . . and fn are sequentially produced from the speaker 11. In this case, the frequencies f1 to fn bear the relationships given by the equation (2), so that, by sequentially depressing the switches S1, S2, . . . and Sn the equal tempered scale having a constant diminishing ratio between adjacent notes respectively can be obtained. FIG. 2 shows the relationships of the voltages e1, e2, . . . and en supplied to the oscillator 9 and the frequencies f1, f2, . . . and fn of the tone signals from the oscillator 9 to the switches S1, S2, . . . and Sn. The solid line indicates the above-described case. The dash line and the chain line illustrate the corresponding relations when the X resistor of each section of the attenuator is subdivided as shown in FIGS. 3 and 4.
By the way, the diminishing ratio $\eta$ between adjacent notes employed in monophonic electronic musical instruments of an ordinary equal tempered scale is as follows:

$$\eta = \frac{1}{12\sqrt[12]{2}} = \frac{1}{1.05946}$$  \hspace{1cm} (3)

Accordingly, with the above construction, when the switches $S_1$, $S_2$, ..., and $S_n$ of the note voltage generator circuit 1 are selectively depressed one after another, the equal tempered scale having a constant diminishing ratio between adjacent notes can be obtained, so that the keyboard switches $S_1$ to $S_n$ are arranged from the higher part of notes toward the lower part of notes. Further, the resistance values $r$, $R$, and $R_n$ of the resistors $X_1$ to $X_{n-1}$, $Y_1$ to $Y_n$ and 5 and 6 are so selected as to satisfy the equations (4) and (5):

$$\frac{R}{r} = \frac{\eta^2}{(\eta - 1)^2}$$  \hspace{1cm} (4)

$$\frac{R_n}{r} = \frac{1}{1 - \eta}$$  \hspace{1cm} (5)

Accordingly, in the note voltage generator circuit 1, the values of the aforementioned resistors $X_1$ to $X_{n-1}$, $Y_1$ to $Y_n$ and 5 and 6 are so selected as to satisfy the equations (4) and (5).

Thus, if any one of the values $r$, $R$, and $R_n$ in the equations (4) and (5) is determined, these values can all be determined. For example, if $r=1 K\Omega$, the equations (4) and (5) become as follows:

$$\frac{R}{r} = \frac{\eta^2}{(\eta - 1)^2}$$  \hspace{1cm} (6)

$$\frac{R_n}{r} = \frac{1}{1 - \eta}$$  \hspace{1cm} (7)

Substituting the value of $\eta$ of the equation (3) into the above equations (6) and (7), it follows that $R=299.67 K\Omega$ and that $R_n=17.818 K\Omega$. Thus, it is possible to obtain a monophonic electronic musical instrument of an equal tempered scale.

As described above, according to this invention, there is no need of providing in the scale voltage generator circuit independent resistance circuits each corresponding to each note as in the prior art and, further, each resistance circuit need not be constructed to include a variable attenuator. Moreover, this invention has a great advantage that the ordinary equal tempered scale can be moderately obtained without adjusting the resistance value of each resistance circuit corresponding to each note.

The foregoing description has been given with regard to the case where only the connection points $P_1$, $P_2$, ..., and $P_n$ of the terminal 2 and the resistor $X_1$, the resistors $X_1$ and $X_2$, the resistors $X_{n-2}$ and $X_{n-1}$ and the resistor $X_{n-1}$ and the terminal 3 are connected to the keyboard switches $S_1$, $S_n$, ..., and $S_n$ in the note voltage generator circuit 1. However, it is also possible to employ such a circuit construction as shown in FIG. 3, in which parts corresponding to those in FIG. 1 are marked with the same reference numerals and characters. Namely, the values $r$, $R$, and $R_n$ of the resistors $X_1$ to $X_{n-1}$, $Y_1$ to $Y_n$ and 5 and 6 are so selected as to satisfy the following equations corresponding to the aforementioned ones (4) and (5):

$$\frac{R}{r} = \frac{\eta^2}{(\eta^2 - 1)^2}$$  \hspace{1cm} (8)

$$\frac{R_n}{r} = \frac{1}{1 - \eta^2}$$  \hspace{1cm} (9)

