United States Patent [19]

Mochida

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[45] **May 7, 1974**

[54] **TONE GENERATOR SYSTEM**

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[73] Assignee: **Nippon Gakki Seizo Kabushiki Kaisha,** Hamamatsu-shi, Japan

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[21] Appl. No.: **311,641**

Related U.S. Application Data

[63] Continuation of Ser. No. 148,746, June 1, 1971, abandoned.

[52] **U.S. Cl.** **84/1.01,** 84/1.25, 84/DIG. 11

[51] **Int. Cl.** **G10h 1/02,** G10h 5/06

[58] **Field of Search.** 84/1.01, 1.03, 1.25, 1.22–1.24, 84/DIG. 11

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Primary Examiner—Richard B. Wilkinson
Assistant Examiner—Stanley J. Witkowski
Attorney, Agent, or Firm—Holman & Stern

[57] **ABSTRACT**

For tone generators in an electronic musical instrument, there are provided a plurality of master oscillators, each for a different octave and each being coupled to frequency dividers having different frequency dividing ratios which ratios are respectively determined to divide down the frequency of the master oscillator to pitches of different notes in the intended octave. The different notes in an octave are obtained by frequency dividing the signal of the single master oscillator, and therefore the number of the master oscillators necessary for the instrument becomes very few. The same lettered notes in different octaves are obtained by frequency dividing the signals of the respectively different master oscillators and are independent in frequency and phase, and therefore there can be obtained much more of a sense of plural different tone sources.

9 Claims, 19 Drawing Figures

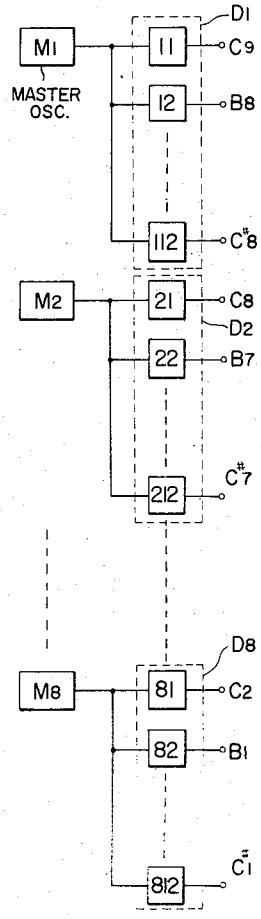


FIG. 1

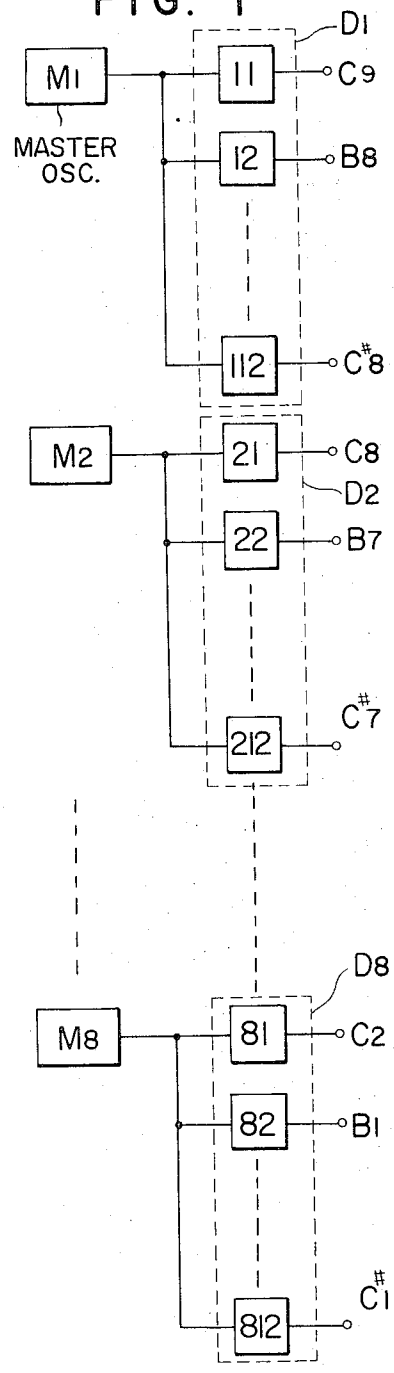


FIG. 2

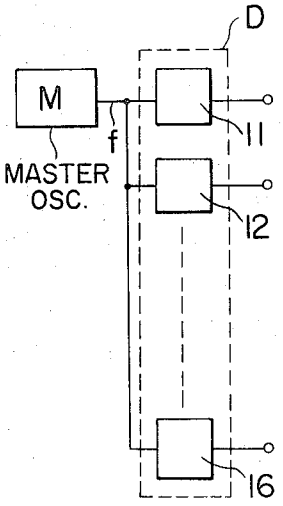


FIG. 4

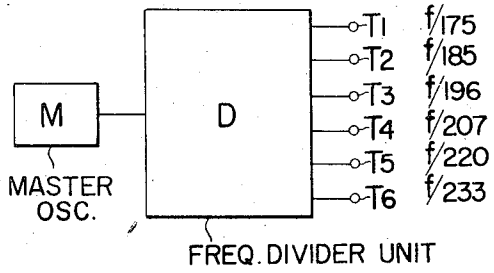


FIG. 3

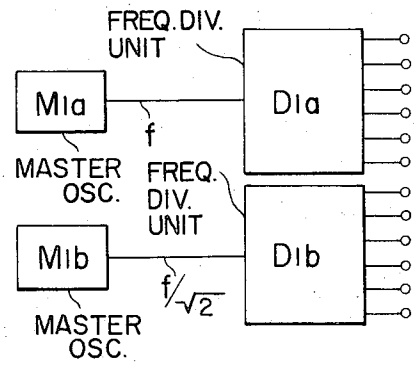


FIG. 5

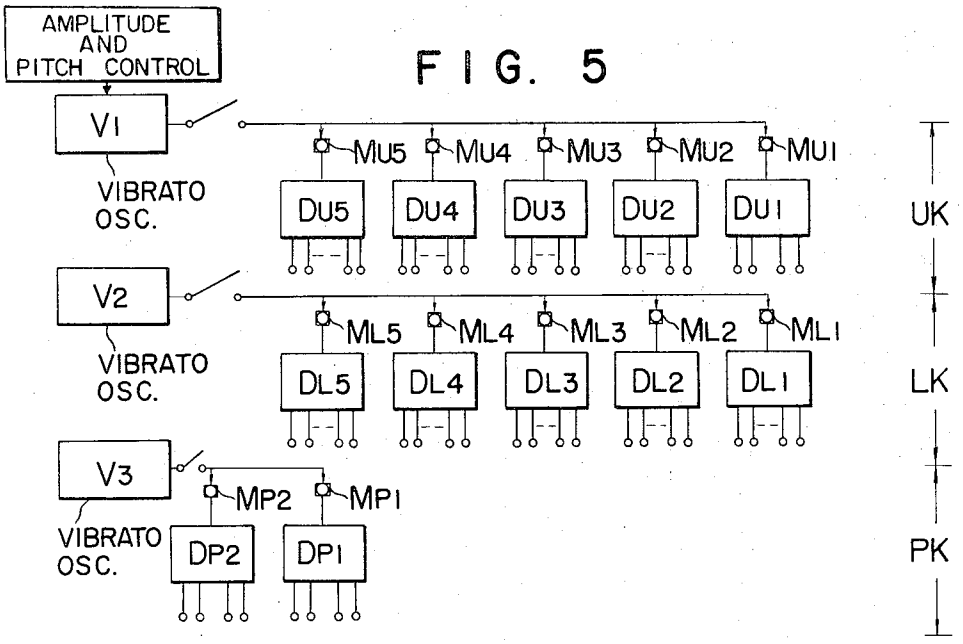
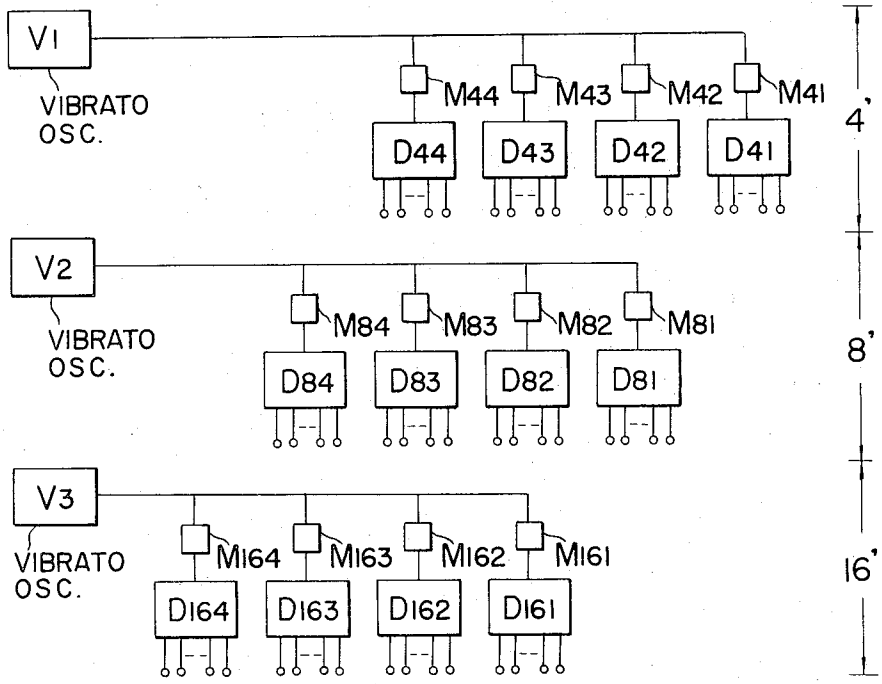

