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[54] **ENVELOPE GENERATOR**

[75] Inventors: **Teruo Hiyoshi; Akira Nakada,** both of Hamamatsu; **Tsutomu Suzuki,** Shizuoka; **Eiichiro Aoki,** Hamamatsu; **Eiichi Yamaga,** Tokyo, all of Japan

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

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[51] **Int. Cl.**[3] **G10H 1/02**

[52] **U.S. Cl.** **84/1.26;** 84/1.13

[58] **Field of Search** 84/1.13, 1.26; 364/718, 364/722

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Primary Examiner—J. V. Truhe
Assistant Examiner—Forester W. Isen
Attorney, Agent, or Firm—Spensley, Horn, Jubas & Lubitz

[57] **ABSTRACT**

An envelope generator comprises a counting circuit and counting control means capable of controlling a counting mode of the counting circuit, i.e., operation and non-operation of the counting circuit, counting speed, addition and subtraction etc., in accordance with an envelope shape to be obtained. There are various predetermined counting modes corresponding to different envelope shapes and the envelope generator includes selection means for causing the counting control means to select a desired one of the counting modes.

16 Claims, 30 Drawing Figures

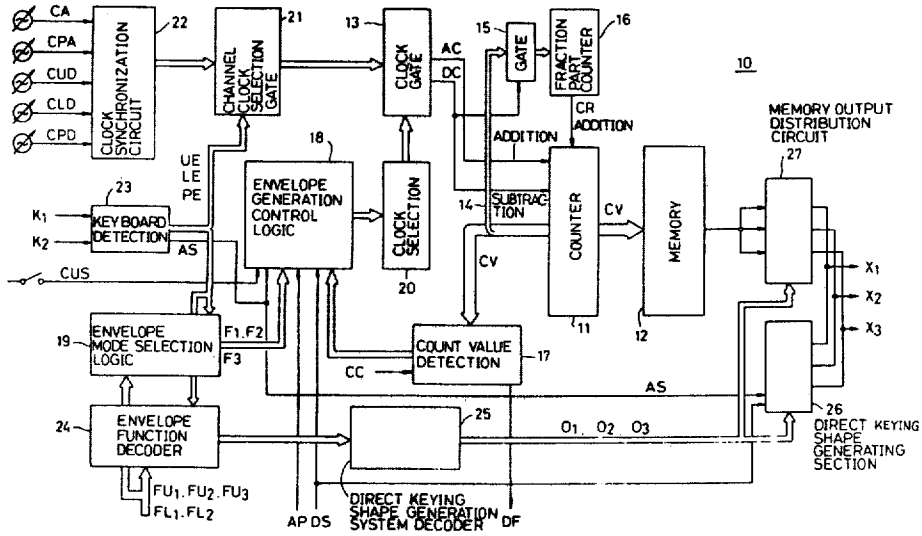


FIG. 1 (a)

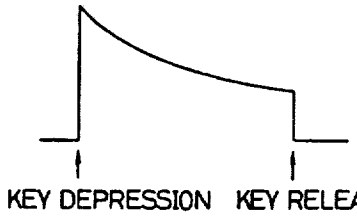


FIG. 1 (b)

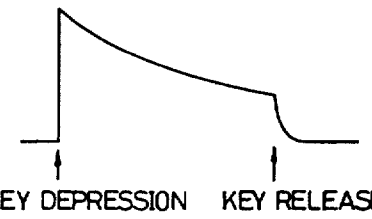


FIG. 12

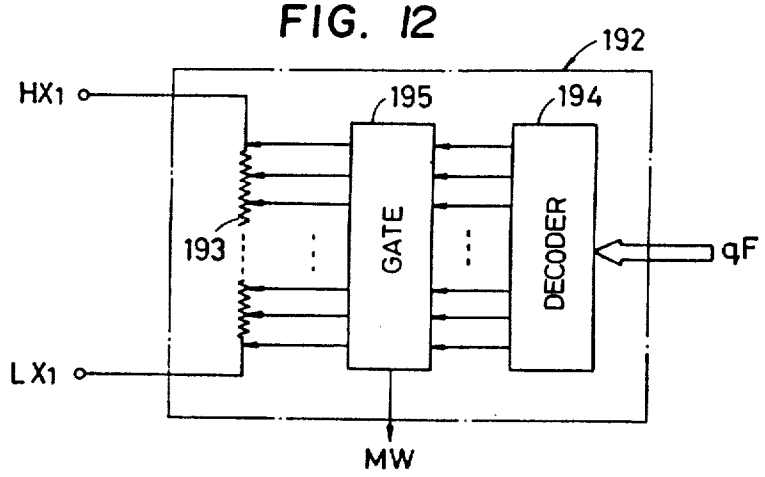


FIG. 13

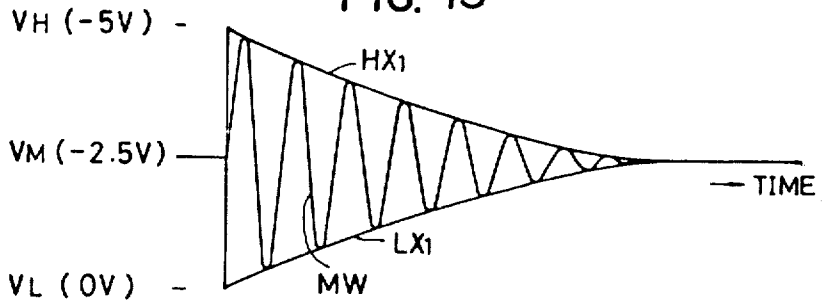


FIG.2

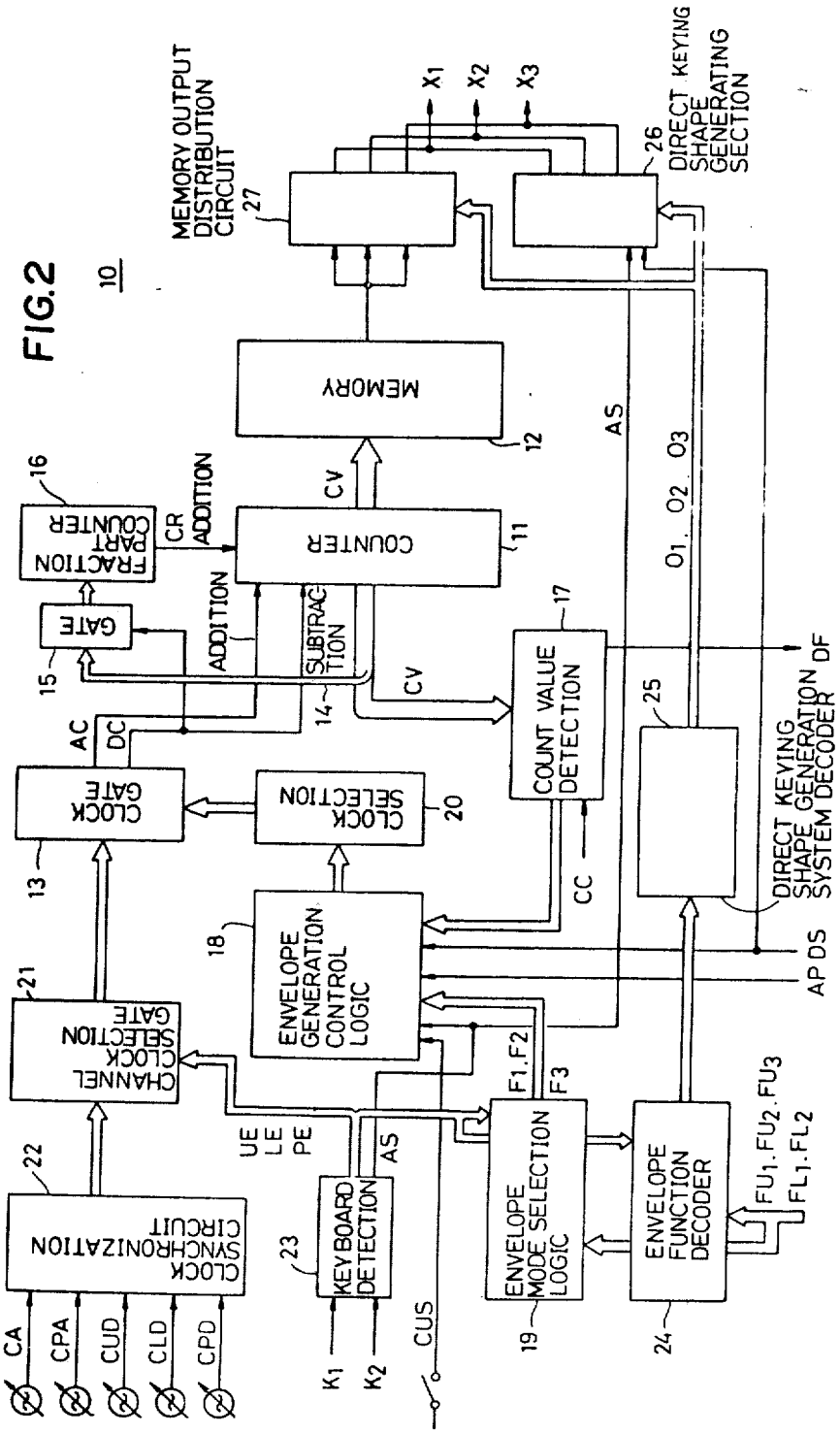

10
MEMORY OUTPUT DISTRIBUTION CIRCUIT
27
X1
X2
X3
26
DIRECT KEYING SHAPE GENERATING SECTION
MEMORY
12
CV
AS
O1. O2. O3
16
FRACTION PART COUNTER
CR
ADDITION
COUNTER
11
GATE
15
ADDITION
SUBTRACTION
14
CV
17
COUNT VALUE DETECTION
25
AC
DC
CLOCK GATE
13
CLOCK SELECTION
20
DIRECT KEYING SHAPE GENERATION SYSTEM DECODER
DF
18
ENVELOPE GENERATION CONTROL LOGIC
CC
AP DS
21
CHANNEL CLOCK SELECTION GATE
F1.F2
F3
UE
LE
PE
AS
ENVELOPE MODE SELECTION LOGIC
19
ENVELOPE FUNCTION DECODER
24
FU1.FU2.FU3
FL1.FL2
22
CLOCK SYNCHRONIZATION CIRCUIT
23
KEY BOARD DETECTION
CA
CPA
CUD
CLD
CPD
K1
K2
CUS

FIG. 3

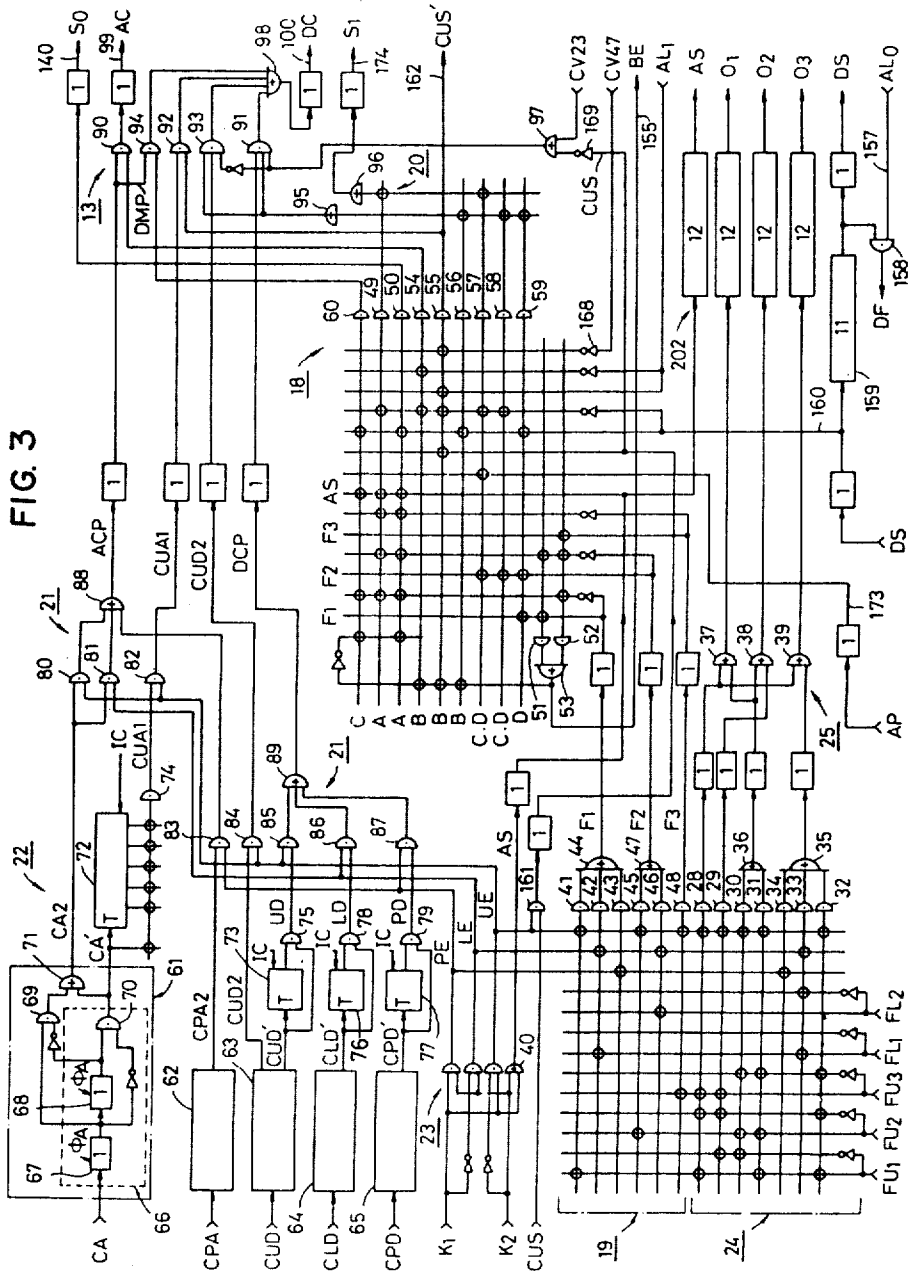

S0
AC
S1
CUS'
CV23
CV47
BE
AL1
AS
O1
O2
O3
DS
AL0
DMP
DF
ACP
CUA1
CUD2
DCP
F1
F2
F3
AS
C
A
A
B
B
B
C.D
C.D
D
IC
CUA1
CA2
CA'
UD
LD
PD
PE
LE
UE
CPA2
CUD2
CUD'
CLD'
CPD'
CA
CPA
CUD
CLD
CPD
K1
K2
CUS
AP
FU1
FU2
FU3
FL1
FL2