The connection points $P_1$, $P_2$, $P_n$, ..., and $p_n$ of the terminal 2 and the resistor $X_1$, the resistors $X_1$ and $X_2$, the resistors $X_{n-2}$ and $X_{n-1}$ and the resistor $X_{n-1}$ and the terminal 3 are connected to the power source 7 through the keyboard switches $S_1$, $S_2$, $S_n$, ..., and $S_{n-1}$, respectively. Further, points $P'_1$, $P'_2$, ..., and $P'_{n-1}$ led out from the mid points dividing the resistors $X_1$, $X_2$, ..., and $X_{n-1}$, into two respectively, are connected to the power source 7 through the keyboard switches $S_1$, $S_2$, $S_n$, ..., and $S_{n-1}$, respectively.

Thus, since the equations (8) and (9) are satisfied, in the case of depressing the switches $S_1$, $S_2$, $S_n$, ..., and $S_{n-1}$, one after another, voltages divided between the output terminals $B_1$ and $B_2$ are the same as the voltages $e_1$, $e_2$, ..., obtained in the case of FIG. 1. However, in the case of depressing the switches $S_2$, $S_3$, $S_{n-1}$, ..., one after another, if the values of the resistors $X_1$ to $X_{n-1}$ on the sides of the terminal 2 and 3 from their dividing points are taken as $r'$ and $r''$, respectively, and if $r' = r''$, it follows that

$$e_r + e_s' + e_r' + e_s'' + e_{r'} + e_{s''} + \cdots .$$

and if $r'=r''=r/2$, it follows that

$$e_r + e_s' + e_r' + e_s'' + e_{r'} + e_{s''} + \cdots .$$

Accordingly, voltages $e_1'$, $e_2'$, $e_n'$, ..., which are a little higher than the voltages $e_1$, $e_2$, $e_n$, ..., obtained by depressing the switches $S_2$, $S_3$, $S_{n-1}$, ..., in the case of FIG. 1, therefore, it is preferred that $r'=r''=r/2$ but, in any case, it is possible to obtain an equal tempered scale close to the ordinary equal tempered scale. In FIG. 2, the broken line indicates the relationships of the voltages $e_1$, $e_2$, ..., $e_n$, $e_1'$, $e_2'$, $e_n'$, ..., supplied to the oscillator 9 to the switches $S_1$, $S_2$, ..., in the case of $r'=r''$ in the example of FIG. 3, and the relationships of the frequencies $f_1'$, $f_2'$, $f_3'$, ..., of the signals derived from the oscillator 9 to the switches $S_1$, $S_2$, ..., in this case, $f_1'$, $f_2'$, ..., indicate oscillation frequencies in the cases of the voltages $e_1'$, $e_1'$. FIG. 3 illustrates such a modified form of the note voltage generator circuit 1 in which the connection points $P_1$, $P_2$, $P_n$, ..., and $p_n$ of the terminal 2 and the resistor $X_1$, the resistors $X_1$ and $X_2$, the resistors $X_{n-2}$ and $X_{n-1}$ and the resistor $X_{n-1}$ and the terminal 3 are connected to the power source 7 through the keyboard switches, respectively, and in addition, the points $P'_1$, $P'_2$, ..., and $p_n$ led out from the dividing points of the resistors $X_1$ to $X_{n-1}$ are also connected to the power source 7 through the keyboard switches, respectively. Enlarging such an idea, it is also possible that points led out from more than two points dividing each of the resistors $X_1$ to $X_{n-1}$ into more than three are connected to the power source 7 through the keyboard.
switches. In practice, however, if the points led out from more than two points dividing each of the resistors $X_1$ to $X_{n-1}$ into more than three are connected to the power source $7$ through the keyboard switches, the resulting scale is deteriorated as compared with the equal tempered scale in the monophonic electronic musical instrument of the ordinary equal tempered scale. Consequently, in such a case, the number into which each of the resistors $X_1$ to $X_{n-1}$ is divided is limited to less than three.