AMPLITUDE AND PITCH CONTROL
V1
VIBRATO OSC.
MU5 MU4 MU3 MU2 MU1
DU5 DU4 DU3 DU2 DU1
UK
V2
VIBRATO OSC.
ML5 ML4 ML3 ML2 ML1
DL5 DL4 DL3 DL2 DL1
LK
V3
VIBRATO OSC.
MP2 MP1
DP2 DP1
PK

FIG. 6


V1
VIBRATO OSC.
M44 M43 M42 M41
D44 D43 D42 D41
4'
V2
VIBRATO OSC.
M84 M83 M82 M81
D84 D83 D82 D81
8'
V3
VIBRATO OSC.
MI64 MI63 MI62 MI61
DI64 DI63 DI62 DI61
16'

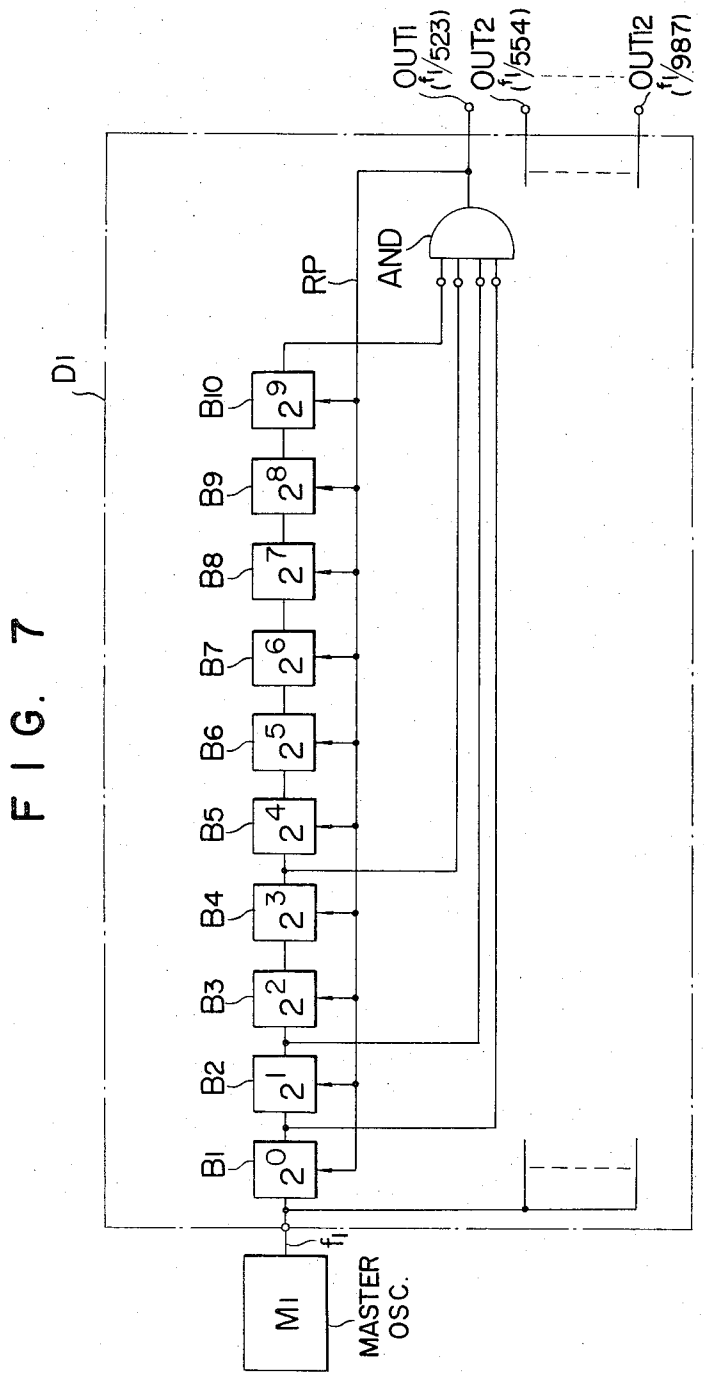

OUT1 (f1/523)
OUT2 (f1/554)
OUT12 (f1/987)
AND
RP
D1
B10
B9
B8
B7
B6
B5
B4
B3
B2
B1
2^9
2^8
2^7
2^6
2^5
2^4
2^3
2^2
2^1
2^0
f1
M1
MASTER OSC.