FIG. 4

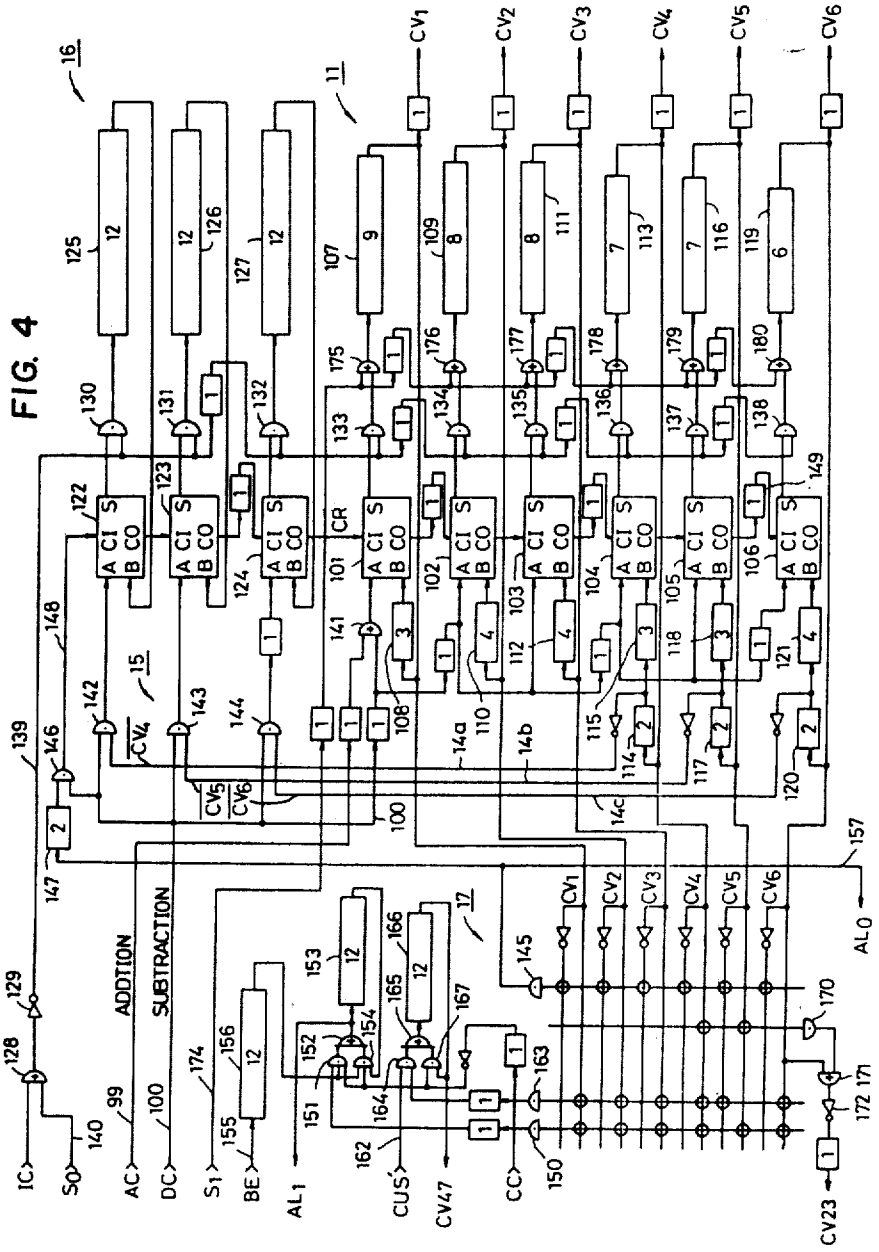
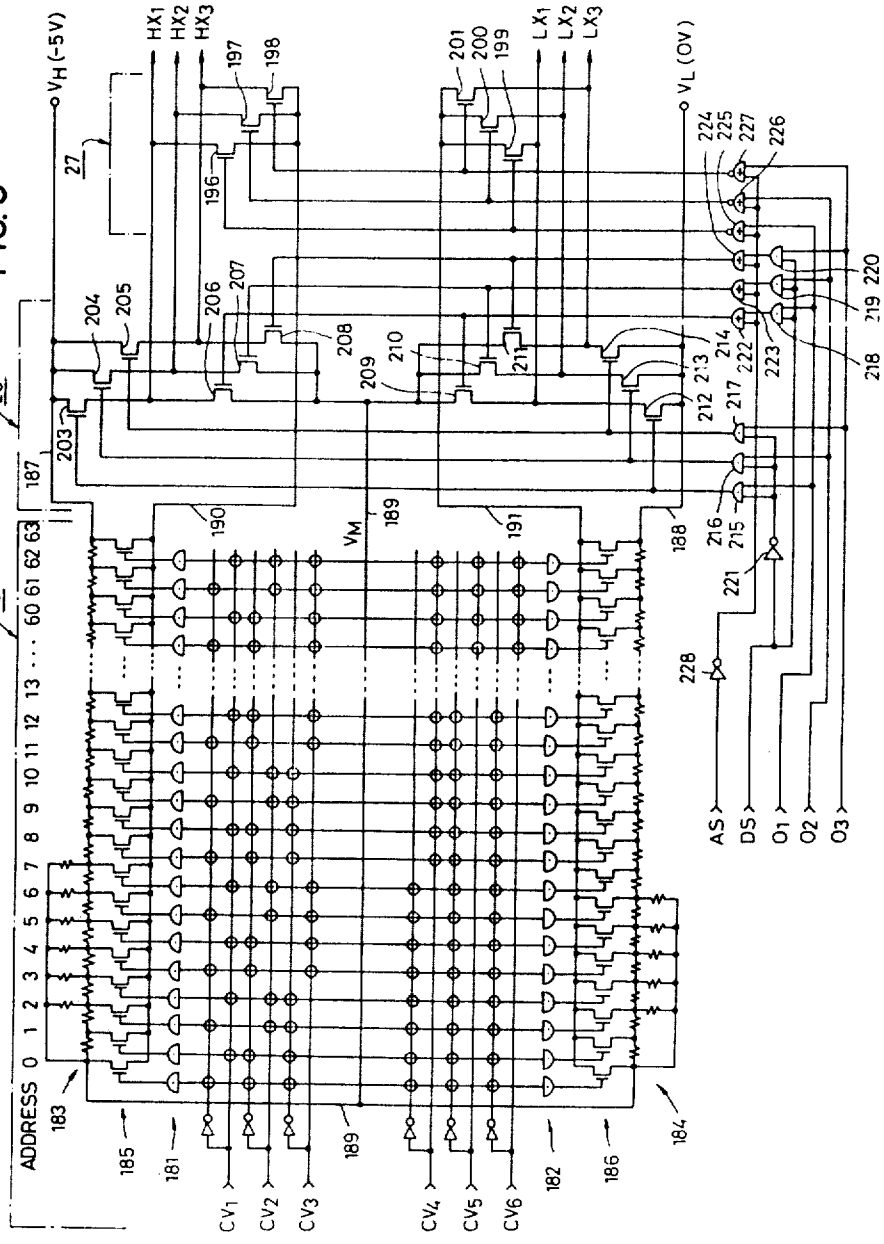

ADDITION
SUBTRACTION
IC
SO
AC
DC
S1
BE
AL1
CUS
CV47
CC
AL0
CV1
CV2
CV3
CV4
CV5
CV6
CV23
A CI S
B CO
CR

FIG. 5


V_H (-5V)
HX1
HX2
HX3
LX1
LX2
LX3
V_L (0V)
V_M
ADDRESS 0 1 2 3 4 5 6 7 8 9 10 11 12 13 ... 60 61 62 63
AS
DS
O1
O2
O3
CV1
CV2
CV3
CV4
CV5
CV6

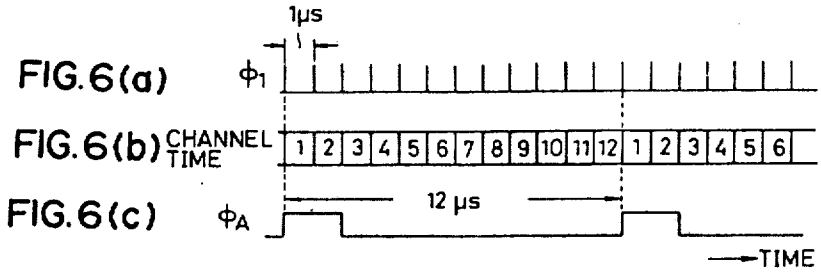
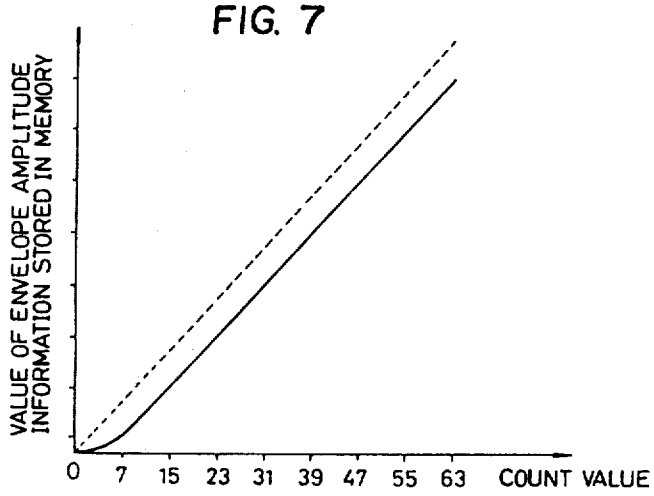
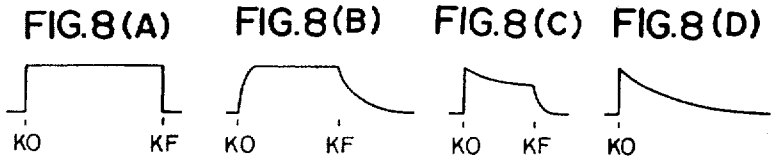

1μs
FIG. 6(a)
ϕ_1
FIG. 6(b)
CHANNEL TIME
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6
FIG. 6(c)
ϕ_A
12 μs
TIME

FIG. 7


VALUE OF ENVELOPE AMPLITUDE INFORMATION STORED IN MEMORY
0 7 15 23 31 39 47 55 63
COUNT VALUE


FIG. 8(A)
FIG. 8(B)
FIG. 8(C)
FIG. 8(D)
KO
KF
KO
KF
KO
KF
KO

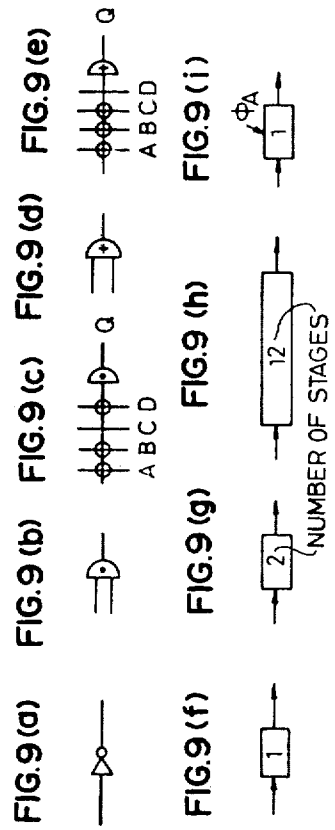
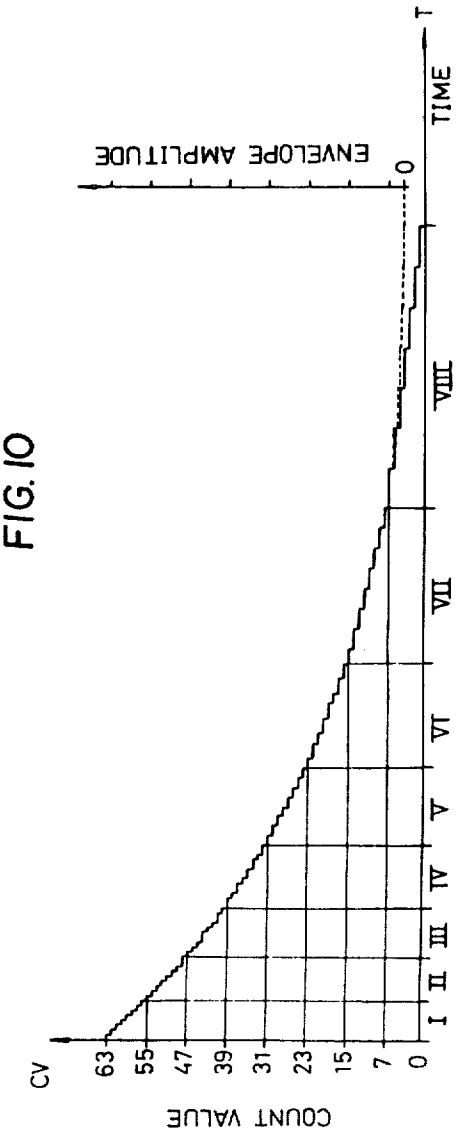
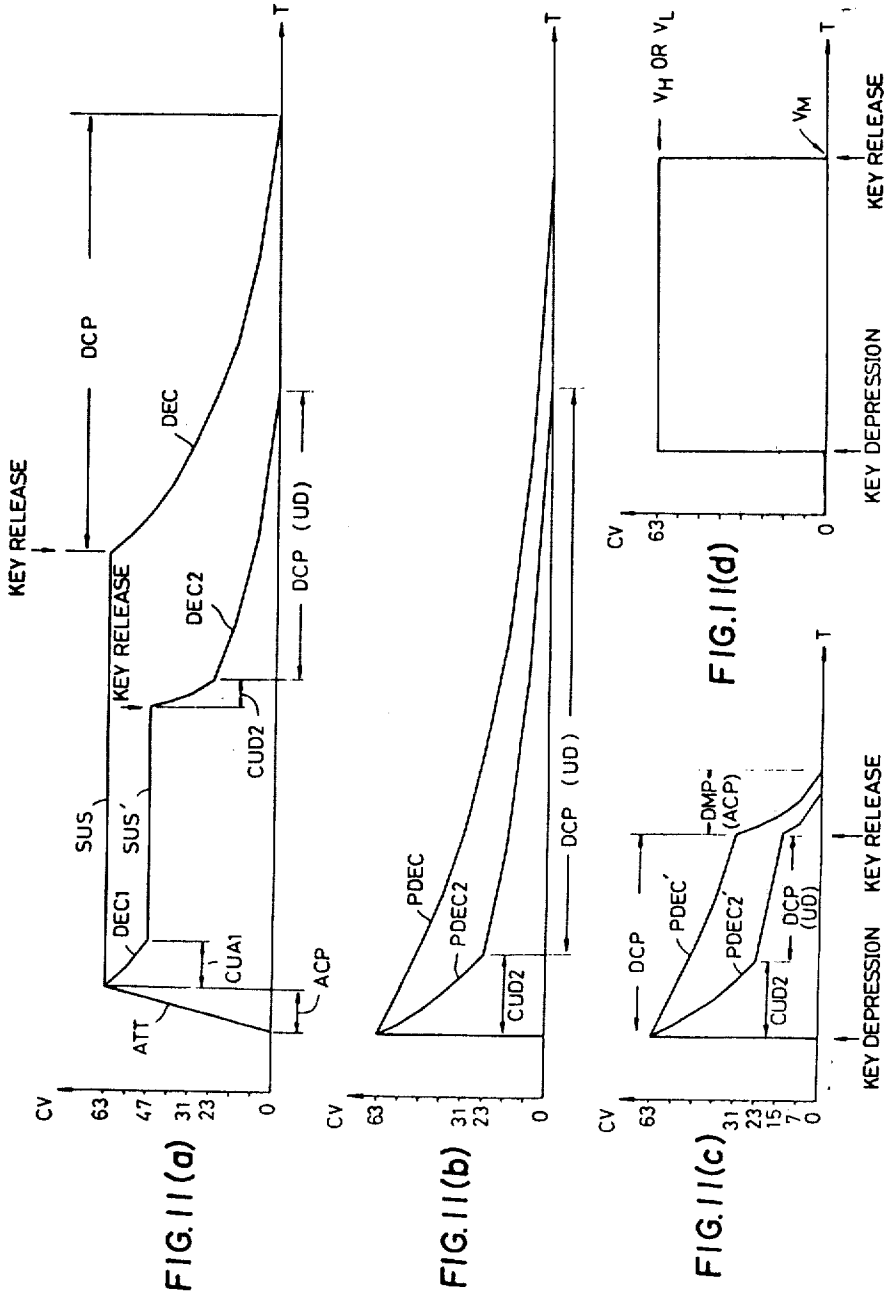