FIG. 4 shows another modified form of this invention which is constructed in view of the above and in which two points dividing each of the resistors $X_1$ to $X_{n-1}$ of the note voltage generator circuit I into three are connected to the power source $7$ through the keyboard switches. In FIG. 4, parts corresponding to those in FIG. 1 are identified by the same reference numerals and characters and no detailed description will be repeated. The values $r$, $R$, and $R_0$ of the switches $X_1$ to $X_{n-1}$, $Y_1$ to $Y_4$, and $S_5$ and $S_6$ are so selected as to satisfy the following conditions corresponding to the aforesaid equations (4) and (5):

$$ R = \frac{\eta^2}{(q^n - 1)^2} \quad (10) $$

$$ R_0 = \frac{1}{1 - q^n} \quad (11) $$

The connection points $P_1$, $P_2$, $P_3$, ..., $P_{n-1}$, and $P_n$ of the terminal 2 and the resistor $X_1$, the resistors $X_2$, $X_3$, $X_4$, ..., $X_{n-2}$ and $X_{n-1}$ and the resistor $X_{n-1}$ and the terminal 3 are connected to the power source $7$ through the keyboard switches $S_1$, $S_2$, $S_3$, ..., and $S_{n-2}$. Further, points $P_1''$, $P_1'''$, $P_2''$, $P_2'''$, ..., $P_n''$, and $P_n'''$ led out from two points dividing each of the resistors $X_1$ to $X_{n-1}$ are connected to the power source $7$ through the keyboard switches $S_2$, $S_3$, $S_4$, $S_5$, $S_6$, ..., and $S_{n-3}$.

With such an arrangement, since the conditions of the equations (10) and (11) are satisfied, when the switches $S_1$, $S_2$, $S_3$, ..., are sequentially depressed, the voltages obtained between the output terminals $8_a$ and $8_b$ are the same as the voltages $e_1$, $e_2$, $e_3$, ..., obtained in the case of the example of FIG. 1. However, where the switches $S_2$, $S_3$, $S_4$, ..., are depressed one after another, if the values of the respective portions of each of the resistors $X_1$, $X_2$, ..., $X_{n-1}$ divided into three, that is, the portion on the side of the terminal 2, the central portion and the portion on the side of the terminal 3, are taken as $r''$, $r'''$ and $r'$$''$ and if $r'' \approx r''' \approx r'''$, it follows that

$$ e(r'' + r''') + e'' + e(r'' + r''') + e'' $$

and if $r'' \approx r''' \approx r''' \approx r/3$, it follows that

$$ \frac{2e_2 + e_3}{3} = \frac{2e_3 + e_4}{3} = \frac{2e_4 + e_5}{3} $$

and voltages $e_3''$, $e_4''$, $e_5''$, ..., a little higher than the voltages $e_2$, $e_3$, $e_4$, ..., obtained by depressing the switches $S_2$, $S_3$, $S_4$, ..., in the case of FIG. 1, is obtained. Further, in the case of sequentially depressing the switches $S_2$, $S_3$, $S_4$, ..., if $r'' \approx r''' \approx r'''$ as described above, it follows that

$$ e(r'' + r''') + e'' + e(r'' + r''') + e'' $$

and voltages $e_3''$, $e_4''$, $e_5''$, ..., a little higher than the voltages $e_2$, $e_3$, $e_4$, ..., obtained by depressing the switches $S_2$, $S_3$, $S_4$, ..., in the case of FIG. 1, is obtained. Consequently, in such a case, it is preferred that $r'' \approx r''' \approx r/3$ but, in any case, an equal tempered scale approximate to the equal tempered scale can be obtained. In FIG. 2, the chain line indicates the relationships of the voltages $e_1$, $e_2$, $e_3$, $e_4$, $e_5$, $e_6$, ..., applied to the oscillator 9 to the switches $S_1$, $S_2$, ..., and the relationships of the frequencies $f_1$, $f_2$, $f_3$, $f_4$, $f_5$, $f_6$, ..., of the signals derived from the oscillator 9 to the switches $S_1$, $S_2$, ..., in this case, $f_2''$, $f_3''$, $f_4''$, $f_5''$, $f_6''$, ... indicate the oscillation frequencies of the voltages $e_3''$, $e_4''$, $e_5''$, $e_6''$, ....

Although the foregoing description has been given in connection with the case where the output terminals $8_a$ and $8_b$ of the note voltage generator circuit I are led out from the terminals 2 and 4, they can be led out from a desired or point adjustable 2' of the resistor 5 and the terminal 4 to raise or lower the pitch of all notes of the scale as required to tune the instrument to a standard pitch.