FIG. 7

FIG. 8

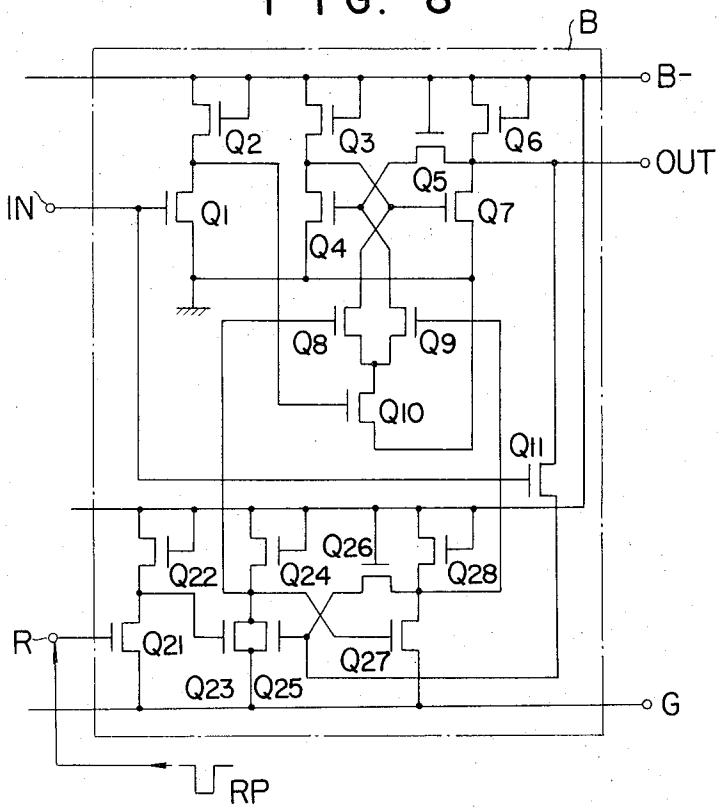

B
B-
OUT
IN
Q1
Q2
Q3
Q4
Q5
Q6
Q7
Q8
Q9
Q10
Q11
Q22
Q24
Q26
Q28
R
Q21
Q27
Q23
Q25
G
RP

FIG. 12

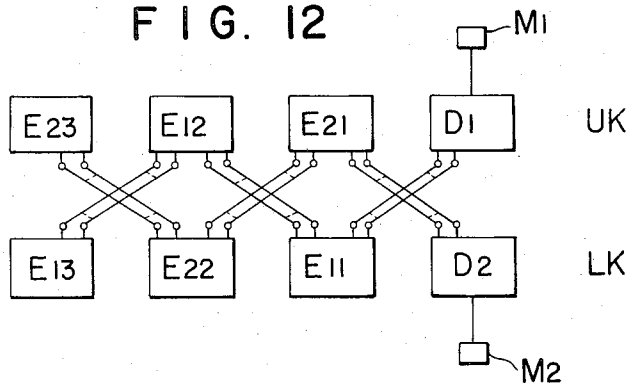

M1
E23
E12
E21
D1
UK
E13
E22
E11
D2
LK
M2

FIG. 9

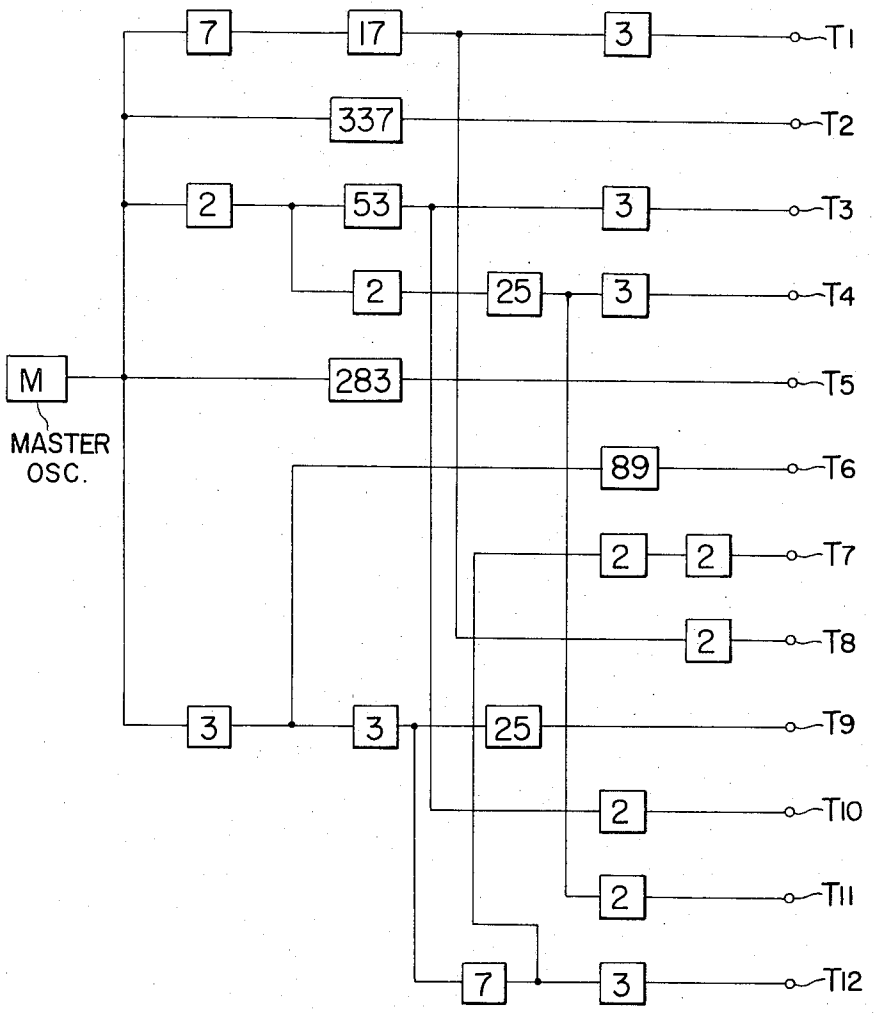

7
17
3
T1
337
T2
2
53
3
T3
2
25
3
T4
M
283
T5
MASTER OSC.
89
T6
2
2
T7
2
T8
3
3
25
T9
2
T10
2
T11
7
3
T12

FIG. 10

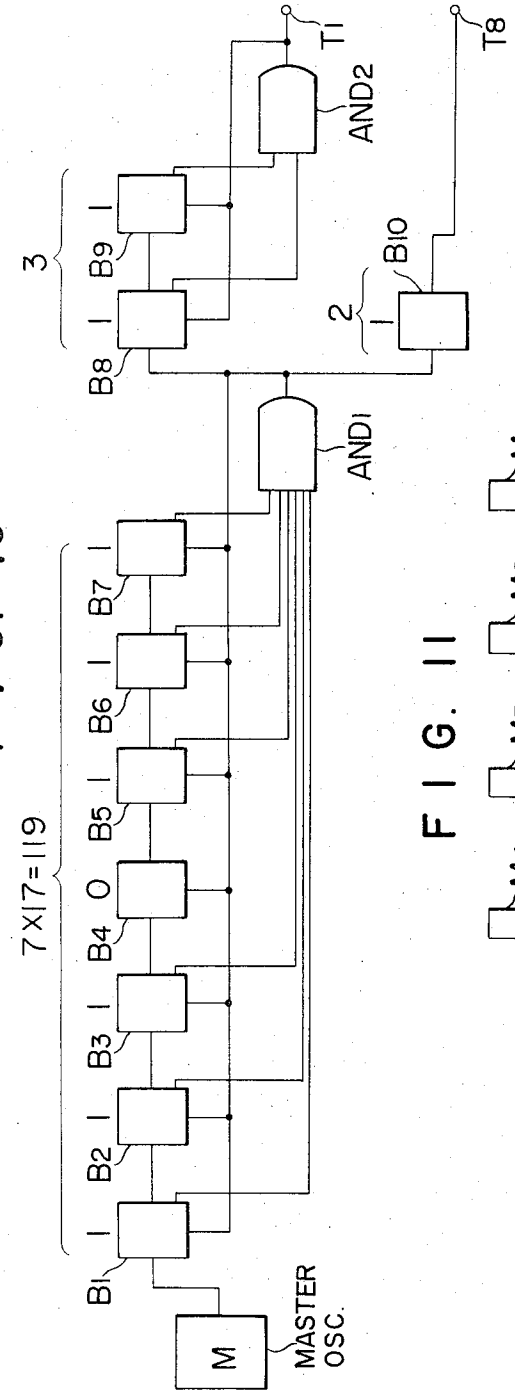

T1
T8
AND2
AND1
3
2
7X17=119
B1
B2
B3
B4
0
B5
B6
B7
B8
B9
B10
M
MASTER OSC.