FIG.9(a)
FIG.9(b)
FIG.9(c)
FIG.9(d)
FIG.9(e)
A B C D
FIG.9(f)
FIG.9(g)
FIG.9(h)
FIG.9(i)
NUMBER OF STAGES

FIG. 10


ENVELOPE AMPLITUDE
TIME
T
0
I
II
III
IV
V
VI
VII
VIII
CV
COUNT VALUE
63
55
47
39
31
23
15
7
0


KEY RELEASE
DCP
DEC
KEY RELEASE
DEC2
DCP (UD)
CUD2
SUS
SUS'
DEC1
CUA1
ATT
ACP
CV
63
47
31
23
0
T
FIG. 11(a)
PDEC
PDEC2
CUD2
DCP (UD)
CV
63
31
23
0
T
FIG. 11(b)
VH OR VL
VM
KEY RELEASE
KEY DEPRESSION
CV
63
0
T
FIG. 11(d)
DCP
PDEC'
PDEC2'
DMP-(ACP)
DCP (UD)
CUD2
KEY DEPRESSION
KEY RELEASE
CV
63
31
23
15
7
0
T
FIG. 11(c)

ENVELOPE GENERATOR

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

BACKGROUND AND SUMMARY OF THE INVENTION

This invention relates to an envelope generator of an electronic musical instrument.

In a conventional envelope generator, a single envelope shape of a predetermined shape is stored in an envelope memory and this envelope shape is read out of the envelope memory by driving a readout control counter with a constant clock pulse. Accordingly, only one envelope shape can be produced by one such conventional envelope generator.

It is an object of the present invention to provide a novel envelope generator capable of selectively producing envelope shapes of different shapes with a single memory and counter. According to the invention, contents of a memory are so set that the amplitude level of an envelope shape will correspond to a count value of a memory readout control counter whereby an envelope shape whose amplitude varies in accordance with variation in the count value of the counter is produced. Further, various counting modes of the counter are set by a counter control circuit in accordance with various envelope shapes and a desired one of such envelope shapes is selectively produced by controlling the counting operation of the counter in accordance with a selected one of such counting modes. The term "counting modes" means modes of all elements concerning the counting operation of the counter including timings of starting, stopping and resuming counting, an order of upcounting and downcounting, a counting speed (i.e. a rate of a counting clock pulse) and a switching timing of the counting speed. A term "mode" hereinafter used signifies the above described "counting mode".

In the embodiment of the present invention to be described hereinbelow, four kinds of envelope shapes, i.e., "direct keying mode (A)", "sustain mode (B)", "percussive damp mode (C)" and "percussion mode (D)" as shown in FIG. **8** can be produced. An envelope generation control logic is provided for selectively controlling the counting operation of the counter with respect to each of the above described four kinds of modes. This selection is designated by an envelope mode select signal. The selected counting mode can be changed by a curve select signal.

In a case where the envelope shape of the percussive damp mode is generated by a conventional envelope generator of a type wherein an envelope shape is read out by using a counter and an envelope memory, the envelope abruptly falls upon release of a depressed key, as shown in FIG. **1**(a). This abrupt fall of the envelope causes an ending of a musical tone resembling a click sound. The envelope of the percussive damp mode is generally used for simulating a sound which is produced when a depressed piano key is released during production of a tone and the sound resembling a click sound is undesirable for an ending of a piano tone. According to the present invention, the envelope in the percussive damp mode is provided with a decay shape which, as shown in FIG. **1**(b), falls quickly upon release of the depressed key in response to a high rate damp clock pulse whereby generation of the undesirable click sound is prevented.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**(a) is a graphical diagram showing an envelope shape of the percussive damp mode generated by digital processing employing a conventional envelope counter;

FIG. **1**(b) is a graphical diagram showing an envelope shape of the percussive damp mode to be generated by the envelope generator according to the present invention;

FIG. **2** is a block diagram illustrating one example of the envelope generator according to this invention;

FIGS. **3**, **4** and **5** are three parts of FIG. **2**, FIG. **3** being a block diagram showing circuit elements around a count operation control section in detail, FIG. **4** being a block diagram showing circuit elements around a counter section in detail, FIG. **5** being also a block diagram illustrating circuit elements around a memory section in detail.

FIGS. **6A–6C** are a set of timing graphs indicating the time relation of clock pulses employed in the envelope generator shown in FIG. **2**;

FIG. **7** is a graphical representation indicating relationships between the count values of a counter and the contents stored in a memory employed in the envelope generator.

FIG. **8A–8D** are a set of graphs indicating envelope shapes in various modes which can be generated by the aforementioned envelope generator;

FIGS. **9A–9I** are a set of diagrams indicating methods of illustrating a variety of circuit elements;

FIG. **10** is a graphical representation indicating variations in count value of a counter in detail in the case where a decay envelope shape of exponential characteristic is generated by the polygonal line approximation with envelope amplitude levels on the right-hand vartical line, count values in the last region VIII being converted into exponential function values as indicated by the broken line;

FIG. **11** is a set of graphical representations schematically indicating the variations in count value of the counter in providing various envelope modes, FIG. **11**(a) through FIG. **11**(d) showing a sustain mode, a percussion mode, a percussive damp mode, and a direct keying mode, respectively, and an ordinary mode and a mode in which a curve selection function is effected being plotted in each of FIG. **11**(a) through FIG. **11**(c);

FIG. **12** is a block diagram illustrating one example of a musical tone shape memory in an electronic musical instrument utilizing envelope shapes generated by the envelope generator described above; and

FIG. **13** is a graphical representation schematically indicating a state that an envelope is given to a musical tone signal in the circuit shown in FIG. **12**.

DETAILED DESCRIPTION OF THE INVENTION

One preferred embodiment of this invention will be described with reference to the accompanying drawings.

Shown in FIG. **2** is an envelope generator **10** which is utilized for envelope control of an electronic musical instrument. A keyboard code K_1, K_2 is produced when a key of a keyboard (not shown) is depressed, and it represents the sort of keyboard to which the key thus depressed belongs. The relationships between the con-

tents of the key codes K_1, K_2 and the sorts of keyboards are as indicated in Table 1 below:

TABLE 1

	K_1	K_2
Upper keyboard	1	0
Lower keyboard	0	1
Pedal keyboard	1	1

A decay start signal DS is provided when the depression of the key which has produced the aforementioned keyboard code K_1, K_2 is released. When the envelope generator **10** has produced one envelope shape, a decay finish signal DF is provided, as described later. If the decay start signal DS and the decay finish signal DF are provided simultaneously, a clear signal CC is produced. Upon production of this clear signal CC, the decay start signal DS and the keyboard code K_1, K_2 are cleared. Accordingly, the keyboard code K_1, K_2 is kept produced for the period of time from the depression of key to the generation of the clear signal CC, and represents the fact that the tone of the key depressed is being produced by the electronic musical instrument. On the other hand, the decay start signal DS is produced for the period of time from the release of key to the production of the clear signal CC, and represents the fact that the tone of the key depressed is being produced but decayed. An attack pulse AP is a single pulse which is produced when a key is depressed.

These signals K_1, K_2, DS, CC and AP are produced by a tone production assignment circuit (not shown), which may be referred to as "a key assignor" or "a channel processor" of the electronic musical instrument, and are applied to the envelope generator **10**. The tone production assignment circuit is capable of simultaneously producting plural tones through time sharing treatment and assigning the tone of one depressed key to one of a plurality of time-shared tone production channels. Accordingly, the above-described signals K_1, K_2, DS, CC and AP are supplied in time-sharing manner in synchronization with the time of the channel assigned to which production of the tone of the depressed key has been assigned. Therefore, the envelope generator **10** operating by receiving these signals K_1, K_2, DS, CC and AP can carry out a time sharing operation which is illustrated in FIGS. **3** to **5** in detail.

FIG. **6**(a) is a graphical representation indicating a main clock pulse ϕ_1 which is adapted to control the time sharing operation of each channel. The period of the main clock pulse is, for instance, one microsecond (10^{-6} second). As the number of channels is twelve (12), time slots (each having 1 microsecond in time width) obtained by sequentially dividing time with the clock pulses ϕ_{11} correspond to the first to twelfth channel times, respectively. Hereinafter, as is shown in FIG. **6**(b) the time slots will be referred to as the first through twelfth channel times, respectively, when applicable. It goes without saying that the channel times are cyclically provided. A synchronization clock pulse ϕ_A as shown in FIG. **6**(c) has a period of twelve microseconds and is employed for allowing an attack clock pulse and a decay clock pulse (described later) to synchronize with the whole channel time (12 microseconds).

Referring back to FIG. **2**, the count output of a counter **11** is applied to a memory **12** where it is converted into envelope amplitude information whose value corresponds to the count value CV thereof. The contents in the memory **12** are as shown in FIG. **7**, for instance, showing an exponential characteristic in the vicinity (0–7) of the count value 0 and a linear characteristic in the other count values (8–63). It goes without saying that amplitude information indicating a linear relation with the whole count values (0–63) as shown by the broken line may be stored in the memory **12**.

The count value of the counter **11** is increased by the attack clock pulses AC supplied from a clock gate **13** thereto and is decreased by the decay clock pulses DC also supplied from the clock gate **13** thereto. In the case where an exponentially varying decay envelope is obtained by the polygonal line approximation, the data of predetermined higher significant bits in the counter **11** is fed back to a fraction part counter **16** through a line **14** and a gate **15** at a timing of the decay clock pulse DC. A carry signal CR is provided as a result of the computaion effected by the fraction part counter **16**. This carry signal CR is applied to the addition input of the counter **11**. Accordingly, the extent of the subtraction by the decay clock pulses DC is changed according to the frequency of application of the carry signals CR, and the count value CV is changed exponentially.

The change with time of the count value CV of the counter **11** corresponds to the shape of the envelope generated. Therefore, a variety of envelope shapes can be obtained by controlling the count operation of the counter **11**. A count value detecting circuit **1** operates to detect the fact that the count value of the counter **11** has reached a predetermined value, and to supply a signal representative of a state of the counter **11** to an envelope generation control logic **18**. This envelope generation control logic **18** operates to generate an envelope shape as desired by controlling the addition or subtraction, count speed, count start, and count stop of the counter **11**. The mode of an envelope shape is determined with the aid of envelope mode selecting signals F1–F3 provided by an envelope mode selection logic **19**. Furthermore, the shape of the envelope shape designated by the envelope mode selecting signals F1–F3 can be switched by a curve selecting signal CUS applied to the envelope mode selection logic **19**.

A clock selection circuit **20** operates to open the clock gate **13** with the aid of the output of the envelope generation control logic **18**, and to allow one of a plurality of clock pulses supplied from a channel clock selection gate **21** to be applied, as the attack clock pulse AC or the decay clock pulse DC, to the counter **11**. In this example, different attack clock pulses or decay clock pulses are employed separately according to the sorts of keyboards, whereby with the same envelope shape the attack time or the decay time is changed separately according to the sorts of keyboards. Therefore, attack clock signals CA for the upper and lower keyboards, an attack clock signal CPA for the pedal keyboard, a decay clock signal CLD for the lower keyboard, a decay clock signal CUD for the upper keyboard, and a decay clock signal CPD for the pedal keyboard are generated separately and are applied through a clock synchronization circuit **22** to the channel clock selection gate **21**. The clock synchronization circuit **22** operates to cause the pulse widths of the aforementioned clock signal CA–CPD to synchronize with one cyclical period (12 microseconds) of the whole channel time.

A keyboard detection circuit **23** serves to decode the keyboard code K_1, K_2 and to output an upper keyboard signal UE, a lower keyboard signal LE, or a pedal keyboard signal PE according to the content thereof. If

either of the data K_1 and K_2 is "1", the keyboard detection circuit **23** produces an attack start signal AS representing that by the depression of the key, the concerning channel should be in a tone production mode. The keyboard signals UE, LE, and PE operate to open the channel clock selection gate **21** in time sharing manner according to the respective time slots corresponding to their generations, and to select in time sharing manner the clock pulses corresponding to the keyboards of the tones assigned to the channels. The clock pulses thus selected are multiplexed separately according to the attack clock pulse and the decay clock pulse, and are supplied to the clock gate **13**.

The envelope mode selection logic **19**, basing on envelope function switching data FU_1, FU_2, FU_3, FL_1 and FL_2 and the keyboard signals UE, LE and PE, outputs in time sharing manner envelope mode selecting signals **F1**, **F2** and **F3** corresponding to functions selected by the player.

In the envelope generator **10** of this example, three envelope shapes are produced in a parallel mode from three groups X_1, X_2 and X_3 and four envelope modes as shown in FIGS. **8**(A) through (D) can be provided. FIGS. **8**(A) through (D) indicate a direct keying mode, a sustain mode, a percussive damp made, and percussion mode, respectively. In FIG. **8**, reference characters KO and KF are intended to designate the timing of the key-on and that of the key-off, respectively. In general, the envelope shape of the direct keying mode and one of the envelope shapes of the remaining three modes are combined and are distributed suitably to the three groups X_1, X_2 and X_3 thereby to produce tones.