It will be apparent that many modifications and variations may be effected without departing from the scope of the novel concepts of this invention.

I claim as my invention:

1. A monophonic electronic musical instrument of an equal tempered scale comprising keyboard switches corresponding to notes of said equal tempered scale, a note voltage generator circuit for producing a note voltage corresponding to each of said keyboard switches in response to the depression of each of the keyboard switches, an oscillator for producing a tone signals having a frequency corresponding to said note voltage, an amplifier for amplifying said tone signal, and a speaker connected to said amplifier, characterized in that said note voltage generator circuit includes a plurality of first resistors connected in series between first and second terminals, a plurality of second resistors each connected between the connection point of adjacent ones of said plurality of first resistors and a third terminal common to said first and second resistors and third and fourth resistors connected between said first and third terminals and said second and third terminals, respectively; the connection points of adjacent ones of said plurality of first resistors are connected through said keyboard switches to the one end of a DC power source connected at the other end to said third terminal; output terminals are led out from said first and third terminals or the mid point of said third resistor and said third terminal; and if the diminishing ratio between adjacent notes of the equal tempered scale is taken as $\eta$, if the values of said first and second resistors
are taken as \( r \) and \( R \), respectively; and if the values of said third and fourth resistors are taken as \( R_o \), they bear the following relationships:

\[
\frac{R}{r} = \frac{\eta}{(\eta - 1)^2}
\]

(1)

\[
\frac{R_o}{r} = \frac{1}{1-\eta^2}
\]

(2).

2. A monophonic electronic musical instrument of an equal tempered scale comprising keyboard switches corresponding to notes of said equal tempered scale, a note voltage generator circuit for producing a note voltage corresponding to each of said keyboard switches in response to the depression of each of the keyboard switches; an oscillator for producing a tone signal having a frequency corresponding to said note voltage, an amplifier for amplifying said tone signal, and a speaker connected to said amplifier, characterized in that said note voltage generator circuit includes a plurality of first resistors connected in series between first and second terminals, a plurality of second resistors each connected between the connection point of adjacent ones of said plurality of first resistors and a third terminal common to said first and second resistors and third and fourth resistors connected between said first and third terminals and said second and third terminals, respectively; the connection points of adjacent ones of said plurality of first resistors and two points of each of said plurality of first resistors dividing it into two are connected through said keyboard switches to the one end of a DC power source connected at the other end to said third terminal; output terminals are led out from said first and third terminals or the mid point of said third resistor and said third terminal; and if the diminishing ratio between adjacent notes of the equal tempered scale is taken as \( \eta \), if the values of said first and second resistors are taken as \( r \) and \( R \), respectively; and if the values of said third and fourth resistors are taken as \( R_o \), they bear the following relationships:

\[
\frac{R}{r} = \frac{\eta^2}{(\eta^2 - 1)^2}
\]

(3)

3. A monophonic electronic musical instrument of an equal tempered scale comprising keyboard switches corresponding to notes of said equal tempered scale, a note voltage generator circuit for producing a note voltage corresponding to each of said keyboard switches in response to the depression of each of the keyboard switches, an oscillator for producing a tone signal having a frequency corresponding to said note voltage, an amplifier for amplifying said tone signal, and a speaker connected to said amplifier, characterized in that said note voltage generator circuit includes a plurality of first resistors connected in series between first and second terminals, a plurality of second resistors each connected between the connection point of adjacent ones of said plurality of first resistors and a third terminal common to said first and second resistors and third and fourth resistors connected between said first and third terminals and said second and third terminals, respectively; the connection points of adjacent ones of said plurality of first resistors and two points of each of said plurality of first resistors dividing it into three are connected through said keyboard switches to the one end of a DC power source connected at the other end to said third terminal; output terminals are led out from said first and third terminals or the mid point of said third resistor and said third terminal; and if the diminishing ratio between adjacent notes of the equal tempered scale is taken as \( \eta \), if the values of said first and second resistors are taken as \( r \) and \( R \), respectively; and if the values of said third and fourth resistors are taken as \( R_o \), they bear the following relationships:

\[
\frac{R}{r} = \frac{\eta^3}{(\eta^3 - 1)^3}
\]

(5)

\[
\frac{R_o}{r} = \frac{1}{1-\eta^2}
\]

(6).