FIG. 11

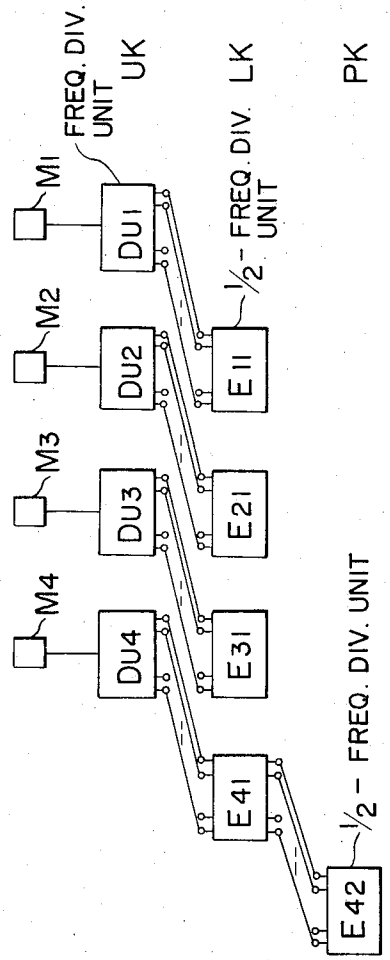

M1
M2
M3
M4
FREQ. DIV. UNIT
UK
LK
PK
DU1
DU2
DU3
DU4
1/2 - FREQ. DIV. UNIT
E11
E21
E31
E41
E42
1/2 - FREQ. DIV. UNIT

FIG. 13

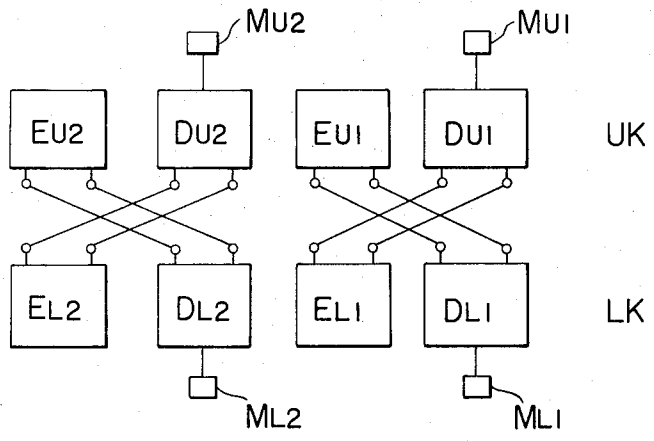

MU2
MU1
EU2
DU2
EU1
DU1
UK
EL2
DL2
EL1
DL1
LK
ML2
ML1

FIG. 17

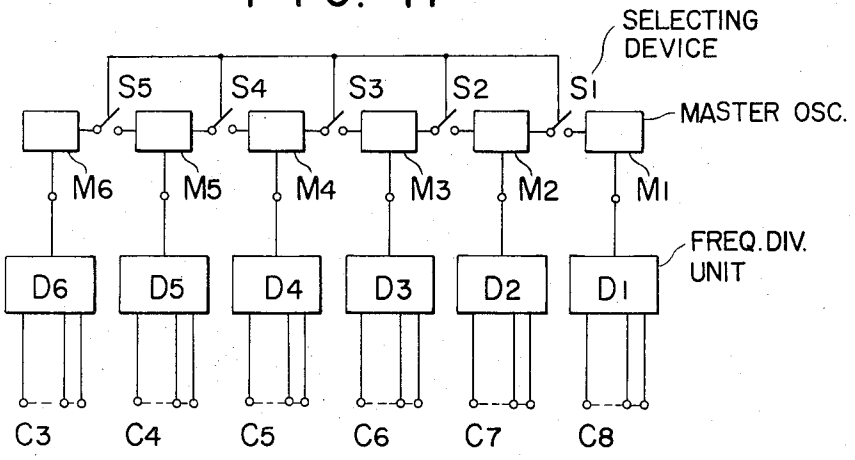

SELECTING DEVICE
S5
S4
S3
S2
S1
MASTER OSC.
M6
M5
M4
M3
M2
M1
FREQ.DIV. UNIT
D6
D5
D4
D3
D2
D1
C3
C4
C5
C6
C7
C8

FIG. 14

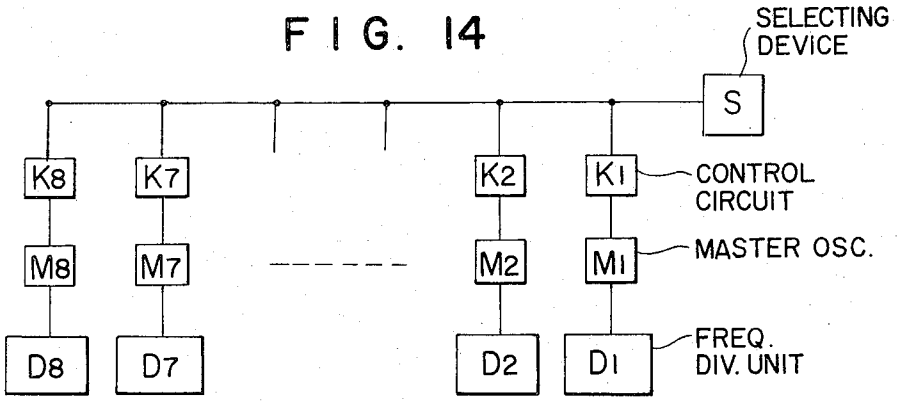


FIG. 15

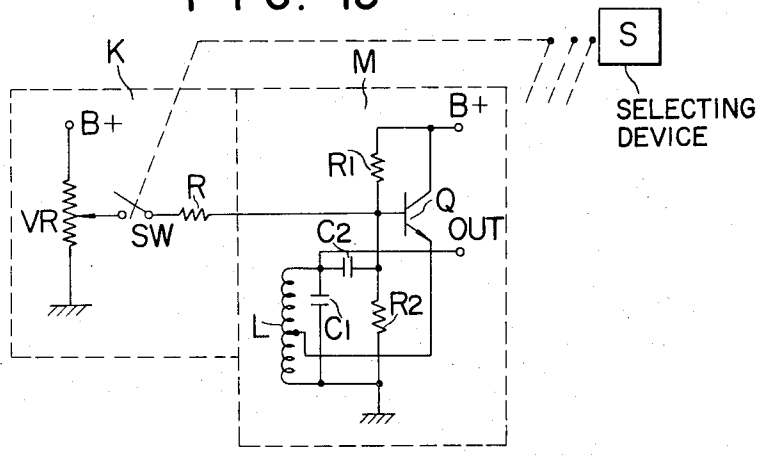
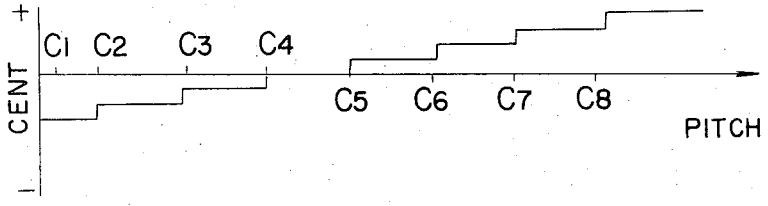


FIG. 16



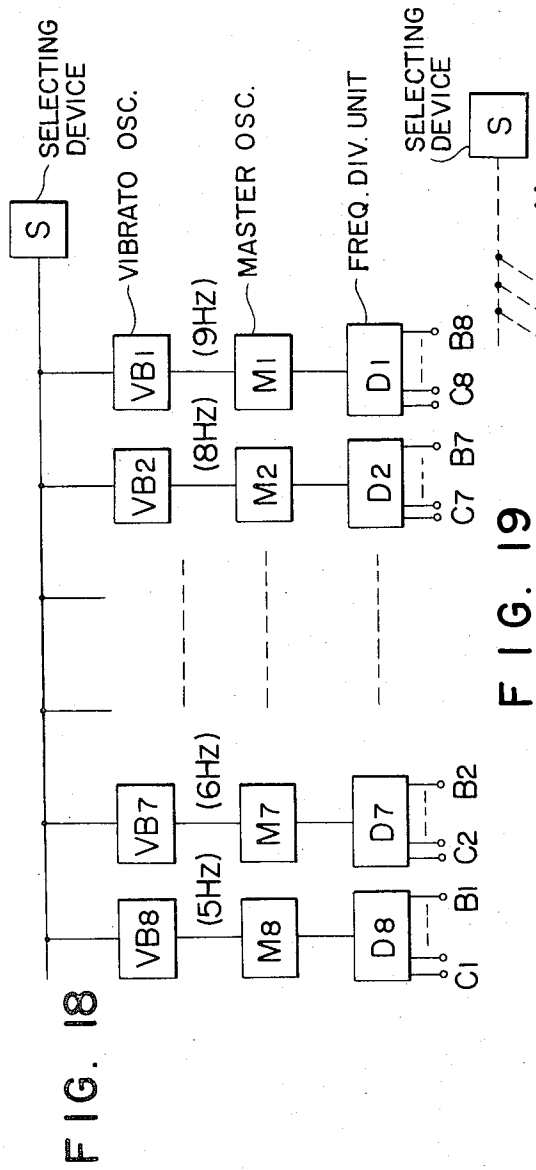

SELECTING DEVICE
S
VIBRATO OSC.
MASTER OSC.
FREQ. DIV. UNIT
SELECTING DEVICE
S
VB1
VB2
VB7
VB8
(9Hz)
(8Hz)
(6Hz)
(5Hz)
M1
M2
M7
M8
D1
D2
D7
D8
B8
C8
B7
C7
B2
C2
B1
C1

FIG. 18

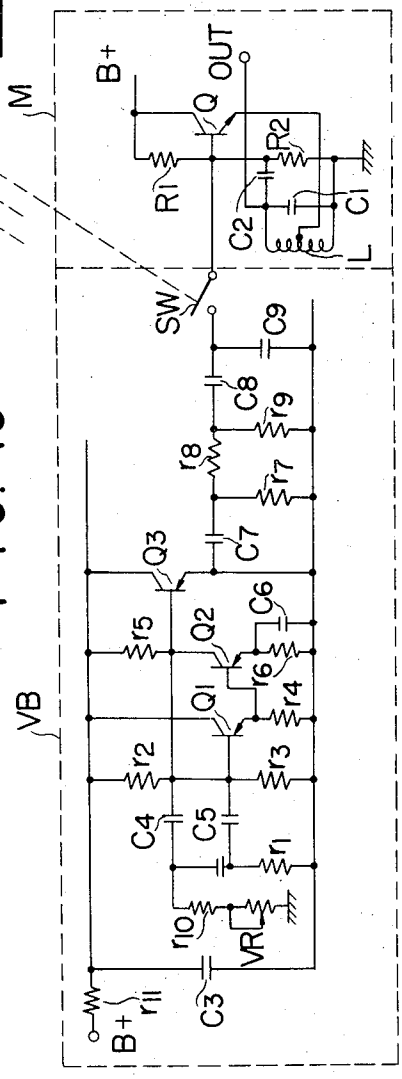

M
B+
Q OUT
R1
R2
C2
C1
L
SW
C9
C8
r9
r8
r7
C7
Q3
C6
r5
Q2
r6
Q1
r4
r2
r3
C4
C5
r1
r10
VR
C3
r11
B+
VB

FIG. 19

TONE GENERATOR SYSTEM

This is a continuation of application Ser. No. 148,746, filed June 1, 1971, now abandoned.

BACKGROUND OF INVENTION

This invention relates generally to tone generator systems for electronic musical instruments, and more particularly to a type thereof wherein a separate master oscillator is provided for each of the octaves, and different notes in an octave are obtained by dividing the frequency of master oscillator by respectively predetermined dividing ratios.

A typical example of the heretofore employed tone generator systems for electronic musical instruments, which may be categorized as "frequency-divider tone generator systems," comprises 12 master oscillators respectively generating 12 notes in the highest one octave of the instrument. The output frequencies of the 12 oscillators are successively divided by one-half so that subsequent octaves are thereby obtained. Although this type of tone generator system is economical in manufacture, the same lettered notes in successive octaves such as C_8, C_7, C_6 .... are in an exact duplicating frequency relation with each other, and the phases thereof are also locked together. For this reason, when a plurality of keys of the same lettered notes in various octaves are depressed simultaneously or a key is depressed with the octave coupler stop switched on, a plurality sensation (a sense that the sounds are coming out from a plurality of tone sources) caused thereby is rather weak.

Another type of the heretofore employed tone generator systems, which may be termed an "individual tone generator system," comprises fully independent oscillators for all notes, thus being very expensive in its manufacture. However, in this kind of tone generator system, all of the same lettered notes in various octaves such as C_1, C_2, C_3, C_4, ... are not in the exact integer multiple relationship, and the phases thereof are not locked together. For this reason, when a plurality of keys of the same lettered notes in various octaves are depressed simultaneously, a composite sound rich in the plurality-sensation, such as that produced by a piano, pipe organ, or the like natural instrument, which has individual tone sources for all of the notes, or by a plurality of monophonic musical instruments played simultaneously, can be obtained.

Although the so-called "individual tone generator system" has the above described advantageous features, it also possesses disadvantages such as requiring much labor and skill in tuning and necessitating a precaution in its design for eliminating interference between the oscillators because a plurality of the oscillators of nearly equal frequencies (different by a same tone) are arranged side by side in a limited space in the musical instrument. Furthermore, in the low-frequency range of the tone scales (for instance, from several tens of Hz to several hundreds of Hz), the sizes of the capacitors and indicators of the oscillators are much enlarged, thus inevitably causing the instrument to become large sized and expensive in manufacture.

It is widely known that in the natural musical instruments such as wind instruments and the piano, the frequencies in the treble regions and the bass regions are deviated somewhat from those of the equal temperament scales in such a manner that sounds of higher frequencies are deviated higher in pitch and those of low frequencies are deviated lower in pitch from the nominal frequencies in the equally tempered scale. These temperament characteristics peculiar to these musical instruments produce a sensation which is more pleasant to listeners when the musical instruments are played, and the hereinbefore mentioned plurality sensation can be obtained when a plurality of such musical instruments are played simultaneously.

Differing from the natural musical instruments, the electronic musical instruments of the conventional types have been designed and manufactured so that the frequencies of the tone generators accurately coincide with those of the equal temperament. For this reason, even if the conventional electronic musical instruments are designed to produce sounds similar to the tone color and attenuation characteristics of those of the wind instruments or pianos, the music playing effects thereof are different from those of the natural musical instruments because of the difference in the above described temperament characteristics.

Furthermore, in the tone generator systems of the individual tone generator type or of the frequency-divider type, when it is desired to obtain vibrato sounds effectuated on the outputs of the individual or master oscillators, each of the individual, master oscillators must be provided with a vibrato oscillator. As a result, the number of the vibrato oscillators becomes considerable, causing the musical instrument to be expensive. Furthermore, in the case of the frequency-divider type tone generator system, where each of the master oscillators is provided with a vibrato oscillator, vibrato effects of the same frequency, depth, and phase relation are rendered on the same tone-names in all of the octaves, whereby the results thus obtained become rather simple and monotonous and has had the drawback of lacking richness in sensation.