The 3-bit envelope function switching data FU_1, FU_2 and FU_3 are to select the envelope functions of the upper keyboard tones, while the 2-bit envelope function switching data FL_1 and FL_2 are to select the envelope functions of the lower keyboard tone. For the pedal keyboard tone, it is unnecessary to provide selection data especially, because only one envelope function is selected at all times. Thus, in this example, the envelope functions can be selected separately according to the sorts of keyboards. In this connection, it is obvious that the data FU_1, FU_2, FU_3, FL_1 and FL_2 are set by switching means (not shown). The term "envelope function" as herein used is intended to mean combination of envelope modes distributed to the groups X_1, X_2 and X_3. Accordingly, the envelope function switching data FU_1, FU_2, FU_3, FL_1 and FL_2 are to represent which mode of envelope shape should be distributed to which group (X_1, X_2 or X_3) in the channel of the upper or lower keyboard tone. In order to process the function switching data separately according to the channels, the time-shared keyboard signal UE, LE and PE are applied to the envelope mode selection logic **19** and an envelope function decoder **24**.

The envelope shapes as shown in FIGS. **8**(B), (C) and (D) which change with time are produced by the system of the counter **11** and the memory **12** with the aid of the control operation of the envelope generation control logic **18**. The direct keying shape as shown in FIG. **8**(A) is produced by the system of a direct keying shape generating system decoder **25** and a direct keying shape generating section **26**. It goes without saying that the counter **11** and the memory **12** may be employed for producing the direct keying shape only.

The envelope function decoder **24** serves to decode in time sharing manner the function switching data including the direct keying mode, and to apply a time-shared decoded output to the direct keying shape generation system decoder **25**. The decoder **25** is so designed that it produces outputs O_1, O_2 and O_3 corresponding to the groups X_1, X_2 and X_3. More specifically it outputs the direct keying shape selecting signal (O_1, O_2, or O_3) in correspondence to the group (X_1, X_2 or X_3) which should produce the direct keying mode envelope shape in the envelope function decoded by the above described envelope function decoder **24**.

The direct keying shape generating section **26** produces the envelope shape of the direct keying mode in the group X_1, X_2 or X_3 to which the direct keying shape selecting signal O_1, O_2 or O_3 is supplied. In the group X_1, X_2 or X_3 corresponding to the selecting signal O_1, O_2 or O_3, the direct keying shape (FIG. **8**(A)) having a constant level is produced for the period of time from the generation of the attack start signal AS to the generation of the decay start signal DS, that is, the period of time from the depression of a key to the release of the key.

A memory output distribution gate **27** serves to distribute the envelope shape signals read out of the memory **12** to any one of the groups X_1–X_3 where no direct keying shape selecting signals O_1–O_3 are provided. For instance, in the case where the direct keying mode envelope shapes are produced in the groups X_1 and X_2, and the percussion mode envelope shape is produced in the group X_3, the percussion mode envelope shape is produced in the system of the counter **11** and the memory **12**, and this envelope shape is distributed to the group X_3 by the gate **27**.

The counter **11**, the gate **15**, the fraction part counter **16**, and the count value detection circuit **17** in the envelope generator **10** shown in FIG. **2** are illustrated in FIG. **4** in more detail. The memory **12**, the direct keying shape generating section **26** and the memory output distribution gate **27** are illustrated in FIG. **5** in detail. The remaining elements around the envelope generation control logic **18** are illustrated in FIG. **3** in detail.

Before describing the various elements in FIGS. **3** to **5** in detail, a variety of symbols or figures employed therein will be described with reference to FIG. **9**. FIG. **9**(a) shows an inverter, FIGS. **9**(b) and **9**(c) show AND circuits, and FIGS. **9**(d) and **9**(e) show OR circuits. In the AND circuits and the OR circuits, if the number of inputs are relatively small, an illustration method as shown in FIGS. **9**(b) and **9**(d) is employed; and if the number of inputs are relatively large or some out of hte number of signals are selectively applied thereto, an illustration method as shown in FIGS. **9**(c) and **9**(e) is employed. In the illustration method shown in FIGS. **9**(c) and **9**(e), one input line is provided on the input side of the circuit, and signal lines are intersected with the input line, the intersections of the input line and the signal lines being encircled. Accordingly, in the case of FIG. **9**(c), the logical expression is $Q=A\cdot B\cdot D$. In the case of FIG. **9**(e), the logical expression is $Q=A+B+C$. Shown in each of the FIGS. **9**(f), **9**(g) and **9**(h) is a shift register for delay of 1-bit signals (or a delay flip-flop circuit). The numeral ("1" or "12") in the block is intended to designate the number of delay stages. In the case where no shift clock signal is indicated as in FIGS. **9**(f), **9**(g) and **9**(h), the shifting is carried out by the above-described main block pulse ϕ_1 (in practice, a two-phase clock signal is used). For instance, a "one" stage shifting means the delay of one microsecond. In the case where a clock pulse ϕ_A is indicated as the shift clock signal as in FIG. **9**(i), the

circuit is a delay flip-flop circuit controlled by clock pulses ϕ_A applied at a period of 12 microseconds thereto (in practice, a two-phase clock signal is employed).

In this example, the signal is each channel is processed in time sharing manner. Therefore, it is inevitably necessary to coincide the signals in one and the same channel in a process where the signals are allowed to pass through a variety of delay elements. Accordingly, delay flip-flop circuits and shift registers such as those shown in FIGS. **9**(f) through (i) are provided for timing adjustment at a number of places in the circuits shown in FIGS. **3** to **5**, but they will not be designated by reference characters.

As was described before, switching of the envelope modes produced by the output groups X_1, X_2 and X_3 of the envelope generator **10** is carried out on the basis of the envelope function switching data FU_1–FU_3, FL_1 and FL_2. The relationships between the envelope function switching data of keyboards and the envelope modes outputted by the groups X_1, X_2 and X_3 are indicated in Table 2 below.

TABLE 2

		Function switching data			Modes of the groups			Direct keying shape selecting signals		
		Fu_1	FU_2				X_3			
	No.	FU_1	FU_2	3	X_1	X_2	FU_3	O_1	O_2	O_3
Upper keyboard	1	0	0	0	A	A	A	0	0	0
	2	1	0	0	B	B	A	0	0	1
	3	1	1	0	A	A	D	1	1	0
	4	0	1	0	A	A	C	1	1	0
	5	0	0	1	B	A	B	0	1	0
	6	1	1	1	D	D	D	0	0	0
	7	0	1	1	C	C	C	0	0	0
	8	1	0	1	A	B	A	1	0	1
		FL_1	FL_2							
Lower keyboard	1	0	0		A	A	A	0	0	0
	2	1	0		B	B	A	0	0	1
	6	1	1		D	D	D	0	0	0
	7	0	1		C	C	C	0	0	0
Pedal keyboard	2		Fixed		B	B	A	0	0	1

In Table 2:

Reference character "A" designates a direct keying mode such as shown in FIG. **8**(a);

Reference character "B" designates a sustain mode such as shown in FIG. **8**(B);

Reference character "C" designates a percussive damp mode such as shown in FIG. **8**(C); and

Reference character "D" designates a percussion mode such as shown in FIG. **8**(D).

Numerals 1 through 8 listed in the left column of Table 2 are intended to designate the envelope function numbers, in which like numerals specify like functions (being equal in combination of the envelope modes produced from the groups X_1, X_2 and X_3). For instance, the number obtained when the switching data FU_1, FU_2 and FU_3 of the upper keyboard are "1 1 1" and the number obtained when the switching data FL_1 and FL_2 of the lower keyboard are "1 1", are equal to each other, i.e. No. 6 function. In the case of the pedal keyboard note, the switching data are fixed or the function number is fixed to No. 2, and therefore, the envelopes in the sustain mode B and the direct keying mode A are provided.

Indicated in the right column of Table 2 are the contents of the direct keying shape selecting signals O_1, O_2 and O_3 corresponding to the contents of the envelope function switching data. The signals O_1, O_2 and O_3 correspond to the groups X_1, X_2 and X_3, respectively. In a group wherein contents of the signal O_1, O_2 or O_3 are "1", the envelope shape in the direct keying mode produced by the direct keying shape generating section **26** is outputted; and in a group wherein contents of the signal are "0", the envelope shape produced by the system of the counter **11** and the memory **12** is outputted. In addition, it should be noted that the circuit is so designed that when all of the groups X_1, X_2 and X_3 produce the envelopes in the direct keying mode, the system of the counter **11** and the memory **12** produces the direct keying shape. Accordingly, in the case when all of the groups X_1, X_2 and X_3 are of the direct keying mode A, all of the direct keying shape selecting signals O_1, O_2 and O_3 are "0".

Referring back to FIG. **3**, a logical circuit is formed in the envelope function decoder **24** so that when a function is selected in which it is necessary to allow the direct keying shape generating section **26** (FIG. **2**) to produce the envelope in the direct keying mode, the function selection is detected and the decoded outputs are provided separately according to the channels. Referring to Table 2, such functions are found in the lines of Nos. 2, 3, 4, 5 and 8. Accordingly, when with the upper keyboard tones the function switching data FU_1, FU_2 and FU_3 have the data shown in the lines described above, AND circuits **28** through **32** operate as in the following logical expressions: The AND circuits **28** through **32** are made operable by the upper keyboard signal UE.

AND circuit 28 (detecting No. 8)

$FU_1 \overline{FU_2} FU_3 UE$

AND circuit 29 (detecting No. 5)

$\overline{FU_1} \overline{FU_2} FU_3 UE$

AND circuit 30 (detecting No. 4)

$\overline{FU_1} FU_2 \overline{FU_3} UE$

AND circuit 31 (detecting No. 3)

$FU_1 FU_2 \overline{FU_3} UE$

AND circuit 32 (detecting No. 2)

$FU_1 \overline{FU_2} \overline{FU_3} UE$

Furthermore, in the case of the lower keyboard tone, a logic of $FL_1 \cdot \overline{FL_2} LE$ is provided in an AND circuit **33** so that the latter operates when the function switching data FL_1 and Fl_2 have the data shown in the line of No. 2.

As the function of the pedal keyboard tone is fixed to No. 2, an AND circuit **34** is enabled by the pedal keyboard signal PE. It is obvious that the signal PE can be applied directly to an OR circuit **35** without the provision of the AND circuit **34**.

Function Nos. 3 and 4 out of Function Nos. 2, 3, 4, 5 and 8 are for distributing the direct keying mode A to the groups X_1 and X hd 2. Therefore, the outputs of the AND circuits **30** and **31** are applied through an OR

circuit **36** to OR circuits **37** and **38** in the direct keying shape generation system decoder **25**. In this decoder **25**, the OR circuit **37** outputs the direct keying shape selecting signal O_1 corresponding to the group X_1, the OR circuit **38** outputs the signal O_2 corresponding to the group X_2, and the OR circuit **39** outputs the signals O_3 corresponding to the group X_3. As Function No. 5 is for distributing the direct keying mode A to the series X_2, the output of the AND circuit **29** is applied to the OR circuit **38** of the decoder **25**. As Function No. 8 is for distributing the direct keying mode A to the groups X_1 and X_3, the output of the AND circuit **28** is applied to the OR circuits **37** and **39** of the decoder **25**. As Function No. 2 is for distributing the direct keying mode A to the group X_3, the outputs of the AND circuits **32, 33** and **34** are applied through the OR circuit **35** to the OR circuit **39** of the decoder **25**.

Accordingly, the direct keying shape selecting signals O_1, O_2 and O_3 are produced according to the values of the function switching data FU_1, FU_2, FU_3, FL_1 and FL_2, as indicated in the right column of Table 2.

The upper keyboard signal UE, the lower keyboard signal LE, and the pedal keyboard signal PE are generated in synchronization with the channel times to which the tones of the keyboards are assigned, with the keyboard code K_1, K_2 being decoded by the keyboard detection circuit **23**. In the keyboard detection circuit **23**, an OR circuit **40** receives the data of bits K_1, K_2 and produces the attack start signal AS in synchronization with the time of the channel at which the key board code K_1, K_2 is present, i.e., to which the production of a tone of the depressed key is assigned.

The envelope modes selecting signals F1, F2 and F3 produced by teh envelope mode selection logic **19** are representative of the modes of envelope shapes which are to be produced by the system of the counter **11** and the memory **12**. The envelope mode section logic **19** produces the envelope mode selecting signals F1, F2 and F3 by collecting the function switching data provided separately according to the keyboards onto common lines. In other words, if function numbers are equal, the values of the data FU_1 and FU_2 are equal to those of the data FL_1 and FL_2. Accordingly, logic circuits are formed so that the data FU_1 and FL_1 are collected to form the data F1, the data FU_2 and FU_1 are collected to form the data F2; and the data FU_3 is formed into the data F3. Since the function of the pedal keyboard tone is fixed to No. 2, no particular switching data is provided; however, all that is necessary for the function of the pedal keyboard tone is to produce signals F1, F2 and F3 whose values are equal to the value "1 0 0" in Function No. 2 of the switching data FU_1, FU_2 and FU_3 of the upper keyboard. As the switching data FU_1, FU_2, FU_3, FL_1 and FL_2 are applied in direct current mode, the data are selected by the keyboard signals UE, LE and PE in synchronization with the channel times to which the keyboards are assigned, and the envelope mode selecting signals F1, F2, and F3 in time sharing manner separately according to the channels.

Accordingly, in the envelope mode selection logic **19**, the data FU_1 and the upper keyboard signal UE are inputted to an AND circuit **41**, the data FL_1 and the lower keyboard signal LE are inputted to an AND circuit **42**, the pedal keyboard signal PE is applied to an AND circuit **43**, and the outputs of these AND circuits **41, 42** and **43** are applied to an OR circuit **44** to obtain the data F1. In this connection, it is not always necessary to provide the AND circuit **43**; that is, the signal PE can be applied directly to the OR circuit **44**. The data FU_2 and the upper keyboard signal UE are applied to an AND circuit **45**, the data FL_2 and the lower keyboard signal LE are applied to an AND circuit **46**, and the outputs of the two AND circuits **45** and **46** are applied to an OR circuit **46** to obtain the data F2. The data FU_3 are the upper keyboard signal UE are applied to an AND circuit **48** to obtain the data F3.

Indicated in the following Table 3 are relationships between the values of the envelope mode selecting signals F1, F2 and F3 and the envelope modes selected thereby.

TABLE 3

Mode		F1	F2	F3
Direct keying	(A)	0	0	0
Sustain	(B)	1	0	0
		0	0	1
		1	0	1
Percussive damp	(C)	0	1	0
		0	1	1
Percussion	(D)	1	1	0
		1	1	1

In the envelope generation control logic **18**, AND circuits provided respectively for the envelope modes are enabled according to the values of the envelope mode selecting signals F1, F2 and F3.

In the case of the direct keying mode A, the signals F1, F2 and F3 are "0 0 0", and therefore AND circuits **49** and **50** to which the inversion signals of these signals are applied are made operable.

In the case of the sustain mode B, the signals F1 and F2 are "1 0" or the signals F1 through F3 are "0 0 1". The signals are detected by an AND circuit **51** or **52**, and the detection signal is applied to an OR circuit **53** to obtain the sustain mode selecting signal BE. The output "1" of the OR circuit **53** enables AND circuits **54, 55** and **56**.