SUMMARY OF THE INVENTION

Therefore, the primary object of the present invention is to provide a tone generator system wherein the number of the master oscillators is substantially economized.

Another object of the invention is to provide a tone generator system wherein the advantages in the "frequency dividing tone generator system" and the "individual tone generator system" are also preserved.

Still another object of the invention is to provide a tone generator system wherein a synchronous/asynchronous operation control and vibrato control can be achieved in a simpler manner, and the temperament or tuning of the tone scales is much facilitated.

A further object of the invention is to provide a tone generator system which can create a good "plurality sensation" despite the reduced number of the master oscillators.

These and other objects of the present invention can be achieved by a tone generator system comprising a plurality of master oscillators each for different octave and each followed by and coupled to frequency dividers having respectively different frequency dividing ratios which ratios are respectively predetermined to divide the frequency of the master oscillator down to pitches of different notes in the octave.

The nature, principle, and utility of the present invention will be better understood from following de-

tailed description of the invention when read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is a block diagram of a tone generator system constituting an embodiment of the present invention;

FIG. 2 is a block diagram of one part of a tone generator system constituting another embodiment of the present invention;

FIG. 3 is a block diagram of a part corresponding to one octave of the same embodiment of the invention;

FIG. 4 is a block diagram showing a combination of a main oscillator and a frequency divider unit forming one part of the same example;

FIG. 5 is a block diagram of a tone generator system arranged in accordance with the keyboards, which constitutes still another embodiment of the present invention;

FIG. 6 is a block diagram of the tone generator system arranged in accordance with the coupler systems, which constitutes still another embodiment of the invention;

FIG. 7 is a block diagram showing a detailed organization of a frequency divider unit in the form of a logic circuit;

FIG. 8 is a circuit diagram showing a detailed organization of one part of the frequency divider unit;

FIG. 9 is a diagram showing the factorization of the frequency dividing ratios of the component frequency dividers included in the frequency divider unit;

FIG. 10 is a logic circuit organization of the same frequency divider unit;

FIG. 11 is a block diagram of the tone generator system constituting still another embodiment of the invention;

FIG. 12 is a block diagram of the tone generator system constituting still another embodiment of the invention wherein the frequency divider units of integer frequency ratios and half-frequency divider units are interconnected;

FIG. 13 is a block diagram showing another arrangement of these frequency divider units;

FIG. 14 is a block diagram of a tone generator system constituting still another embodiment of the invention wherein the oscillation frequencies of the master oscillators are made adjustable;

FIG. 15 is a circuit diagram showing the detailed organization of a master oscillator and a control circuit employed in FIG. 14;

FIG. 16 is a diagram showing a tuning (or temperament) characteristics of the tone generator system obtainable in the example shown in FIG. 14;

FIG. 17 is a block diagram of a tone generator system wherein the operation of the master oscillators is selectably in synchronism and in non-synchronism;

FIG. 18 is a block diagram of a tone generator system wherein vibrato oscillators are provided respectively for the master oscillators; and

FIG. 19 is a circuit diagram showing a master oscillator and a vibrato oscillator employed in the example shown in FIG. 18.

DETAILED DESCRIPTION

Referring now to FIG. 1 showing an embodiment of the present invention, there are indicated eight master oscillators M_1, M_2, M_3, ..., M_8 for providing eight octaves, each of which is an ordinary oscillator of, for instance, Hartley type, the frequency produced in any one of the master oscillators being twice that produced by immediately subsequent master oscillator. When an output of these master oscillators M_1, M_2, M_3, ..., M_8 is supplied to a corresponding set of 12 frequency dividers such as **11, 12, ... , 112; 21, 22, ..., 212;** .....; or **81, 82, ..., 812,** 12 notes in each octave such as C_9, B_8, ..., C_8 # ; C_8, B_7, ..., C_7 # ; ....; or C_2, B_1, ..., C_1 # ; are obtained.

In the case where the frequency dividers are of a construction employing a plurality of stages of cascade connected binary counters and obtaining a desired frequency dividing ratio by feedbacks, it is convenient that the number of stages n in each of the above mentioned twelve frequency dividers for one octave be selected to be equal for all of the dividers, and by so doing, the frequency dividing ratio d of each of the 12 frequency dividers falls within a range of

$$2^n \geqq d > 2^{n-1}.$$

Furthermore, the approximation error ϵ (an error between a frequency of the equal temperament pitch and an actually obtained frequency) in this case can be expressed as $\epsilon \leqq 1/2\,d$.

For instance, when the number n of the stages of the binary counters is 10 as later indicated in FIG. 7, all of the frequency dividing ratios d are respectively determined to be within the range of $1{,}024 \geqq d > 512$, that is, $1{,}024 \geqq d \geqq 513$, and the approximating error at this time is within $\epsilon \leqq 1/1{,}026$, that is, less than 1.8 cents. If it is desired, this approximation errors ϵ_o may be made smaller than the above mentioned value by properly selecting frequency dividing ratios d of a more suitable values.

The term "frequency dividing ratio" is herein used instead of the ordinary "frequency dividing factor" to prevent confusion with the common factors or greatest common factor used hereinafter.

In the case where the allowable approximation error ϵ_o is first given, the necessary number n of stages of the binary counters can be defined, by employing the above indicated formula, as being an integer satisfying $n \geqq \log_2(1/\epsilon_o - 2)$. Accordingly, when the number of stages of the binary counters is determined to satisfy the above relation, the actual approximation errors ϵ_o are always less than the allowable error ϵ_o (namely $\epsilon \leqq \epsilon_o$).

Where the frequency range of the intended octave is from f_l to f_h, wherein f_l is a frequency of the lowest pitch among the 12 notes, and f_h is a frequency of the highest pitch among the same 12 notes and is equal to $2^{11/12} \cdot f_l$, the frequency f_1 of the master oscillator M_1 in FIG. 1 is selected in a range of

$$2^n \cdot f_l \geqq f_1 > 2^{n-1/12} \cdot f_l,$$

$$\text{or } 2^{n-11/12} \cdot f_h \geqq f_1 > 2^{n-1} \cdot f_l,$$

and thereby the frequency dividing ratio d for each of the frequency dividers **11, 12, ..., 112** can consequently be determined.

The above described precedures of determining n and d will now be described more fully for the case of obtaining notes of an equal temperament scales ranging from C_8 # (4,434.99 Hz) to C_9 (8,372.02 Hz). Where the frequency errors with respect to the standard pitches are to be less than 1.8 cents, the number n of

stages of the binary counters is determined as being 10 from the above described relation, and from the above described frequency range, it is apparent that the oscillation frequency of the master oscillator M_1 should be within a range of from 4,286.47 to 4,541.36 kHz. When the oscillation frequency f_1 of the first master oscillator M_1 is determined as being a value within the above described frequency range, the frequency dividing ratios of the dividers are determined as being those whereby tones respectively nearest to the 12 notes of C_8 #, D_8, ..., B_8, C_9 are obtainable. Table 1 shows an example wherein a frequency of 4,379 kHz is selected for the first master oscillator M_1, and the frequency dividing ratios are made equal to integers, whereby tones nearest to the notes of an equal temperament are obtained.

TABLE 1

Tone name	Frequency dividing ratio	Error (in cent)
C_8	523	+0.17
B_8	554	+0.48
A_8#	587	+0.31
A_8	622	+0.05
G_8#	659	+0.01
G_8	698	+0.47
F_8#	740	−0.68
F_8	784	−0.68
E_8	830	+0.61
D_8#	880	−0.66
D_8	932	−0.05
C_8#	987	+0.68

In this case, the approximation errors are less than 0.7 cent and are found to be sufficient for practical purposes.

Of course, values other than the above indicated can be employed, and when larger errors are allowable, all of the frequency dividing ratio can be reduced, and the numbers of the stages of the binary counters can be reduced.

The oscillation frequency f_2 of the second main oscillator M_2 is selected at 2,189.5 kHz, one-half of the oscillations frequency f_1 of the first master oscillator M_1, and the oscillation frequencies f_3, f_4, ... of the succeeding master oscillators M_3, M_4, ... are similarly determined.

Although, in the above described embodiment of the present invention, there are provided master oscillators, the output thereof being frequency divided into 12 note pitches, it is of course possible for the frequency of each master oscillator to be divided into six frequencies so that notes in one-half of an octave are obtained. FIG. **2** indicates such an example, wherein the output of the master oscillator M is supplied to six frequency dividers **11** through **16,** included in a frequency divider unit D, each of which has a frequency dividing ratio adapted to produce one of the six notes included in the half octave supported by the master oscillator M. In this example, representing the number of stages in the binary counter by n and the oscillation frequency of the master oscillator M by f, the oscillation frequency f of the master oscillator is selected to satisfy the following relationship.

$$2^n \cdot f_l \geqq f > 2^{n-1/6} \cdot f_l,$$

wherein f_l is the frequency of the lowest note among the six notes, and the frequency dividing ratio d for each of the frequency dividers is determined in accordance with the oscillation frequency f of the master oscillator.

The procedure for obtaining the notes of an equal temperament, in the octave ranging from G_8 (6,271.93 Hz) to C_9 (8,372.02 Hz) will now be described in greater detail. The allowable frequency deviation (or error) is first assumed to be 1.8 cent or less. As a result, the number of stages n is determined to be 10, and the oscillation frequency f of the master oscillator is obtained as being in a range of from 4,541.36 kHz to 4,286.47 kHz. The oscillation frequency f and the frequency dividing ratios d for obtaining C_9, B_8, A_8 #, ... , G_8 from this oscillation frequency f are determined properly under the above described restriction, until satisfactory combinations of f and d are found for rendering least frequency errors.

Table 2 shows a result of such determination, the oscillation frequency f of the master oscillator being selected to equal 4,379 kHz.

TABLE 2

Tone name	Frequency dividing ratio	Frequency error
C_9	523	+0.17
B_8	554	+0.48
A_8#	587	+0.31
A_8	622	+0.05
G_8#	659	+0.01
G_8	698	+0.47

All of the above indicated errors fall within an error range of 0.7 cent, which is much smaller than the initially assumed error range of 1.8 cents.

Although the above described embodiment of the invention makes possible the acquiring of scales corresponding six notes constituting a half octave, it is apparent that the remainder of the notes in the subsequent half octave may also be obtained by employing frequency dividers of the same compositions. That is, as shown in FIG. **3,** the oscillation frequency f of the first master oscillator M is divided in the first frequency divider unit D_{1a} (including six dividers) for obtaining the six notes as shown in Table 2, and the oscillation frequency of the second master oscillator M_{1b}, which is equal to $1/\sqrt{2}\, f$, is frequency divided in the second frequency divider unit D_{1b} (including six dividers) of similar organization as that of the first frequency divider unit D_{1a}, so that six other notes from F_8 # to C_8 # in the next half octave can be obtained.

In this manner, manufacturing of the frequency divider units can be much simplified because of the similar organization of the first and the second frequency divider units D_{1a} and D_{1b}, thus being well adapted to an organization including integrated circuits. It will be apparent that the above described organization of the tone generator circuit for the highest pitch octave may also be applied to the tone generator circuits for the subsequent octaves.

In the case where frequency errors of greater values are allowed, the number of stages of the binary counters may be reduced, for instance, to eight, and the frequency dividing ratios may also be reduced as shown in FIG. **4.** In this case, the frequency dividing ratios and frequency errors corresponding to the output terminals T_1, T_2, ..., T_6 of the frequency divider unit D are as shown in Table 3, and the frequency errors are well

within ±3 cents, causing no deleterious effects in practical applications.

TABLE 3

Output terminal	Frequency dividing ratio	Frequency error (cent)
T_1	175	−2.8
T_2	185	+1.0
T_3	196	+1.0
T_4	207	−1.9
T_5	220	+1.0
T_6	233	+1.6

In FIG. **5**, there is indicated an example wherein a plurality of those generator systems, each organized as shown in FIG. **1**, are provided for the upper keyboard section, lower keyboard section, and the pedal keyboard section of an electronic musical instrument, respectively. All of the tone generator systems have master oscillators, one provided for each octave, and thus the upper keyboard has master oscillators Mu_1 through Mu_5, and frequency divider units Du_1 through Du_5 respectively connected to the master oscillators Mu_1 through Mu_5. Likewise, the lower keyboard has master oscillators ML_1 through ML_5 connected respectively to frequency divider units DL_1 through DL_5, and the pedal keyboard has main oscillators Mp_1 and Mp_2 connected respectively to frequency divider units Dp_1 and Dp_2.

Since all of these master oscillators are operated independently and not in synchronism with other oscillators, tone pitches in different octaves are by no means in an integer multiple relationship with each other, and the phase relations thereof are not definite. For this reason, when two keys in a keyboard in one-octave different relationship are depressed simultaneously, or when they are sounded with an octave coupler stop switched on, or even when two keys of the same pitch but in different keyboards are depressed simultaneously, the hereinbefore mentioned plurality sensation can be obtained as well as the pleasant, widespreading, and natural sensations.

As an auxiliary effect rendering device, each of the keyboards may be provided with a vibrato device (or ultra-low-frequency oscillator) such as V_1, V_2, or V_3, and the output of each vibrato device may be supplied simultaneously to the master oscillators in the corresponding keyboard, when an electronic musical instrument thus provided with vibrato devices is operated, vibrato signals will be produced only in the specific keyboard wherein the vibrato device is activated to effectuate vibrato on all of the tones produced by the selected specific keyboard, and the auditory sensation is thereby enhanced due to the contract between the sounds having and not having vibrato effect, or by the slight deviation of pitches between the sounds effectuated with the vibrato effect. Otherwise, it may be so devised that not only the ON-OFF control of the vibrato signals, but also the pitches and amplitudes of the vibrato signals, may also be controlled.

In addition the above described vibrato rendering device, another type of auxiliary effect rendering device may also be employed. One example of such a device is one for changing pitches (frequencies) of the main oscillators. This may be carried out by changing the d.c. level of frequency controlling terminals of these master oscillators included in a specific keyboard. When the pitches of the master oscillators included in the upper keyboard section are elevated slightly, the melody-playing portion of the performance can be enhanced, and when the pitches of the master oscillators included in the pedal keyboard section are lowered slightly stable and natural sensation of the performance can be obtained,

Although in the above described embodiment of the invention, the tone generator circuits are provided separately for each of the keyboard sections, the tone generator circuits may also be provided separately for each of the coupler groups as shown in FIG. **6**. In this case, the tone generator circuits are made independent for each group of the couplers such as the standard 8-foot register, 4-foot register which are one octave higher than the 8-foot register, and 16-foot register which are one octave lower than the 8-foot register. For the 4-foot register, there are provided master oscillators M_{41}, M_{42}, M_{43}, and M_{44}, respectively, followed by frequency divider units D_{41}, D_{42}, D_{43}, and D_{44}; for the 8-foot register, master oscillators M_{81}, M_{82}, M_{83}, and M_{84}, respectively, followed by frequency divider units D_{81}, D_{82}, D_{83}, and D_{84}; and for the 16-foot register, master oscillators M_{161}, M_{162}, M_{163}, and M_{164}, respectively followed by frequency divider units D_{161}, D_{162}, D_{163}, and D_{164}. In addition, the above described auxiliary effect rendering devices may also be provided for each of the coupler groups for obtaining substantially the same effects as described above. For instance, vibrato oscillators V_1, V_2, and V_3 are provided respectively for the 4-foot, the 8-foot and the 16-foot registers, and respectively connected to the master oscillators in the respective foot registers as shown in FIG. **6**.

In FIG. **7**, there is shown an example wherein each of the above described frequency dividers included in a frequency divider unit D_1 is constituted by binary counters. A signal f_1 from the master oscillator M_1 is applied to 10 stages of binary counters B_1 through B_{10} connected in cascade. Each of the binary counters B_1 through B_{10} is composed of MOS type field-effect transistors Q_1 through Q_{28} as indicated in FIG. **8**, and has an input terminal IN, output terminal OUT, and a reset terminal R. The resettable binary counter depicted in FIG. **8** is of typical and conventional construction. For purposes of completeness, and as will be apparent to those skilled in the art, field-effect transistors Q_2, Q_3, Q_5, Q_6, Q_{22}, Q_{24}, Q_{26}, and Q_{28} of the binary counter function as resistance elements so as to control biasing for the active part of the circuit. The other field-effect transistors form the active part of the circuit which constitutes a conventional flip-flop construction.

In the operation of a frequency divider for the case wherein the frequency f_1 of the master oscillator M_1 is divided into 1/523, for obtaining the tone C_9, an AND circuit detects the instant when the outputs of the binary counters B_1, B_2, B_4, and B_{10} become 1 simultaneously and applies a reset pulse R_P to the reset terminals R, R, ... of all of the binary counters. Since the number 523 can be expressed as a binary number 1000001011, that is, $2^9+2^3+2^1+2^0$, the cascade connected binary counters can count a number from 0000000000 to 1000001011, and an output signal having a frequency equal to $f_1/523$ can be obtained from the output terminal OUT_1 of the frequency divider unit D_1. Frequency dividing circuits for rendering frequencies of 1/554, ..., 1/987 may be organized in a similar manner with respectively proper feed backs, and the

output signals from these frequency dividers are delivered from the output terminals OUT_2, ... , OUT_{12}.

The hereinbefore described frequency divider unit D_1 for an octave is formed by all of the 12 series of the above described binary counter circuits, and the 12 notes (for instance, from C_8 to B_8) in each octave of an electronic musical instrument are obtained from the above described 12 output terminals. It is herein assumed that the frequency dividing ratios may be suitably selected as shown in Table 4.

TABLE 4

Terminal	Frequency Dividing ratio	Factorization
T_1 (C_8 =4186Hz)	357	3×7×17
T_2 (C_8# =4435 Hz)	337	337
T_3 (D_8=4699Hz)	318	2×3×53
T_4 (D_8# =4978Hz)	300	2^2×3×5^2
T_5 (E_8=5274 Hz)	283	283
T_6 (F_8=5588 Hz)	267	3×89
T_7 (F_8# =5920Hz)	252	2^2×3^2×7
T_8(G_8=6272 Hz)	238	2×7×17
T_9 (G_8# =6645 Hz)	225	3^2×5^2
T_{10} (A_8=7040 Hz)	212	2^2 ×53
T_{11} (A_8# =7459 Hz)	200	2^2×5^2
T_{12} (B_8=7902 Hz)	189	3^3 ×7

When the frequency dividing ratios are resolved into factors, the results as shown in the right-hand column can be obtained, and from these results, it is apparent that these frequency dividing ratios have several common factors. Accordingly, in the practical construction of the frequency dividing circuits, at least some of the binary counter circuits corresponding to the greatest common factor can be used commonly for the simplification of the organization.