In the cases of the percussive damp mode C and the percussion mode D, the signal F2 is "1" in both cases. Accordingly, AND circuits **57** and **58** which are used commonly for both of the modes C and D are enabled when the signal F2 is "1". The signals F1 and F2 have "1 1" only when the percussion mode is selected. Therefore, an AND circuit **59** for only the percussion mode is made operable when each of the signals F1 and F2 has "1". An AND circuit **60** provided for only the percussive damp mode C is enabled when the signal F1 is "0" and the output of the OR circuit **53** is "0" (other than the sustain mode B).

In the clock synchronization circuit **22**, the upper and lower keyboard attack clock signal CA is applied to a rising and decaying differentiation circuit **61**, while the pedal keyboard attack clock signal CPA is applied to a rising and decaying differentiation circuit **62**. The upper keyboard decay clock signal CUD is applied to a rising and decaying differentiation circuit **63**, while the lower keyboard decay clock circuit CLD is applied to a decaying differentiation circuit **64**. The pedal keyboard decay clock signal CPD is applied to a decaying differentiation circuit **65**. Only the rising and decaying differentiation circuit **61** is illustrated in detail; however, the other rising and decaying differentiation circuits **62** and **63** are identical with the differentiation circuit **61**. A block **66** encircled in the differentiation circuit **61** is a decaying differentiation circuit. The arrangement of

each of the decaying differentiation circuit is identical with that of the block **66**.

In each of the rising and decaying differentiation circuits **61** through **63**, the clock signals are delayed by 12 microseconds by means of delay flip-flop circuits **67** and **68**, respectively, which are controlled by the clock pulse ϕ_A having a period of 12 microseconds, and an AND circuit **69** produces a rising detection pulse 12 microseconds in pulse width in synchronization with the rising part of the input clock signal. The period of the rising detection pulse is equal to that of the input clock signal. In addition, an AND circuit **70** provides a decaying detection pulse 12 microseconds in pulse width in synchronization with the decaying part of the input clock signal. The rising detection pulse and decaying detection pulse are applied to an OR circuit **71**. Thus, the circuits **61**, **62** and **63** produce clock pulses CA2, CPA2 and CUD2, respectively, which have frequencies twice as high as those of input clock signals CA, CPA and CUD, respectively, and have a pulse width of 12 microseconds (twelve channel times).

In the aforementioned circuits **61** and **63**, the decaying detection pulse is taken out of the AND circuit **70** so as to output as count clock pulses CA' and CUD' respectively for a counter **72** of modulo 2^5 and a counter **73** of modulo 2^1. When all of the 5-digit outputs of the counter **72** become "1" and the pulse CA' 12 microseconds in width is applied thereto, an AND circuit **74** output a signal "1". This output of the AND circuit **74** is utilized as a first curve selecting clock pulse CUA1. The frequency of this clock pulse CUA1 is $\frac{1}{2}^5$ of the frequency of the clock pulse CA' ($\frac{1}{2}^6$ pf of the frequency of the clock pulse CA2), and its pulse width is 12 microseconds.

An AND circuit **75** produces a pulse UD when its input conditions are established by the output of the counter **73** and the clock pulse CUD'. Therefore, the frequency of the pulse UD is $\frac{1}{2}$ of the frequency of the clock pulse CUD' ($\frac{1}{4}$ of the frequency of the clock pulse CUD2), and its pulse width is 12 microseconds.

The decaying differentiation circuits **64** and **65** operate similarly as in the aforementioned block **66**, and produce clock pulses CLD' and CPD' equal in frequency to the clock pulses CLD and CPD, each of the pulses CLD' and CPD' having a pulse width of 12 microseconds. The clock pulses CLD' and CPD' are subjected to $\frac{1}{2}$ frequency division in counters **76** and **77** each having modulo **2**, and are shaped to have a pulse width of 12 microseconds by AND circuits **78** and **79**, respectively. It should be noted that upon energization of the envelope generator **10**, the initial clear signal IC is applied to the reset terminals of the counters **72**, **73**, **76** and **77**.

The upper and lower keyboard attack clock pulse CA2, the pedal keyboard attack clock pulse CPA2, the first curve selecting clock pulse CUA1, the second curve selecting clock pulse CUD2, the upper keyboard decay clock pulse UD, the lower keyboard clock pulse LD, and the pedal keyboard decay clock pulse PD, each synchronized to have the 12 microsecond pulse width, are supplied to the channel clock selection gate **21**. In this gate **21**, the upper keyboard signal UE makes AND gates **80**, **82**, **84** and **85** operable to select the clock pulses, CA2, CUA1, CUD2 and UD. The lower keyboard signal LE makes AND circuits **81** and **86** operable to select the clock pulses CA2 and LD. The pedal keyboard signal PE makes AND circuits **83** and **87** operable to select the clock pulses CPA2 and PD. In each of the pulses CA2 through PD, one pulse is synchronized with the 12 channel times. Therefore, these pulses can be selected in time sharing manner without changing their frequencies. The attack clock pulses CA2 and CPA2 selected in time sharing manner are applied, as an attack clock pulse ACP to an AND circuit **90** of the clock gate **13** through an OR circuit **88**. The attack pulses UD, LD, and PD selected by the AND circuits **85**, **86** and **87** are applied to an OR circuit **89** so as to be applied, as a decay clock pulse DCP, to an AND circuit **91** of the clock gate **13**. The first curve selecting clock pulse CUA1 selected in time sharing manner is applied to an AND circuit **92** of the clock gate **13**, while the second curve selecting clock pulse CUD2 is applied to an AND circuit **93** thereof. The output ACP of the aforementioned OR circuit **88** is applied also to an AND circuit **94** of the clock gate **13**, and is utilized a clock pulse DMP for the percussive damp mode.

The clock pulses inputted to the AND circuits **90** through **94** of the clock gate **13** are selected by the outputs from the envelope generation control logic **18** or by control signals obtained through OR circuits **95**, **96** and **97** of the clock selection circuit **20**. The output of the AND circuit **90** is applied, as the attack pulse AC, to the counter **11** of modulo **64** through a line **99**. The outputs of the AND circuits **91** through **94** are applied to an OR circuit **98** so as to be applied, as the decay clock pulse DC, to the counter **11** through a line **100**.

The counter **11** comprises: an addition section of 16-bits up of full-adders **101** through **106**; and a 12-stage shift counter section for holding the addition result of each bit in time sharing manner for every channel. More specifically, the addition result of the least significan bit is held in a 9-stage shift register **107** and a 3-stage shift register **108**, and the data of the second bit is held in an 8-stage shift register **109** and a 4-stage shift register **110**. The data of the third bit is held in an 8-stage shift register **111** and a 4-stage shift register **112**. The data of the fourth bit is held in a 7-stage shift register **113**, a 2-stage shift register **114**, and a 3-stage shift register **115**. The data of the fifth bit is held in a 7-bit stage shift register **116**, a 2-stage shift register **117**, and a 3-stage shift register **118**. The data of the most significant bit is held in a 6-stage shift register **119**, a 2-shift register, **120**, and a 4-stage shift register **12**. The reason why the 12-stage shift register is divided into several parts is for synchronization of the channel times for the above-described data. For this channel time synchronization, delay flip-flop circuits are provided in the counter **11**; however, they are not designated by reference numerals.

The fraction part counter **16** of modulo **8** is made up of 3-bit full-adders **122**, **123** and **124**, and 12-stage shift registers **125**, **126** and **127**. In each of the full-adders **101** through **106** and **122** through **124**, reference characters A and B designate input terminals, reference character CI designates a carry signal input terminal from a less significant bit, reference character S designates an output terminal for the addition result of a relevant bit, and reference character CO designates a carry signal output terminal. The addition result held in a shift register is fed back to the input terminal B of the respective adder and is added to the data which are applied to the input terminal A and the input terminal CI. The carry signal output terminals CO are successively cascade-connected to the carry signal input terminals CI of the more significant bits.

Upon energization the initial clear signal IC is applied, whereupon the signal of a counter clear line **139** is made to be "0" through an OR circuit **128** and an inverter **129**, and AND circuits **130** through **138** in the counter **11** and the fraction part counter **16** are therefore made inoperable, as a result of which the count values of the channels are cleared to "0". The same thing occurs in the case also where a count value clear signal So is applied through a line **140** from the envelope generation control logic **18** shown in FIG. **3**, as described later.

In production of the envelope having attack characteristics, the attack pulse AC as described later is applied through a line **99** and an OR circuit **141** to the adder **101** of the least significant bit in the counter **11**, and the count value in the counter is increased.

In production of the envelope having decay characteristics, the decay clock pulse DC is applied through a line **100** to all of the adders **101** through **106** in the counter **11**. Accordingly, in the counter **11** "1 1 1 1 1 1" is added for every timing of the decay clock pulse DC, which means that the content of the counter **11** is subtracted by "0 0 0 0 0 1". Thus, the value in the counter is decreased.

Polygonal Line Approximation of an Envelope Having Exponential Characteristics

In this embodiment, an exponential characteristic polygonal line approximation is carried out with respect to the decay part of an envelope shape. For this purpose, AND circuits **142, 143** and **144** in the gate **15** of the fraction part counter **16** used for computation of the polygonal line approximation are so designed as to be enabled by the application of the decay clock pulse DC.

The data of the more significant bit in the counter **11** is fed back to the least significant bit (adder **101**) through a feedback circuit including a computation circuit. The computation circuit included in the feedback circuit is the gate **15** and the fraction part counter **16**, operating to convert the data of three higher bits in the counter **11**, which are fed back through lines **14a, 14b** and **14c**, into a pulse CR having a speed corresponding to (inversely proportional to) the value of the data and to apply the pulse CR to the carry signal input terminal CI of the least significant bit adder **101** in the counter **11**.

The data CV_4, CV_5 and CV_6 of the three higher bits of the counter **11** (the outputs of the adders **104, 105** and **106**) are obtained from shift registers **114, 117** and **120**, and are supplied to the lines **14a, 14b** and **14c** after being inverted respectively. The inversion data $\overline{CV_4}$, $\overline{CV_5}$, and $\overline{CV_6}$ supplied to the lines **14a, 14b** and **14c** are inputted to adders **122, 123**, and **124** through AND circuits **142, 143, 144** for every generation timing of the decay clock pulse DC, respectively. Accordingly, the data $\overline{CV_4}$, $\overline{CV_5}$ and $\overline{CV_6}$ are repeatedly added by the fraction part counter **16** for every generation timing of the decay clock pulse DC. Since the fraction part counter **16** is of the three bits, whenever its counter value reaches eight in decimal notation, a single carry signal CR is outputted by the adder **124**. This carry signal CR is applied to the least significant bit adder **101** in the counter **11** so as to increase the value stored in the counter **11**. On the other hand, simultaneously the decay clock pulse DC is applied to the counter **11** through the line **100** to decrease the value stored in the counter **11**. Therefore, in practice, the count values CV_1 through CV_6 in the counter **11** are not changed when the carry signal CR is applied to the fraction part counter **16**. In other words, the carry signal CR applied to the addition input of the counter **11** operates to prohibit the subtraction of the decay clock pulse DC from the value of the counter **11**.

One example of this computation is indicated in Table 4 below. The numerals 1, 2, 3 . . . in the left column in Table 4 are representative of the timing of application of the decay clock pulse DC. The arrows in the column of the carry signal CR indicate the generation of the carry signal CR. It is assumed that the count value of the fraction part counter **16** is "0 0 0" when the count value of the counter **11** is "1 1 0 0 0 0". In this case, when the decay clock pulse DC is applied thereafter (Timing **2**), the content of the fraction part counter **16** becomes "0 0 1" by the feedback data $\overline{CV_6}$, $\overline{CV_5}$ and $\overline{CV_4}$. In this operation, the count value of the counter **11** is subtracted to be "1 0 1 1 1 1".

TABLE 4

DC's timing	Count value of counter 11						Carry	Count value of fraction part counter 16		
	CV_6	CV_5	CV_4	CV_3	CV_2	CV_1	CR			
1	1	1	0	0	0	0	←	0	0	0
2	1	0	1	1	1	1		0	0	1
3	1	0	1	1	1	0		0	1	1
4	1	0	1	1	0	1		1	0	1
5	1	0	1	1	0	0		1	1	1
6	1	0	1	1	0	0	←	0	0	1
7	1	0	1	0	1	1		0	1	1
8	1	0	1	0	1	0		1	0	1
9	1	0	1	0	0	1		1	1	1
10	1	0	1	0	0	1	←	0	0	1
11	1	0	1	0	0	0		0	1	1
12	1	0	0	1	1	1		1	0	1
13	1	0	0	1	1	1	←	0	0	0
14	1	0	0	1	1	0		0	1	1
.			.						.	
.			.						.	
.			.						.	

The data $\overline{CV_6}$, $\overline{CV_5}$ and $\overline{CV_4}$ applied to the fraction part counter **16** through the gate **15** is obtained by inverting the three higher bits CV_6, CV_5 and CV_4 out of the computation results of the counter **11** in the previous computation timing. Therefore, at the computation timing **2**, a value "0 0 1" obtained by inverting the data CV_6, CV_5 and CV_4 "1 1 0" provided at the computation timing **1** is applied to the fraction part counter **16**. Accordingly, during the period of time from computation timing **3** to computation timing **2**, the value "0 1 0" obtained by inverting the value "1 0 1" of the data CV_6–CV_4 is repeatedly applied to the fraction part counter **16**. During the period of time from computation timing **2** to computation timing **5**, no carry signal CR is produced by the fraction part counter **16**. Therefore, the count value of the counter **11** is successively decreased by the decay clock pulse DC. However, at the computation timing **6**, the computation result of the fraction part counter **16** becomes "1 0 0 1", whereby the carry signal CR is produced thereby. In this operation, in the counter **11** the data "1 1 1 1 1 1" due to the decay clock pulse DC operating as a subtraction input and the input data "0 0 0 0 0 1" due to the carry signal CR are added to the computation result "1 0 1 1 0 0" obtained at the previous computation timing **5**. In the computation, the carry output CO is merely produced by the most significant bit adder **106**, and no substantial computation is carried out. Therefore, the count value of the counter **11** is not changed. Similarly, when the

carry signal CR is produced by the fraction part counter 16, the count value of the counter 11 is not changed.

The fraction part counter **16** is of modulo **8**. Therefore, if it is assumed that the decimal value of the feedback data $\overline{CV_6}$, $\overline{CV_5}$ and $\overline{CV_4}$ from the counter **11** is K, then one carry signal CR is produced whenever 8/K decay clock pulses are supplied. Furthermore, as the data CV_4, CV_5 and CV_6, higher than the third bit, of the counter **11** are fed back to the fraction part counter **16**, the count rate of the fraction part counter **16**, namely, the values of the input data $\overline{CV_6}$, $\overline{CV_5}$ and $\overline{CV_4}$ are changed whenever the content of the counter is advanced by eight steps (subtracted by eight).

Accordingly, if it is assumed that the number of decay clock pulses DC necessary for advancing the content of the counter by eight steps is N; then

(step number of counter **11**) = (subtraction pulse number by pulse DC) − (addition pulse number by carry signals CR).

Therefore, in general, the following equation is established:

$$8 = N - \left(N/\frac{8}{K}\right) = \frac{8N - KN}{8}$$

In consequence, the following relation is established between N and K:

$$N = 64/(8-K)$$

Upon application of N pulses DC, the content of the counter **11** is decreased by eight steps. Therefore, the inclination (rate) in subtraction variation of the counter **11** is 8/N which depends on the value K of the data $\overline{CV_6}$, $\overline{CV_5}$ and $\overline{CV_4}$ fed back to the fraction part counter **16**. Accordingly, the value of the counter **11** is linearly changed (changed with a constant inclination) for the period of time during which the value K is maintained unchanged; however, the inclination in count value variation of the counter **11** is changed if the value K is changed.

The data $\overline{CV_6}$, $\overline{CV_5}$ and $\overline{CV_4}$ forming the value K, or the data CV_6 CV_5 and CV_4 is of 3-bits, and therefore the value K varies in eight ways. More specifically, as indicated in the following Table 5, the value K in the counter **11** of modulo **64** varies in eight steps, i.e. regions I–VIII. *Such counting operation may be called a "nonlinear counting mode", characterized in that the change in accrued count value CV for a fixed number of applied count pulses is not always uniform, but rather changes as a function of the accrued count value.* In the left column of Table 5, the ranges of the count values CV of the counter **11** included in the regions I through VIII are indicated by decimal numbers.

TABLE 5

Time	CV	CV_6	CV_5	CV_4	$\overline{CV_6}$	$\overline{(K)/CV_5}$	$\overline{CV_4}$	$\frac{8}{K}$	N
	63								
I	↓	1	1	1	0	0	0	0	8
	56								
	55								
II	↓	1	1	0	0	0	1	8	9
	48								
	47								

TABLE 5-continued

Time	CV	CV_6	CV_5	CV_4	$\overline{CV_6}$	$\overline{(K)/CV_5}$	$\overline{CV_4}$	$\frac{8}{K}$	N
III		1	0	1	0	1	0	4	10
	↓								
	40								
	39								
IV		1	0	0	0	1	1	$\frac{8}{3}$	13
	↓								
	32								
	31								
V		0	1	1	1	0	0	2	16
	↓								
	24								
	23								
VI		0	1	0	1	0	1	$\frac{8}{5}$	21
	↓								
	16								
	15								
VII		0	0	1	1	1	0	$\frac{8}{6}$	31
	↓								
	8								
	7								
VIII		0	0	0	1	1	1	$\frac{8}{7}$	56
	↓								
	0								

In Table 5, as was described before, 8/K indicates the number of decay clock pulses DC necessary for producing one carry signal CR in each of hte regions I through VIII, and N designates the total number of pulses DC supplied in each of the regions I through VIII. In the last region VIII, the pulse number N is 56 instead of 64 because the count value CV becomes zero with seven steps decreased. Referring to Table 5 and Table 4 described before, it can be understood that the count operation from computation timing **2** to computation timing **11** in Table 4 indicates the operation in region III in Table 5.

As the value K is gradually increased whenever the region is shifted toward VII from I (the value of the feedback data CV_6, CV_5 and CV_4 is gradually decreased as the count value of the counter decreases), the inclination 8/N in count value variation of the counter **11** becomes as the region is shited toward VIII. Therefore, a decay curve of exponential characteristics as shown in FIG. **10** can be obtained by eight-step polygonal lines in each of the regions I through VIII.

Referring back to FIG. **4**, the count value data CV_1 through CV_6 of the counter **11** are applied to an AND circuit **145** of the count value detection circuit **17** after being inverted by respective inverters. Therefore, when the count value of the counter **11** becomes zero (0) in the last region VIII, the AND circuit **145** produces an output "1", which enables an AND circuit **146** through a delay shift register **147**. Whenever the decay clock pulse DC is applied to the AND circuit **146**, the latter **146** is operated to apply a signal "1" to the carry signal input terminal of an adder **122** of the fraction part counter **16** through a line **148**. When all of the data in the counter **11** are "0", the feedback data $\overline{CV_6}$, $\overline{CV_5}$ and $\overline{CV_4}$ are "1 1 1". *With this arrangement, the counter of FIG. 4 is operable to count in an "exponential manner" in response to count pulses applied thereto, producing an accrued count value CV which may be represented by the serial juxtaposition of differently sloped polygonal line*

segments as shown in FIG. 10. Therefore, whenever the decay clock pulse DC is applied to the counter **16**, the carry signal CR is produced by the fraction part counter **16**, as a result of which "1" is added to the counter **11**. While "1 1 1 1 1 1" is added to the counter **11** in response to the decay clock pulse DC at all times, "1" is added thereto by the above-described carry signal CR. Therefore, the count value "0" is maintained in the counter **11**.

The above-described computation operations are all carried out in time sharing manner separately for the respective channels. Therefore, the many delay flip-flop circuits not designated by reference numerals are so arranged that the channel times between the computation data in computation circuits are coincident with one another. In addition, in the counter **11** there are some shift registers in which the number of delay stages for signals led therefrom is different. This is also for coincidence of the channel times. For instance, the data of the adders **105** and **106** are deviated by one microsecond from each other by the delay flip-flop circuit **149** interposed therebetween. Therefore, the data $\overline{CV}_5$ is led out with a delay of 9 microseconds by the shift registers **116** and **117**, and the data $\overline{CV}_6$ is led out with a delay of 8 microseconds by the shift registers **119** and **120**, so that the channel times of the data $\overline{CV}_5$ and $\overline{CV}_6$ are coincident with each other.

Sustain Mode:

FIG. **11**(a) is a set of graphs indicating variations of the count value CV of the counter **11** with time T in the case where the sustain mode is selected.

When the sustain mode B is selected, in the envelope generation control logic **18** in FIG. **3**, the AND circuits **54**, **55** and **56** are enabled. If the decay start signal DS is not generated yet and the count contents CV_1 through CV_6 of the counter **11** ar not "1", the conditions for the AND circuit **54** are satisfied, and therefore the AND gate **90** in the clock gate **13** is enabled. Upon depression of a key, one of the keyboard signals UE, LE and PE becomes "1", as a result of which the attack clock pulse ACP is supplied to the AND circuit **90** through the OR circuit **88** of the clock select gate **21**. Accordingly, upon depression of a key, first of all, the pulse ACP is selected as the attack clock pulse AC by the AND circuit **90**, and the pulse thus selected is applied to the addition input of the counter **11**, that is, it is applied only to the least significant bit adder **101** through the OR circuit **141** in the counter **11**. As a result, the count value CV of the counter **11** is gradually increased from "0" up to "63" at the rate of the attack clock pulse AC.

Thus, the envelope shape of an attack part ATT (FIG. **11**(a)) is obtained by addition. The shape of the attack part ATT has a resolution degree of 63 steps corresponding to the modulo of the counter **11**.

When the count value CV has reached the maximum value **63**, all of the data CV_1 through CV_6 are "1". Therefore, the data are detected by the AND circuit **150** of the count value detection circuit **17**, and the signal "1" is stored in the relevant channel of a shift register **153** through an AND circuit **151** and an OR circuit **152**. This storage is self-held through an AND circuit **154**. In this connection, it should be noted that the AND circuits **151** and **154** are enabled only when the sustain mode selection signal BE is applied from the OR circuit **53** of the envelope generation control logic **18** through a line **155** and a shift register **156**.

When the AND circuit **150** detects that the count value CV is all "1", and all "1" detection signal AL_1 is applied to the envelope generation control logic **18** through the OR circuit **152**. The detection signal AL_1 is stored in the aforementioned shift register **153**, and therefore the detection signal AL_1 is not eliminated even if the count value CV is changed thereafter.

In the envelope generation control logic **18**, if the all "1" detection signal AL_1 becomes "1", a signal "0" is applied to the AND circuit **54** through an inverter, as a result of which the AND circuit **90** of the clock gate **13** is made inoperable. Accordingly, the application of the attack clock pulse AC is prohibited. Thus, the counting operation of the counter **11** is suspended, so as to hold a certain count value (**63** in this case), whereby the shape of a sustain part SUS (FIG. **11**(a)) is obtained.

Upon release of the depressed key, the decay start signal DS is raised to "1" and is applied to the AND circuit **56** of the envelope generation control logic **18** through a line **160**. The output "1" of the AND circuit **56** is applied to the AND circuit **91** and **93** of the clock gate **13** through the OR circuit **95**. In the case where a curve selection function described later is not selected yet, the output of the OR circuit **97** is "1", and therefore the AND circuit **91** is enabled but the AND circuit **93** is made inoperable. Therefore, the decay clock pulse DCP supplied from the OR circuit **89** of the clock selection gate **21** is selected by the AND circuit **91**, and is applied, as the decay clock pulse DC, to the subtraction input of the counter **11** through the OR circuit **98** and the line **100**.

As the operation of the counter **11** is suspended at the maximum count value **63**, subtraction is carried out from the maximum count value **63** toward the minimum value 0. In this operation, the computation for the polygonal line approximation of exponential characteristic is carried out as was described before, whereby the envelope shape of a decay part DEC exponentially varying as shown in FIG. **10** is obtained.

When the count value of the counter **11** has reached zero (0), an all "0" detection signal AL_0 is produced from the AND circuit **145** of the count value detection circuit **17**, and is applied to the AND circuit **158** (FIG. **3**) through a line **157**. To the other input of the AND circuit **158**, the decay start signal DS is applied through a line **160** and a shift register **159** for timing control, and the output "1" of the AND circuit **158** is applied, as the decay finish signal DF, to the aforementioned tone production assignment circuit (not shown). Upon generation of the decay finish signal DF, the clear signal CC is provided by the tone production assignment circuit because the generation of the decay finish signal DF means that the tone production in the relevant channel time has been finished. This clear signal CC is applied to the detection circuit **17** in FIG. **4**, as a result of which the AND circuits **151** and **154** are made inoperable so as to eliminate the storage of the all "1" detection signal AL_1.

Sometimes the electronic musical instrument has a function that, when after release of a key but before completion of the decay the same key is depressed again, the tone for the depressed key is assigned to the same channel (hereinafter referred to as "a key-on-again function" when applicable). In this case, the clear signal CC is produced in that channel once even if no decay finish signal DF is produced. In this case, even during the decay (the count value of the counter being decreased) the all "1" detection signal AL_1 is changed to "0", and the attack clock pulse AC is selected instead of the decay clock pulse DC. Accordingly, it is possible to

allow the envelope shape of the relevant channel to rise during the decay.

In addition, it is also possible to allow the attack part ATT in the sustain mode to rise extremely steeply. What is considered as one method for achieving this purpose is to employ high speed clock pulses as the attack clock pulses ACP, or the clock signals CA and CPA. In another method considered, the addition by the attack clock signal AC is not carried out in the counter **11**, but a counter set signal S_1 described later is produced as soon as the attack start signal AS is raised to "1" upon depression of a key, and the count value of the counter **11** is set to "1 1 1 1 1 1" simultaneously, so that the sustain part SUS is obtained without the attack part TATT.

Curve Section in Sustain Mode

The envelope consisting of the parts ATT, SUS and DEC shown in FIG. **11**(a) is ordinarily obtained in the sustain mode. If the curve selection function is effected, the envelope is changed into an envelope consisting of parts ATT, DEC1, SUS' and DEC 2.

When the curve selection function is effected, the curve section signal CUS becomes "1", and the AND gate **161** in FIG. **3** is enabled. The upper keyboard signal UE is applied to the other input of the AND circuit **161**, and therefore the curve selection signal CUS is selected only during the channel time of the upper keyboard tone and is applied to the AND circuit **55** of the envelope generation control logic **18**. In other words, in this example, the curve selection function is effected for the upper keyboard tone only.

Similarly as in the ordinary sustain mode, the attack part ATT is realized by applying the pulse ACP as the attack clock pulse AC to the counter **11** thereby to gradually increase the count value of the counter **11** from "0" to "63". When the count value of the counter **11** reaches the maximum value **63**, the all "1" detection signal AL_1 is produced by the count value detection circuit **17** and is applied to the AND circuit **55** of the envelope generation control logic **18**. Under the conditions that the sustain mode B is selected, the curve selection signal CUS is "1", the decay start signal DS is "0", and the count value CV of the counter **11** is not **47** or less (the signal CV**47** is "0"), the AND circuit **55** is enabled when the aforementioned signal AL_1 becomes "1", so as to apply its output "1" to the AND circuit **92** in the clock gate **13** and to the line **162**.

When the AND circuit **92** is thus enabled, the first curve selection clock pulse CUA**1** supplied by the clock select gate **21** is selected, and is applied to the subtraction input of the counter **11** through the OR circuit **98** and the line **100**. Therefore, in the counter **11** computation is carried out according to the first curve selection clock pulse CUA**1**, and the count value of the counter **11** is gradually decreased. When the count value data CV_6 through CV_1 become "1 0 1 1 1 1", the AND circuit **163** in the count value detection circuit **17** is operated to apply its output "1" to the AND circuit **164**. Accordingly, when the count value CV of the counter **11** reaches decimal **47**, it is detected by the AND circuit **163**, and the signal "1" is stored in the shift register **166** through the AND circuit **164** and the OR circuit **165** at the channel time thereof. In this connection, the AND circuit **164** is maintained enabled by the signal CUS' supplied through the line **162** for the period of time when the first curve selection clock pulse CUA**1** is selected. The count value "47" detection signal CV**47** stored in the shift register **166** is self-held by means of the AND circuit **167**, and is inverted by the inverter **168** in the envelope generation control logic **18** thereby to make the aforementioned AND circuit **55** inoperable. As a result, the AND circuit **92** is made inoperable, and therefore the application of the first curve selection clock pulse CUA**1** is prohibited.

Thus, the count value CV of the counter **11** is decreased from the maximum value 63 to value 47, whereby a decay shape, or the first decay part DEC 1 shown in FIG. **11**(a), is obtained. This first decay part DEC 1 is obtained by approximation of an exponential characteristic decay shape with two polygonal lines in regions I and II in FIG. **10** or Table 5.

When the count value detection signal CV**47** becomes "1", the count operation of the counter **11** is suspended. Therefore, the count value CV of the counter **11** is held at the value **47**, and the sustain part SUS' is formed.

Upon release of the key, the decay start signal DS becomes "1". Therefore, the output of the AND circuit **56** of the envelope generation control logic **18** is raised to "1" and is applied to the AND circuits **91** and **93** of the clock gate **13**. In this case, as the curve selection signal CUS is "1", the signal applied to the OR circuit **97** through the inverter **169** is "0". Furthermore, when the count value CV of the counter **11** is more than twenty-four (24), the other input of the OR circuit **97** is "0". Therefore, the output of the OR circuit **97** is "0", and the AND circuit **93** is enabled. Accordingly, the second curve selection clock pulse CUD**2** is selected by the AND circuit **93**, and is applied as the decay clock pulse DC, to the counter **11** and the gate **15** of the fraction part counter **16** through the OR circuit **98** and the line **100**.

Thus, upon release of the key, the operation of the counter **11** is started again, whereby the second decay part DEC **2** is formed. With respect to the first half of the second decay part DEC **2**, the computation is carried out according to the second curve selection clock pulse CUD**2** so that an exponential decay characteristic approximation is effected with three polygonal lines in the aforementioned regions III, IV and V. However, when the computation of region V is completed and the count value CV becomes 23 or less, the decay clock pulse DC is switched from the pulse CUD**2** to the pulse DCP.

In the count values of 24 and larger values, i.e., in the count value data CV_6 through CV_1 from "1 1 1 1 1 1" to "0 1 1 0 0 0", the data CV_6 is "1" or the data CV_5 and CV_4 are "1 1". Therefore, in the count value detection circuit **17**, the data CV_5 and CV_4 are applied to the AND circuit **170** whose output is applied to the OR circuit **171**, and the data CV_6 is applied to the OR circuit **171** so as to detect that the count value CV is 24 or more. When the count value CV becomes 23 and less, the output of the OR circuit **171** becomes "0" and the output of "0", and the output of the inverter **172** becomes "1". The output "1" of the inverter **172** is applied, as a count-value-23- or -less detection signal CV**23**, to the OR circuit **97** in FIG. **3**. Accordingly, when the count value CV becomes 23 or less, the output of the OR circuit **97** is raised to "1", the AND circuit **93** in the clock gate **13** is made inoperable, and the AND gate **91** is enabled. As a result, the decay clock pulse DCP is selected by the AND gate **91**, and is applied to the counter **11** and the gate **15** of the fraction part counter **16**. Thus, the computation with respect to re-

gions VI, VII and VIII for the count values of 23 and smaller values is carried out according to the decay clock pulse DCP. The decay clock pulse DCP corresponding to the second curve selection clock pulse CUD2 is the upper keyboard decay clock pulse UD. As was described before, the frequency of the clock pulse UD is $\frac{1}{4}$ of the frequency of the clock pulse CUD2. Therefore, as is shown in FIG. **11**(a), in the second decay part DEC **2** the variations of the parts in regions VI, VII and VIII where polygonal line approximation is carried out according to the clock pulse UD are considerably gradual when compared with those of the parts in regions III, IV and V where polygonal line approximation is carried out according to the second curve selection clock pulse CUD **2**.

Percussion Mode

FIG. **11**(b) indicates variations with time of the count value CV of the counter **11** where the percussion mode is selected. In FIG. **11**(b), a decay curve PDEC having a constant exponential characteristic indicates an ordinary percussion mode, while a decay curve PDEC2 whose exponential characteristic is changed from one to the other indicates a percussion mode where the curve selection function is effected.

At the start of depressing a key, a single attack pulse AP is produced in synchronization with the channel time to which the production of a tone for the depressed key is assigned, and is applied through a line **173** to the AND circuit **57** in the envelope generation control logic **18**. In the case where the percussion mode has been selected, the AND circuits **57**, **58** and **59** are enabled. Therefore, the attack pulse AP is applied through the AND circuit **57** to the OR circuit **96**. Accordingly, in response to the attack pulse AP, the counter set signal S_1 of one microsecond in pulse width is outputted by the OR circuit **96**. The counter set signal S_1 is applied through the line **174** to the counter **11** in FIG. **4** so that all of the count value data CV_1 through CV_6 of the counter **11** are set to "1". In other words, the signals "1" are stored in the shift registers **107**, **109**, **111**, **113**, **116** and **119** through the OR circuits **175** to **180**, respectively. Thus, in the initial period of depressing the key, the count value CV of the counter **11** is increased to "63" from "0" at once. During the key depression, the decay start signal DS is "0", and therefore the output of the AND circuit **58** in the envelope generation control logic **18** is raised to "1". This output "1" of the AND circuit **58** is applied through the OR circuit **95** to the AND circuit **91** so as to select the decay clock pulse DCP. Therefore, the counter **11** carries out the exponential characteristic polygonal line approximation computation, and the count value CV thereof is gradually decreased. Upon release of the key, the AND circuit **59** is operated to allow the AND circuit **91** to continuously select the delay clock pulse DCP. Therefore, irrespective of the key release, the count value of the counter **11** is decreased.

Thus, the decay curve PDEC in the ordinary percussion mode is computed in response to the clock pulse DCP which is constant over regions I through VIII, and is obtained as an envelope having a constant exponential characteristic.

Since the output of the OR circuit **97** (FIG. **3**) is "0" with the count value CV being from "63" to "24" when the curve selection signal CUS is set to "1", the AND gate **93** of the clock gate **13** is enabled. Accordingly, in regions I through V where the count value CV is from "63" to "24" the second curve selection clock pulse CUD **2** is applied, as the decay clock pulse DC, to the counter **11** and to the gate **15** of the fraction part counter **16**. Therefore, in the case where the curve selection function is effected, the polygonal line approximation computation is carried out according to the second curve selection clock pulse CUD2 for the first half of the decay curve PDEC2, or the polygonal line regions I through V. When the count value CV of the counter **11** becomes 23 less, as was described before, the detection signal CV23 becomes "1", and the AND circuit **91** is enabled by the output "1" of the OR circuit **97**. Therefore, the decay clock pulse DC applied to the counter **11** is switched from the second curve selection clock pulse CUD2 to the clock pulse DCP (the upper keyboard clock pulse UD), whereby for regions VI through VIII of the decay curve PDEC2 the polygonal line approximation computation is carried out according to the slow decay clock pulse DCP (UD).

Percussive Damp Mode

In the case where the percussive damp mode is selected, the count value CV of the counter **11** is varied as shown in FIG. **11**(c). Reference character PDEC' designates a curve in an ordinary percussive damp mode, and reference character PDEC2' designates a curve obtained when the curve selection function is effected.

In the case where the percussive damp mode C is selected, the AND circuits **57**, **58** and **60** in the envelope generation control logic **18** are enabled. Therefore, during the key depression, the count operation of the counter **11** is controlled by the outputs of the AND circuit **57** and **58** similarly as in the case of the above-described percussion mode D.

If the key is released during the tone production, the decay start signal DS on the lint **160** is raised to "1", and in this case the attack start signal AS is "1". Therefore, the conditions for the AND circuit **60** are satisfied. The output "1" of the AND circuit **60** is applied tothe AND circuit **94** of the clock gate **13** to select a damp clock pulse DMP. The damp clock pulse DMP thus selected is applied, as the decay clock pulse DC, to the counter **11** and the gate **15** of the fraction part counter **16** through the OR circuit **98** and the line **100**. The damp clock pulse DMP is higher in rate than the decay clock pulse DCP employed for an ordinary computation. In this embodiment, a special damp clock pulse generating section is not provided, but the attack clock pulse ACP supplied by the OR circuit **88** is employed as the damp clock pulse DMP.

As will be apparent from the above description, during the depression of key, the decay clock pulse DCP at the low rate is used for the polygonal line approximation computation (excepting the pulse CUD2 being used for the first half of the curve selection), whereas upon release of the key the polygonal line approximation computation is executed according to the damp clock pulse DMP at a high rate. Therefore, after release of the key, the count value CV of the counter **11** is abruptly decreased. However, the count value CV is not decreased to "0" at the time instant when the key is released, but is decreased while approximating the exponential characteristic with polygonal lines.

Generation of Direct Keying Shape by Counter

In the case where the enevelope mode selecting signals F1 through F3 specify the direct keying mode A, the AND circuits **49** and **50** in the envelope generation

control logic **18** are enabled. During the key depression, the attack start signal AS is "1", and the decay start signal DS is "0". Therefore, the input conditions of the AND circuit **49** are satisfied. The output "1" of the AND circuit **49** is applied, as the counter set signal S_1, to the counter **11** through the OR circuit **96**. During the key depression, the counter set signal S_1 is "1" at all times. Therefore, all of the count value data CV_1 through CV_6 of the counter **11** are maintained set to "1". When the decay start signal DS is raised to "1" by releasing the key, the AND circuit **50** is operated, and the AND circuit **49** is made inoperable. The output "1" of the AND circuit **50** is introduced, as a count value clear signal S_0, to a clear line **139** (FIG. **4**) through the line **140**, thereby to set to "0" all of the count value data of the counter **11**. Accordingly, during the key depression the value of the counter **11** is set to the maximum value 63, but it is cleared to "0" after release of the key. Thus, the envelope in the direct keying mode is obtained as shown in FIG. **11**(d).

Memory **12**

The count value data CV_1 through CV_6 of the counter **11** are applied to the memory **12** shown in FIG. **5**, and are employed as address inputs for reading amplitude information stored in the memory **12**. In this example, the memory **12** is so designed as to convert the count value data CV_1 through CV_6 into analog voltages corresponding to the values thereof. The memory **12** comprises: AND circuit groups **181** and **182** for decoding the inputted count value data CV_1 through CV_6 into addresses **0** through **63**; resistance type voltage division circuits **183** and **184**; and analog gate groups **185** and **186** (indicated by field-effect transistors in FIG. **5**) for obtaining voltages from the resistance type voltage division circuits **183** and **184** according to the decoded outputs of the AND circuit group **181** and **182**. A high voltage V_H (−5 volts for instance) is supplied to a voltage supply line **187** on the address **63** side of the resistance type voltage division circuit **183**, while a low voltage V_L (0 volt for instance) is supplied to a voltage supply line **188** on the address **63** side of the resistance type voltage division circuit **184**. The voltage supply terminals on the address **0** side of the resistance type voltage division circuits **183** and **184** are connected by a common line **189**. Since the voltage division circuits **183** and **184** equal in construction to each other, the voltage V_M is a middle voltage (−2.5 volts for instance) between the high voltage V_H and the low voltage V_L. Therefore, the voltage division circuits **183** and **184** serve to divide a voltage (2.5 volts for instance) which is a half of the potential difference between the high voltage V_H and the low voltage V_L into 64 steps for address **0** through **63**. For eight steps from address **0** to address 7, resistors are arranged so as to obtain exponential voltage division ratios. On the other hand, for fifty-six steps from address **8** to address **63**, equal resistors are series-connected so as to obtain equal voltage division ratios. Therefore, the relationships between the values **0** through **63** of the count value data CV_1 through CV_6 applied as the address inputs and the contents stored in the memory **12** are as indicated by the solid line in FIG. **7**.

Accordingly, in the regions I through VII where the count value CV is from 63 to 8, the count value is converted into analog voltage in linear relationship. However, as the variation of the count value CV itself is approximated in exponential relationship with polygonal lines as was described with reference to FIGS. **10** and **11**, envelope amplitude information (voltage) having a polygonal-line-like decay exponential characteristic and coincident with the variation of the count value CV (that is, the variation of the address input) is read out of the memory **12**. In addition, in the last region VIII where the count value CV is linearly varied from 7 to 0, as the content stored in the memory **12** is exponentially set, envelope amplitude information having an exponential characteristic is automatically read out even if the address input is linearly changed.

As conducive to an understanding of the difference between the variation of the count value CV itself of the counter and the envelope amplitude information read out of the memory **12**, an exponential characteristic waveform directly read out of the memory **12** is indicated by the broken line in FIG. **10**. By the combination of the exponential approximation with polygonal lines by computation and the analogous exponential approximation by reading an exponential waveform in the last region VIII, a decay envelope having an ideal exponential characteristic which reaches a zero level gently can be obtained.

It goes without saying that the whole addresses of the memory **12** may be set linear. In this case, in the last region VIII also, the envelope amplitude values are read out as the variation of the count value CV indicated by the solid line in FIG. **10**.

The memory **12** shown in FIG. **5** is provided with the two resistance type voltage division circuits **183** and **184** to which voltage are applied in the opposite directions. Therefore, two envelope shapes which vary symmetrically about the middle voltage V_M can be obtained from the output lines **190** and **191** of the analog gate groups **185** and **186**, respectively. This is to apply the envelope shapes produced by the groups X_1, X_2 and X_3 to a musical tone waveshape memory formed as a voltage division circuit. For instance, the group X_1 receives an envelope shape HX_1 through the output line **190**, and an envelope shape LX_1 through the output line **191**. These envelope shapes HX_1 and LX_1 are applied to both end terminals of a voltage division circuit **193** of a musical tone waveshape memory **192** as shown by way of example in FIG. **12**, where the potential difference between the shapes HX_1 and LX_1 is subjected to voltage division. Data qF which varies periodically according to the frequency of the tone of a key depressed is applied to a decoder **194** of the memory **192**. A gate **195** of the memory **192** is controlled by the output of the decoder **194**, thereby to obtain the output of the voltage division circuit **193**. Therefore, an envelope-controlled musical tone waveshape signal MW as shown in FIG. **13** is read out of the musical tone waveshape memory **192**.

However, in the case where an envelope is given to a musical tone waveshape by using a voltage-controlled type amplifier or a multiplication circuit, the envelope information read out of the memory **12** may be of only one shape.

The signal (the upper side enevelope shape) on the output line **190** of the memory **12** is applied to analog gates **196**, **197** and **198** of the memory output distribution gate **27**; while the signal (the lower side envelope shape) on the output line **191** thereof is applied to analog gates **199**, **200** and **201** of the memory output distribution gate **27**.

Generation of Direct Keying Shape

The direct keying shape selection signals 0_1, 0_2 and 0_3 outputted by the direct keying shape generation system decoder **25** in FIG. **3**, the attack start signal AS, and the decay start signal DS are supplied to the direct keying shape generating section **26** (FIG. **5**) through a shift register group **202** for timing adjustment.

The direct keying shape generating section **26** comprises: analog gates **203**, **204** and **205** for introducing the high voltage V_H, as the maximum level envelope amplitude value, to the upper side envelope shape outputs HX_1, HX_2 and HX_3 of the output groups X_1, X_2 and H_3; analog gates **206**, **207** and **208** for introducing the middle voltage V_M on the line **189**, as the zero level envelope amplitude value, to the upper side envelope shape outputs HX_1, HX_2 and HX_3 of the output groups X_1, X_2 and X_3; analog gates **209**, **210** and **211** for introducing the middle voltage V_M, as the zero level envelope amplitude value, to the lower side envelope shape outputs LX_1, LX_2 and LX_3 of the output groups X_1, X_2 and X_3; and analog gates **212**, **213** and **214** for introducing the low voltage V_L, as the maximum level envelope amplitude value, to the lower side envelope shape output LX_1, LX_2 and LX_3.

Where the direct keying shape selecting signals 0_1, 0_2 and 0_3 are in the group of "1", the direct keying shape is produced by the direct keying shape generating section **26**. Where the signals 0_1, 0_2 and 0_3 are in the group of "0", an envelope shape read out of the memory **12** through the gate **27** is selected. Therefore, when the signal 0_1, 0_2 and 0_3 are at the "1" level, AND circuits **215**, **216**, **217**, **218**, **219** and **220** corresponding to the signals 0_1, 0_2 and 0_3 of the direct keying shape generating section **26** are enabled. As was desribed before, the direct keying shape selecting signals 0_1, 0_2, and 0_3 are produced only when the keyboard signals UE–PE are produced by depression of a key. In addition, the decay start signal DS is at the "0" level during the key depression, and therefore the output of the inverter **221** is raised to "1", and the AND circuits **215** through **217** are enabled. Accordingly, when one of the signals 0_1, 0_2 and 0_3 is raised to "1" in the combinations indicated in Table 2, the output of tone of the AND circuits **215** through **216** corresponding to this signal is raised to "1", and the analog gates **203** and **212**, or **204** and **213**, or **205** and **214** which correspond to this AND circuit are operated. Thus, the maximum level voltages V_H and V_L are applied to the upper side envelope shape outputs HX_1–HX_3 and the lower side envelope shape outputs LX_1–LX_3 in the groups X_1–X_3 where the signals 0_1–0_3 are "1", respectively. The supply of the aforementioned maximum level voltages H_V and L_V is continued until, upon release of the key, the decay start signal DS is raised to "1" and the AND circuit **215** through **217** are made inoperable. When the decay start signal DS is raised to "1", the AND circuits **218** through **220** are operated, and the analog gates **206** through **208** and **209** through **211** are operated through the OR circuit **222** through **224**. As a result, the middle voltage V_M is applied, as the "0" level voltage of the envelope shape, to the outputs HX_1 through LX_3. Thus, the envelope shape in the direct keying mode as shown in FIG. **11**(d) is obtained.

The analog gates **196** through **201** of the memory output distribution gate **27** are controlled by the outputs of NOR circuits **225**, **226** and **227**. When the attack start signal AS is raised to "1" by depressing a key, the output of an inverter **228** becomes "0" to enable the NOR circuits **225** through **227**. The direct keying shape selecting signals 0_1, 0_2 and 0_3 are applied to the other inputs of the NOR circuits **225** through **227**. When the signals 0_1 through 0_3 are "0", the outputs of the NOR circuits **225** through **227** are raised to "1". By the outputs "1" of the NOR circuits **225** through **227**, the respective analog gates **196** and **199**, or **197** and **200**, or **198** and **201** are operated, thereby to introduce the envelope shape signals supplied through the output lines **190** and **191**, as the upper side envelope shape output HX_1, HX_2 or HX_3 and the lower side envelope shape output LX_1, LX_2 or LX_3, respectively.

For instance, in the case of Envelope Function No. **1** in Table 2, the signals 0_1, 0_2 and 0_3 are "0 0 1". Therefore, the analog gates **205** and **214** of the direct keying shape generating section **26** are operated, and therefore the envelope shape in the direct keying mode is introduced to the upper side envelope shape output HX_3 and the lower side envelope shape output LX_3 of the group X_3. On the other hand, in the memory output distribution gate **27**, the analog gates **196**, **197**, **199** and **200** of the groups X_1 and X_2 are operated, so as to introduce the output of the memory **12**, that is, the envelope shape in the sustain mode B in this case to the upper side envelope shape outputs HX_1 and HX_2 and the lower side envelope shape outputs HX_1 and HX_2 and the lower side envelope shape outputs LX_1 and LX_2.

As is apparent from the above description, the envelope shape produced by the system of the counter **11** and the memory **12** and the direct keying shape produced by the direct keying shape generating section **26** are distributed to the groups X_1, X_2 and X_3.

Upon elimination of the tone production assignment, the attack start signal AS produced for the relevant channel time becomes "0". As a result, the output "1" of the inverter **228** operates the analog gates **206** through **211** through the OR circuits **222**, **223**, and **224**. Therefore, the middle voltage V_M representing the "0" level is introduced to the upper side envelope shape outputs HX_1 through HX_3 and the lower side envelope shape outputs LX_1 through LX_3 of the groups X_1 through X_3, and the output level of the envelope generator **10** is positively held at the level "0". That is, no envelope is produced.

In the above-described embodiment, the memory **12** is so designed as to produce analog voltages; however, it may be so designed as to read out digital envelope amplitude information. Furthermore, a digital-to-analog conversion circuit may be employed as the memory **12**.

As is apparent from the above description, according to this invention, envelope shapes are produced by computation. Therefore, the step number of amplitude variations forming an envelope can be increased to an unlimited extent by combination of addition and subtraction operations of the counter. Accordingly, it is possible to generate envelope shapes in a variety of modes. In addition, all that is necessary for the content stored in the memory adapted to store the envelope amplitude levels is to linearly correspond to the count values of the counter. Therefore, setting the content of the memory can be readily achieved, which leads to the simplification of the construction of the memory. While the step number can be increased to an unlimited extent by computation, the storage capacity of the memory may be equal to the number of modulo. This is considerably economical. Furthermore, an envelope having an exponential characteristic can be readily obtained by

polygonal line approximation computation. In addition, by setting a small part of the storage in the memory to an exponential characteristic, an envelope shape having a fine exponential characteristic which cannot be obtained by polygonal line approximation computation only can be obtained by the device which is simpler in construction than the conventional one.

What is claimed is:

1. An envelope generator for an electronic musical instrument, said generator providing selectably different musical envelope shapes, comprising:

a counting circuit selectively operable in a linear counting mode and in a non-linear counting mode, each in response to count pulses applied thereto;

a count mode control means for switching said counting circuit to one of said linear or non-linear counting modes;

a plurality of clock pulse sources, each supplying count pulses at different rates;

a count rate control means for applying to said counting circuit count pulses from a selected one of said sources;

an envelope shape selection means for programmatically causing (a) said count mode control means to select said counting modes and (b) said count rate control means to apply count pulses from different sources so that the resultant count values of said counting circuit will correspond to a selectable envelope shape; and

a conversion circuit for converting said resultant count values of said counting circuit to amplitude data;

said envelope generator thereby generating an envelope shape having an amplitude variation corresponding to the resultant variation in said count value.

2. An envelope generator as defined in claim 1 wherein said envelope shape selection means includes as one of its selectable envelope shapes a percussive damp mode in which said count mode control means and said count rate control means cooperate to cause said counting circuit to downcount gradually from a maximum count during depression of a key and, subsequently to release of the key, to cause said counting circuit to downcount quickly to a minimum count by applying count pulses of a faster rate to said counting circuit as compared with the rate of count pulses applied prior to release of the key;

whereby said envelope generator generates an envelope shape which is provided with a short decay shape subsequently to release of the key.

3. An envelope generator as defined in claim 1 further comprising:

envelope shape selection means for providing a set of binary coded signal respectively specifying different envelope shapes, said envelope shape selection means operating in response to said signals and to the actual count value of said counting circuit.

4. An envelope generator as defined in claim 3 wherein one of the envelope shapes specifiable by said signals is a direct keying mode in which the envelope becomes maximum value when a key included in said electronic musical instrument is depressed and becomes minimum value when said key is released, and wherein said envelope shape selection means includes circuitry for forcing the count value of said counting means to correspond to said maximum value in response to depression of said key and for forcing the count value to correspond to said minimum value when said key is released.

5. An envelope generator according to claim 3 wherein said instrument includes curve selection switch means for selecting a modified form of the envelope shape specified by said signals, said envelope shape selection means operating in response to actuation of said curve selection switch means to modify the programmatic selection of counting mode and the application of count pulses so as to cause the production of said modified form of selected envelope shape.

6. An envelope generator according to claim 1 wherein said conversion circuit includes a pair of voltage dividers connected between high voltage and low voltage sources, and corresponding two sets of gates respectively connecting points on said pair of dividers to a pair of output lines, said gates being operatively connected to said counting circuit so as to be enabled in accordance with the count value thereof, said envelope generator thereby producing on said pair of output lines two envelope shapes which vary symmetrically about a common voltage intermediate said high and low voltages.

7. An envelope generator for a keyboard electronic musical instrument, comprising:

envelope mode selection logic means for providing a set of binary coded envelope mode selecting signals respectively specifying certain envelope shapes to be produced by said generator,

means for supplying count pulses,

a counter operable to count in a linear manner and in an exponential manner in response to count pulses applied thereto,

count pulse rate selection means for controlling the rate of count pulses applied to said counter, and

envelope generation control logic means for programmatically controlling the manner of counting of said counter and the rate of count pulses applied to said counter in response to the depression and release of a key, to the provided envelope mode selecting signal and to the count value of said counter, so as to cause the count value of said counter to vary with time and to represent the amplitudes of an envelope having the shape specified by said provided envelope mode selecting signal.

8. An envelope generator according to claim 7 together with memory means comprising:

a pair of voltage dividers connected between high voltage and low voltage sources, and

two corresponding sets of gates respectively connecting points on said pair of dividers to a pair of output lines, said gates being operatively connected to said counter so as to be enabled in accordance with the count value thereof, said envelope generator thereby producing on said pair of output lines two envelope shapes which vary symmetrically about a common voltage intermediate said high and low voltages.

9. An envelope generator according to claim 8 together with a musical tone waveshape memory having a voltage division circuit and a gate connected so as to sample selected points of said voltage division circuit at a rate which varies periodically according to the frequency of the tone associated with said depressed key, said pair of output lines from said memory means being connected to opposite ends of said voltage division circuit.

10. An envelope generator used in a keyboard electronic musical instrument for selectively generating an envelope waveshape signal which is used to impart a characteristic varying with time to a musical tone produced by said instrument, comprising:

switch responsive means for producing a binary coded envelope selection signal indicative of a selected one of plural envelope waveshapes available for production by said envelope generator,

envelope mode selection logic for providing one subset of a set of envelope mode selecting signals in response to said binary coded envelope selection signal,

register means for storing envelope waveshape data corresponding to the current value of said envelope waveshape signal which establishes said time varying characteristic of the musical tone,

arithmetic means, receiving waveshape variation data, for arithmetically combining the waveshape variation data with at least a pair of said envelope waveshape data stored in said register means, the resultant new envelope waveshape data being stored in said register means in place of the data previously stored therein, said arithmetic means performing designatable arithmetic operations,

control logic means for programmatically controlling operations of said arithmetic means and producing said waveshape variation data in response to the depression and release of a keyboard key and to the provided subset of envelope mode selecting signals, said provided subset of envelope mode selecting signals at least designating the certain arithmetic operations of said arithmetic means required to obtain said selected one envelope waveshape, and

feedback means for feeding back at least a part of the stored envelope waveshape data of said register means to said control logic means so that the production of said waveshape variation data is modified thereby.

11. An envelope generator according to claim 10 wherein said instrument includes curve selection switch means for selecting a modified form of the envelope shape specified by said signals, said envelope mode selection logic operating in response to actuation of said curve selection switch means to modify the programmatic control of said arithmetic means and the production of said waveshape variation data to cause the production of said modified form of selected envelope shape.

12. An envelope generator as defined in claim 10 wherein said switch responsive means includes as one of its available envelope waveshapes a percussive damp mode in which said control logic means and said arithmetic means cooperate to cause said register means to count down at a first, relatively gradual rate from a maximum count during depression of a key and, subsequent to release of the key, to cause said register means to count down to a minimum count at a second rate that is relatively quicker than said first rate, thereby generating an envelope shape which is provided with a short decay shape subsequent to the release of the key.

13. An envelope generator as defined in clim 10 wherein one of the envelope shapes specifiable by said signals is a direct keying mode in which the envelope becomes maximum value when a key included in said electronic musical instrument is depressed and becomes minimum value when said key is released, and wherein said envelope shape selection logic includes circuitry for forcing the count value of said counting means to correspond to said maximum value in response to depression of said key and for forcing the count value to correspond to said minimum value when said key is released.

14. An envelope generator used in a keyboard electronic musical instrument for selectively generating an envelope waveshape signal which is used to impart a characteristic varying with time to a musical tone produced by said instrument, comprising:

envelope mode selection logic means for providing a set of binary coded envelope mode selecting signals respectively specifying certain envelope shapes to be produced by said generator,

a source of count pulses,

a counter operable to count in selectable manners in response to said count pulses applied thereto,

count pulse rate selection means for controlling the rate of count pulses applied to said counter, and

envelope generation control logic means for programmatically controlling the manner of counting of said counter and the rate of count pulses applied to said counter in response to the depression and release of a key, to the provided envelope mode selecting signal and to the count value of said counter, so as to cause the count value of said counter to vary with time and to represent the amplitudes of an envelope having the shape specified by said provided envelope mode selecting signal, the resultant contents of said counter thus representing said envelope waveshape signal.

15. An envelope generator used in a keyboard electronic musical instrument for selectively generating an envelope waveshape signal which is used to impart a characteristic varying with time to a musical tone produced by said instrument, comprising:

envelope mode selection logic means for providing a set of binary coded envelope mode selecting signals respectively specifying certain envelope shapes to be produced by said generator,

a source of count pulses,

a counter, operable in response to count pulses applied thereto, and having selectably different modes each characterized by a different net change in resultant count value per set number of applied pulses,

count pulse rate selection means for controlling the rate of count pulses applied to said counter, and

envelope generation control logic means for programmatically controlling the mode of counting of said counter and the rate of count pulses applied to said counter in response to the depression and release of a key, to the provided envelope mode selecting signal and to the count value of said counter, so as to cause the count value of said counter to vary with time and to represent the amplitudes of an envelope having the shape specified by said provided envelope mode selecting signal, the resultant contents of said counter thus representing said envelope waveshape signal.

16. An envelope generator used in a keyboard electronic musical instrument for selectively generating an envelope waveshape signal which is used to impart a characteristic varying with time to a musical tone produced by said instrument, comprising:

envelope mode selection logic means for providing a set of binary coded envelope mode selecting signals respectively specifying certain envelope shapes to be produced by said generator,

means for supplying signals for incrementing or decrementing a counter by certain values,

a counter operable to count in selectable manners in response to increment or decrement value signals applied thereto,

rate selection means for controlling the rate at which said increment or decrement value signals are supplied to said counter, and

envelope generation control logic means for programmatically controlling the manner of counting of said counter and the rate at which said increment or decrement value signals are applied to said counter in response to the depression and release of a key, to the provided envelope mode selecting signal and to the count value of said counter, so as to cause the count value of said counter to vary with time and to represent the amplitudes of an envelope having the shape specified by said provided envelope mode selecting signal, the resultant contents of said counter thus representing said envelope waveshape signal.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : RE 30,906

DATED : April 20, 1982

INVENTOR(S) : Teruo Hiyoshi; Akira Nakada

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

Column 27, line 54 and line 56, change "selection" to --selecting--.

Column 29, line 19, change "pair" to --part--.

Signed and Sealed this

Fifteenth Day of *November 1983*

[SEAL]

Attest:

GERALD J. MOSSINGHOFF

Attesting Officer *Commissioner of Patents and Trademarks*