FIG. 9 shows such an example. In this organization, the frequency dividing ratios are resolved into prime factors or second powers of the prime factors, and the frequency dividing unit D is arranged in accordance with these factorization. In the drawing, reference M designates a master oscillator (oscillating, for instance, at 1.49 MHz), and the numerals indicated in the blocks designate the prime factors or the second powers of the prime factors. For instance, a frequncy divider circuit for obtaining a frequency dividing ratio 357 may be factorized into 3 × 7 × 17. On the other hand, another frequency divider circuit for obtaining a frequency dividing ratio 238 may be factorized into 2 × 7 × 17. As a result, some of the binary counters counting the greatest common factor 7 × 17 may be commonly employed for these two circuits, and all together a saving of eight binary counters can be realized. Likewise, in other frequency dividing circuits, many binary dividers counting the common factors may be commonly utilized therebetween.

In FIG. 10, a frequency dividing circuit for counting the frequency dividing ratio 357, and another frequency dividing circuit for counting the frequency dividing ratio 238 are indicated in more concrete logical circuit composition. In the drawing, M designates an oscillator oscillating at a frequency f (about 1.49 MHz), and B_1 through B_{10} designate binary counters. Two AND circuits AND_1 and AND_2 are also employed. The output from the oscillator M is applied to the binary counter B_1, whereby the binary counters B_1 through B_7 successively count output "1" of the previous stage.

Accordingly if "1" outputs of the binary counters B_1through B_3 and B_5 through B_7 are connected to the input side of the AND_1, an AND condition will be satisfied when the binary counters B_1 through B_7 count a binary number of 1110111 (decimally this corresponds to 7 × 17 = 119), and a pulse will be delivered from the output side of the AND_1. This output pulse is applied to reset input terminals of the binary counters B_1 through B_7, whereby the binary counters B_1 through B_7 are reset. The output pulse from AND_1 is further applied to binary counters B_8 and B_{10}.

"1" outputs of the binary counters B_8 and B_9 are applied to the input side of another AND circuit AND_2, whereby when the binary counters B_8 and B_9 count a binary number 11 (corresponding to a decimal value of 3), and AND condition is satisfied, and an output pulse is delivered from the output terminal T_1 of the AND_2, causing the binary counters B_8 and B_9 to reset. As a result, from the output terminal T_1 of the AND_2, a pulse is delivered each time the counters count 357(119 × 3) of the output frequency of the main oscillator M. This means that an output of $f/357$ (= 4,186 Hz when f is 1.49 MHz) is obtained from the output terminal T_1.

Likewise, the output pulses from the AND_1 are counted in the binary counter B_{10}, and an output pulse is delivered from an output terminal T_8 of the binary counter B_{10} each time a number $f/238$ (= 6,272 Hz) is counted therein. The above described AND circuits AND_1 and AND_2 are not required when $1/2^n$ frequency dividers are employed.

As is apparent from the above described example, binary counters B_1 through B_7 may be employed commonly between the two frequency divider circuits for obtaining $f/357$ and $f/238$, and all together a saving of seven binary counters can be effected. Such an economization can be realized with respect to the other frequency divider circuits, and when a circuit as shown in FIG. 9 is organized under the above described principle, a total saving 32 binary counters can be effected.

In FIG. 11 illustrates still another embodiment of the present invention. For the upper keyboard UK, main oscillators M_1, M_2, ... are provided, one for each octave, and the outputs from the master oscillators are supplied respectively to frequency divider units D_{U1}, D_{U2}, ..., each dividing the frequency of the output of the master oscillator by an integer into twelve notes in the specific octave.

For the lower keyboard LK, a number of half-frequency dividers corresponding to the number of keys in the keyboard are provided, and the required notes for the lower keyboard are obtained by frequency-dividing the outputs of frequency divider units for the upper keyboard, but these are of one octave higher than the required notes. More specifically, half-frequency units E_{11}, E_{21}, ..., each having 12 half-frequency dividers are provided, and the outputs from the frequency divider units D_{U1}, D_{U2},.... are supplied respectively to the half-frequency dividers included in the half-frequency divider units E_{11}, E_{21}, ... being utilized as the required musical scale note for the lower keyboard LK.

For the pedal keyboard PK, a required number of half-frequency dividers are further provided, and the outputs of the above described half-frequency dividers included in the half-frequency divider units E_{11}, E_{21}, ... utilized for the lower keyboard are further supplied to

the half-frequency dividers of the pedal keyboard, one octave lower than those of the lower keyboard, to be frequency-divided therein into half-frequencies, whereby the required notes for the pedal keyboard are obtained.

Although in this example, master oscillators and frequency divider units are provided in the upper keyboard UK, it will be apparent that these may also be provided in the lower keyboard LK, with a required number of half-frequency dividers provided in the upper keyboard and the pedal keyboard, whereby the outputs of these half-frequency dividers may be sequentially frequency-divided by those provided in the upper and pedal keyboards.

In FIG. **12**, there is illustrated still another embodiment of the present invention, wherein master oscillators M_1 and M_2 provided for the upper keyboard Uk and the lower keyboard LK generate substantially similar frequencies, and the outputs thereof are frequency-divided respectively by frequency divider units D_1 and D_2 also located in the upper keyboard section UK and the lower keyboard section LK for obtaining the notes in the highest octave in these keyboards. Half-frequency divider units E_{11}, ... , E_{21}, ... are also provided as shown, disposed alternately between the upper and the lower keyboards, and are connected to other one of the two tone source systems formed by $M_1$and D_1, and M_2 and D_2.

In FIG. **13**, showing still another embodiment of the invention, master oscillators M_{U1} and M_{U2} are included in the upper keyboard section UK, wherein M_{U2} generates a frequency about 1/4 times lower than that of the M_{U1}. Likewise, the master oscillator M_{L1} and M_{L2} are included in the lower keyboard section LK, and M_{L2} generates a frequency about 1/4 times lower than that of the M_{L1}. D_{U1} and $D_{U2}$are frequency divider units included in the upper keyboard, and D_{L1} and D_{L2} are frequency divider units included in the lower keyboard. E_{U1}, E_{U2}...., and E_{L1}, E_{L2} ... are half-frequency divider units provided in the upper and lower keybords, respectively, each including 12 half-frequency dividers. In the upper and lower keyboard sections, frequency divider units D and half-frequency divider units E are connected together in an alternate manner, so that the outputs of the frequency divider units in one of the keyboards are supplied to the half-frequency divider unit in the other keyboard.

If it is assumed that the oscillation outputs from the master oscillators M_{U1} and M_{L1}, and M_{U2} and M_{L2} are respectively of substantially similar frequencies, the outputs from the frequency divider units D_{U1} and D_{L1}, and D_{U2} and D_{L2} will be of the same pitches, and these are further supplied to the input of the half-frequency divider units E of the upper and the lower keyboards. Accordingly, the tone generator system for the keyboards are different in different octaves, whereby the outputs from the frequency divider unit D_{U1} and the half-frequency divider units E_{U1} are not in the same phase relationship, and the frequency ratio of these outputs is not exactly 1/2. For this reason, a result similar to that in the independent tone generator system, which has an independent tone source for each octave, can be obtained in this example.

In FIG. **14**, there is illustrated a further embodiment of the present invention, wherein are included master oscillators M_1, M_2, ..., M_8 of different oscillation frequencies, and frequency divider units D_1, D_2, ..., D_8, each including 12 frequency dividers of integer frequency ratios for obtaining 12 notes in an octave, whereby the required notes of, for instance, from C_1 to B_8 are obtained. K_1, K_2, ... K_8 are control circuits for varying the oscillation frequencies of the master oscillators M_1, M_2, ... M_8 depending on their specific scale ranges, and are operated under the selection of a selecting device S.

In FIG. **15**, there is illustrated a detailed organization of the master oscillator M and the control circuit K. The oscillation frequency of the master oscillator M is set at a predetermined value depending on the scale range covered by the master oscillator M, and the signal sent out from the control circuit K is also determined depending on the scale range. The master oscillator M comprises a transistor Q, a coil L, capacitors C_1 and C_2, and resistors R_1 and R_2 connected as shown. The control circuit K comprises a variable resistor VR for dividing a d.c. voltage, a switch SW operated in accordance with the operation of the selecting device S, and a resistor R. The master oscillator M is so arranged that a tone signal is delivered from the output terminal OUT and is supplied to the frequency divider, and the control circuit K varies the bias voltage of the master oscillator M depending on the position of a slider of the variable resistor VR and on the condition of the switch S, thereby controlling the oscillation frequency of the master oscillator M.

In FIG. **16**, there is indicated an example of a tuning characteristic of the tone generator system according to the present invention. In this example, the tone generator system is arranged to have eight octaves, and the frequencies of the master oscillators for respective octaves are determined beforehand. For this reason, the tuning (or temperament) characteristic is constant within each octave, and by varying the characteristic from one octave to another, all of the tuning characteristics are varied in a stepwise manner, thus resembling the frequency characteristics of the natural musical instrument. The adjustment of the tuning characteristic may be undertaken selectively by ON-OFF controlling of the selecting device depending on the type of the musical instrument which the electronic musical instrument is to simulate.

In FIG. **17**, there is illustrated still another embodiment of the present invention wherein M_1, M_2, ..., M_6 are master oscillators each covering a specific octave, the oscillation frequency of the master oscillator M_1 being determined, for instance, to be 1.49 MHz. D_1, D_2, ..., D_6 are frequency divider units each including a plurality of frequency dividers of an integer frequency ratio with binary counters connected in series and with feed backs and thereby dividing the oscillation frequency of the corresponding master oscillator by an integer for rendering the notes in the corresponding octave. For instance, the frequency divider unit D_1 includes twelve frequency dividers each having a frequency dividing ratio equal to an integer such as 357, 337, 318, 300, 283, 267, 252, 238, 225, 212, 200, or 189. S_1, S_2, ..., S_5 are selecting devices interconnected between the master oscillators M_1 through M_6 for changing the operation of these master oscillators between a synchronized operation and a nonsynchronized operation.

The master oscillators M_1, M_2, ..., M_6 are designed in such a manner that the oscillation frequencies thereof are successively lowered by a ratio of 1/2. Fur-

thermore, these oscillators are placed in an independent condition when the selecting devices S_1 through S_5 are open-circuited, and the oscillators are operated in synchronism when the selecting devices S_1 through S_5 are closed. The selecting devices S_1 through S_5 may consist of switches which are operable independently or interlinkedly. These selecting devices may further be provided with a terminal connected to the control terminal of the master oscillators M_1 through M_6, or, when it is required, the devices may be provided with a multiplier circuit or a frequency divider circuit for producing a control signal for a synchronized operation of the master oscillators.

Assuming that the selecting devices S_1 through S_5 are operable in an interlinked relation as shown in FIG. **17**, and that the selecting devices are open circuited as shown, the whole organization of the tone source system is similar to that of the individual type tone generator system wherein the same lettered notes such as C_3, C_4, ..., C_8 in different octaves are in the nonsynchronized relationship. As a result, if the electronic musical instrument is played in this state, a performance effect similar to that of a pure individual tone generator system, which has an individual oscillator for all of the notes, can be obtained.

When the selecting devices S_1 through S_5 are thereafter closed, the master oscillators M_1 through M_6 are all operated in synchronism, and the operational mode thereof is similar to that wherein the tone generator system is composed of frequency divider circuits. At the time when the selecting devices S_1 through S_5 are closed, it may also be so composed that a multiplication circuit or a frequency divider circuit is operated as described above, and the output thereof is employed as a synchronizing control signal between the master oscillators. More specifically, because the oscillation frequencies of these master oscillators are all in a multiplication relation, the master oscillators may be oscillated precisely in synchronism if a specific oscillator is employed as a prime oscillator, and the output thereof is sequentially multiplied or divided to be employed as a control signal for other oscillators. Such a synchronized operation is required when the "beat effect" caused by an interaction of the sounds thus generated is to be prevented.

In the example shown in FIG. **18**, M_1, M_2, ... M_8 are master oscillators generating different frequencies, and D_1, D_2, ..., D_8 are frequency divider units, each dividing the frequency of the corresponding master oscillator by an integers for obtaining twelve notes in the specific octave. By means of these main oscillators and frequency divider units, all of the required notes, for instance, C_1 through B_8 can be obtained.

In addition to the above described components, there are further provided vibrato-effect oscillators VB_1 through VB_8 for applying vibrato signals to the modulation input terminals of the master oscillators M_1, M_2, ..., M_8. The vibrato oscillators are operated selectively under the action of the selecting device S.

In FIG. **19**, there is illustrated a detailed organization of a master oscillator M and a vibrato oscillator VB. The oscillation frequency of the master oscillator M is set at a desired value corresponding to the scale range covered by the master oscillator, and the oscillation frequency of the vibrato oscillator VB is set at a value suitable for the scale range. For instance, in a treble range, the oscillation frequency of the vibrato oscillator VB is set at a higher frequency (of about 8Hz) and in a bass range, the oscillation frequency is set at a lower frequency (of about 5Hz).

Within the master oscillator M, there are provided a transistor Q, a coil L, capacitors C_1 and C_2, and resistors R_1 and R_2. In the vibrato oscillator VB, there are provided transistors Q_1 through Q_3, a switch SW operated in correspondence with the selecting device S, resistors $r_1$through r_{11}, capacitors C_3 through C_9, a variable resistor VR whereby the oscillation frequency of the vibrato oscillator VB is set at a suitable value within the range of from 5 to 10 Hz. With the closure of the switch SW, the master oscillator M is modulated at a vibrato frequency to cause a vibrato effect on all of the signal produced by the master oscillator. In this organization, since the vibrato frequency is varied for each octave in the case where vibrato is affixed to all of the notes under the control of the selecting device S, the vibrato effect thus obtained can create a far rich auditory sensation. Furthermore, the vibrato effect can be affixed selectively to desired octaves under the control of the selecting device S, whereby the rendition of the musical instrument can be made richer.

I claim:

1. A tone generator system for an electronic musical instrument, said system comprising a plurality of master oscillators, each master oscillator having an output frequency signal representative of a different octave; and a plurality of frequency dividers provided for each master oscillator to receive the output thereof, each frequency divider having a different frequency dividing ratio and respectively dividing a frequency of said each master oscillator down to pitches of different notes in said each octave.

2. A tone generator sytem as set forth in claim **1** including one master oscillator for each octave, and wherein 12 frequency dividers are coupled to each master oscillator, the frequencies of each said master oscillator being different from each other by a ratio of 2:1.

3. A tone generator system as set forth in claim **1** wherein one master oscillator is provided for each half octave, and wherein six frequency dividers are coupled to each master oscillator, the frequencies of each said master oscillator being different from each other by a ratio of 2:1.

4. A tone generator system as set forth in claim **1** wherein each of said frequency dividers have respective frequency dividing ratios of reciprocals of integers and comprises a plurality of cascade connected binary counters having outputs connected to an AND circuit.

5. A tone generator system for an electronic musical instrument, said system comprising a plurality of master oscillators and a plurality of groups of frequency dividers couped to individual oscillators; each divider having a different frequency dividing ratio d falling in a range of $2^n \geq d > 2^{n-1}$which is the reciprocal of integers within an approximation error $\epsilon \leq 1/2d$, where n is the number of stages of binary counters needed in said plurality of frequency dividers to satisfy the latter relationship, said plurality of master oscillators and plurality of groups of frequency dividers coupled thereto being provided for rendering notes constituting an octave, and a plurality of cascade connected half-frequency dividers coupled to each frequency divider for successively dividing the output frequencies of said

frequency dividers into 1/2 for rendering notes constituting other octaves.

6. A tone generator system as set forth in claim **5**, wherein said master oscillators and groups of frequency dividers coupled thereto are provided for rendering notes constituting the highest octaves in the electronic musical instrument; said half-frequency dividers being provided for obtaining the remainder of the octaves in the electronic musical instrument, whereby the next highest octave is obtained by dividing any of the output frequencies of said frequency dividers by one half; and the subsequent octaves are obtained by dividing any of the other output frequencies by half-frequency dividers into one half.

7. A tone generator system comprising a plurality of master oscillators and a frequency divider unit coupled to each master oscillator, each unit including a plurality of stages n of binary counters, each divider having a different frequency dividing ratio d falling in a range of $2^n \geqslant d > 2^{n-1}$ which is the reciprocal of integers within an approximation error $\epsilon \leqslant 1/2d$, where n is the number of stages of binary counters needed in said frequency divider unit to satisfy the latter relationship thereby dividing the oscillation frequency of said master oscillators by integers for rendering the notes within the octaves, a plurality of control circuit means each supplying a signal to a corresponding one of said master oscillators and a selecting circuit for selectively operating said control circuit means such that temperament characteristics of a variable nature can be obtained.

8. A tone generator system comprising a plurality of master oscillators and a plurality of frequency dividers coupled to each master oscillator, each divider having a frequency dividing ratio d falling in a range of $2^n \geqslant d > 2^{n-1}$ which is the reciprocal of integers within an approximation error $\epsilon \leqslant 1/2d$, where n is the number of stages of binary counters needed in said plurality of frequency dividers to satisfy the latter relationship whereby dividing the oscillation frequency of said master oscillators by integers for rendering the notes within the octaves, vibrato oscillators individually connected to individual master oscillators for supplying vibrato signals and having oscillation frequencies set at a suitable value for the scale range of the oscillation frequencies of said master oscillators, and a means for selectively controlling the application of said vibrato signals to said master oscillators for rendering the vibrato effect selectively.

9. A tone generator system comprising a plurality of master oscillators and a frequency divider unit coupled to each oscillator, each unit including a plurality of stages n of binary counters, each divider having a different frequency dividing ratio d falling in a range of $2^n \geqslant d > 2^{n-1}$ which is the reciprocal of integers within an approximation error $\epsilon \leqslant 1/2d$, where n is the number of stages of binary counters needed in said frequency divider unit to satisfy the latter relationship thereby dividing the oscillation frequency of said master oscillators by integers for rendering the notes within the octaves, and a plurality of selecting means interconnected between said master oscillators scuh that said master oscillators are operated synchronously when the selecting means are closed and non-synchronously when the selecting means are opened.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,809,787 Dated May 7, 1974

Inventor(s) Yasunori Mochida

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

[30] Foreign Priority Data:

Japanese No. 46544/70 of May 30, 1970

Signed and Sealed this

twenty-sixth Day of *August 1975*

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,809,787 Dated May 7, 1974

Inventor(s) Yasunori Mochida

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

[30] Foreign Priority Data:

Japanese No. 46544/70 of May 30, 1970

Signed and Sealed this

twenty-sixth Day of *August 1975*

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks