



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁵ : G01L 7/06, H03M 7/00	A1	(11) International Publication Number: WO 91/14162 (43) International Publication Date: 19 September 1991 (19.09.91)
(21) International Application Number: PCT/JP90/00323 (22) International Filing Date: 13 March 1990 (13.03.90) (71) Applicant: ICHIKAWA, Kozo [JP/JP]; Piercourts 2-304, 4979-6, Totsuka-cho, Totsuka-ku, Yokohama-shi, Kanagawa-ken 244 (JP). (72) Inventor: LIN, Min-Shiung ; 3rd FL, No. 21, Lane 331, Min-Der Road, Peitou Dist., Taipei (CN). (74) Agents: TOMITA, Kazuko et al.; Kiyoken-Bldg., Yokohama-Just 7F., 12-6, Takashima 2-chome, Nishi-ku, Yokohama-shi, Kanagawa-ken 220 (JP).		(81) Designated States: AT (European patent), AU, BE (European patent), BG, BR, CH (European patent), DE (European patent)*, DK (European patent), ES (European patent), FI, FR (European patent), GB (European patent), HU, IT (European patent), JP, KR, LK, LU (European patent), NL (European patent), NO, RO, SE (European patent), SU. Published <i>With international search report.</i>
(54) Title: METHOD AND APPARATUS FOR ACOUSTIC SIGNAL COMPRESSION (57) Abstract The present invention is related to a method for acoustic signal storage access with minimized memory capacity occupation and the related hardware equipment, and more particularly to the method which analyses and calculates the waveform data of an acoustic signal for storage in a memory and the related hardware equipment required for such storage access process.		

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DESCRIPTION

Method and apparatus for acoustic signal compression

5 BACKGROUND OF THE INVENTION

Conventional method to store acoustic signal electrically is to continuously sample acoustic signals and turn the signals into digital signals for storage in a memory one after another by means of an A/D converter; for retrieval of acoustic signals, read out the data from the memory one after another in proper order according to the order they are originally stored (its reading rate is equal to sampling rate).

15 According to the above-described conventional method, a random access memory (RAM) of big capacity is generally required. For a sampling rate of 10kHz as an example, a capacity of 10^4 bytes is required for an acoustic signal of one second (When 1024 bytes is calculated as 1 K bytes, a capacity of 9.77 K bytes will be required). Therefore, a capacity of 3600×10^4 bytes = 35156.25 K bytes = 35.15625 M bytes will be required for the storage of an acoustic signal of 1 hour. For such a high capacity of RAM, either in dynamic or static state, it is still not possible to build in a single chip through the known technology. If to barely design for the storage of an one hour's acoustic signal, several memory chips must be used.

30 The present invention is to provide a new storage technology which greatly reduces memory capacity occupation. According to the present invention, a half-hour or longer acoustic signal can be stored in a RAM of 256 K bytes (8 bits for each byte, this high capacity of RAM has been

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commercialized). Therefore, it is capable of storing the data recorded in an existing cassette tape. Since the capacity of a ROM can be much larger than a RAM under same I.C. manufacturing technology,
 5 acoustic signals of musics and songs can be pre-stored in a ROM for commercial purpose to replace conventional recording tape.

In the following description, equations (52) and (54) have been simulated through computer
 10 operation with satisfactory result.

PRINCIPLE:

I. EQUATIONS TO BE APPLIED:

1. Assume $F(x)$ continues in real number interval $[a, b]$, and $F'(x)$, $F''(x)$, $\dots$, $F^{(n)}(x)$ ($n \in \mathbb{N}$) all exist,
 15 i then :

$$\begin{aligned} \int_a^b F(x) \sin(H\pi x) dx = & \sum_{i=0}^{\infty} \left\{ \frac{(-1)^i}{(H\pi)^{2i+1}} [F^{(2i)}(b) \cos(bH\pi) \right. \\ & \left. - F^{(2i)}(a) \cos(aH\pi)] \right\} \\ & + \sum_{i=0}^{\infty} \left\{ \frac{(-1)^{i-1}}{(H\pi)^{2i-1}} [F^{(2i-1)}(b) \sin(bH\pi) \right. \\ & \left. - F^{(2i-1)}(a) \sin(aH\pi)] \right\} \dots \dots \dots (1)-1 \end{aligned}$$

20 The above equation can be proved by means of partial integration (in which $F^{(2i)}(x)$ and $F^{(2i-1)}(x)$ are derivatives at $2i$ and $2i-1$ times from x).

Assign that:

$$\begin{aligned} F_{..}(H, a, b) = & \sum_{i=0}^{\infty} \left\{ \frac{(-1)^i}{(H\pi)^{2i+1}} [F^{(2i)}(b) \cos(bH\pi) \right. \\ & \left. - F^{(2i)}(a) \cos(aH\pi)] \right\} \dots \dots \dots (2)-1 \end{aligned}$$

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$$F_{..}(H,a,b) = \sum_{i=1}^{\infty} \left\{ \frac{(-1)^{i-1}}{(H\pi)^{2i}} [F^{(2i-1)}(b) \sin(bH\pi) - F^{(2i-1)}(a) \sin(aH\pi)] \right\} \dots\dots\dots (2)-2$$

Thus:

$$\int_a^b F(x) \sin(H\pi x) dx = F_{.c}(H,a,b) + F_{..}(H,a,b) \dots\dots\dots (1)-2$$

5 In the same way:

$$\begin{aligned} \int_a^b F(x) \cos(H\pi x) dx = & \sum_{i=0}^{\infty} \left\{ \frac{(-1)^i}{(H\pi)^{2i+1}} [F^{(2i)}(b) \sin(bH\pi) - F^{(2i)}(a) \sin(aH\pi)] \right\} \\ & + \sum_{i=1}^{\infty} \left\{ \frac{(-1)^{i-1}}{(H\pi)^{2i}} [F^{(2i-1)}(b) \cos(bH\pi) - F^{(2i-1)}(a) \cos(aH\pi)] \right\} \dots\dots\dots (1)-3 \end{aligned}$$

10 Now, letting:

$$F_{..}(H,a,b) = \sum_{i=0}^{\infty} \left\{ \frac{(-1)^i}{(H\pi)^{2i+1}} [F^{(2i)}(b) \sin(bH\pi) - F^{(2i)}(a) \sin(aH\pi)] \right\} \dots\dots\dots (2)-3$$

$$F_{.c}(H,a,b) = \sum_{i=1}^{\infty} \left\{ \frac{(-1)^{i-1}}{(H\pi)^{2i}} [F^{(2i-1)}(b) \cos(bH\pi) - F^{(2i-1)}(a) \cos(aH\pi)] \right\} \dots\dots\dots (2)-4$$

15 Thus:

$$\int_a^b F(x) \cos(H\pi x) dx = F_{.c}(H,a,b) + F_{..}(H,a,b) \dots\dots\dots (1)-4$$

2. Define an "auxiliary function" in any real number interval $[-M, M]$ ($M > 0$) as follows:

$$P(x) = \begin{cases} L(x); & \text{when } x \in [-M, 0] \\ R(x); & \text{when } x \in [0, M] \end{cases} \dots\dots\dots (3)$$

5 in which $L(x)$ and $R(x)$ are respectively called as "left auxiliary function" and "right auxiliary function", they are a continuous function in real number interval $[-M, 0]$ and $[0, M]$, and $L^{(n)}(x)$ and $R^{(n)}(x)$ ($n \in \mathbb{N}$) exist, $L(0) = R(0)$.

10 $P(x)$ in interval $[-M, M]$ can be expanded by means of Fourier series:

$$P(x) = \frac{1}{2}a_0 + \sum_{n=1}^{\infty} [a_n \cos(n\omega_0 x) + b_n \sin(n\omega_0 x)] \dots\dots\dots (4)-1$$

In above equation (4)-1, if n is taken to k , there is total $2k-1$ items in the right side (some
15 items may be zero). Then, use $P_k(x)$ to express the sum of $2k-1$ items, thus:

$$P_k(x) = \frac{1}{2}a_0 + \sum_{n=1}^k [a_n \cos(n\omega_0 x) + b_n \sin(n\omega_0 x)] \dots\dots\dots (4)-2$$

therefore, the value of a_0 , a_n and b_n in the equations of (4)-1 and (4)-2 are respectively as
20 follows:

$$a_0 = \frac{1}{M} \int_{-M}^0 L(x) dx + \frac{1}{M} \int_0^M R(x) dx$$

$$a_n = \frac{1}{M} \int_{-M}^0 L(x) \cos(n\omega_0 x) dx + \frac{1}{M} \int_0^M R(x) \cos(n\omega_0 x) dx$$

$$b_n = \frac{1}{M} \int_{-M}^0 L(x) \sin(n\omega_0 x) dx + \frac{1}{M} \int_0^M R(x) \sin(n\omega_0 x) dx$$

in which, $\omega_0 = \frac{\pi}{M}$ °

(4)-1 and (4)-2 can also be rewritten as follows:

$$P(x) = c_0 + \sum_{n=1}^{\infty} [c_n \cos(n\omega_0 x - \theta_n)] \dots \dots \dots (4)-3$$

$$P_k(x) = c_0 + \sum_{n=1}^k [c_n \cos(n\omega_0 x - \theta_n)] \dots \dots \dots (4)-4$$

5 in which, $c_0 = \frac{1}{2}a_0$, $c_n = \sqrt{a_n^2 + b_n^2}$, $\theta_n = \tan^{-1}(\frac{b_n}{a_n})$.

In (4)-2 and (4)-4, to what extent the k shall be taken so that $P_k(x)$ can approximate $P(x)$ is determined according to $L(x)$ and $R(x)$ selected. Generally, in interval $[-M, M]$ when M has a fixed value,
 10 the more the points of extreme large and extreme small in $L(x)$ and $R(x)$, the bigger the value of k , and the closer the approximation of $P_k(x)$ to $P(x)$ (this is a matter of mathematics and not within the scope of the present invention, further detail will
 15 be provided when it is required).

II. "SINE WAVEFORM FUNCTION" AND ITS CALCULATION:

$$\text{Function } A_s(S, t) = \int_{-t}^{T-t} P(x) S(x+t) \sin(H\pi x) dx \dots \dots \dots (5)$$

It is called $S(t)$'s "sine waveform function"; in $A_s(S, t)$ the lower mark "s" means sine, in the
 20 parentheses () the first character "s" means function " $S(t)$ ", and the second character "t" represents variable. Further, in this equation, $P(x)$ is an "auxiliary function" as defined in equation (3), $t \in [0, T]$, $0 < T \leq M$, H is any real number.

25 According to the definition of $P(x)$ defined by means of equation (3), $A_s(S, t)$ can also be

rewritten as follows:

$$\begin{aligned}
 A_*(S,t) &= \int_{-t}^0 L(x)S(x+t)\sin(H\pi x)dx \\
 &\quad + \int_0^{T-t} R(x)S(x+t)\sin(H\pi x)dx \\
 &= D_{**}(H, -t, 0) + D_{**}(H, -t, 0) \\
 &\quad + E_{**}(H, 0, T-t) + E_{**}(H, 0, T-t)
 \end{aligned}$$

when substitute equation (1)-2, thus:

$$\begin{aligned}
 A_*(S,t) &= D_{**}(H, -t, 0) + D_{**}(H, -t, 0) \\
 &\quad + E_{**}(H, 0, T-t) + E_{**}(H, 0, T-t) \dots \dots \dots (6)
 \end{aligned}$$

in which, we assign $D(x,t) = L(x)S(x+t)$ and $E(x,t) = R$
 10 $(x)S(x+t)$ (D and E here are respectively a function
 which contains two variables).

In equation (4)-2, if the value of k that
 we take is sufficient to permit $P_k(x)$ to be a very
 close approximation to $P(x)$, then, $A_*(S,t)$ can be
 15 rewritten as follows:

$$\begin{aligned}
 A_*(S,t) &\doteq \int_{-t}^{T-t} P_k(x)S(x+t)\sin(H\pi x)dx \\
 &= \frac{1}{2}a_0 \int_{-t}^{T-t} S(x+t)\sin(H\pi x)dx \\
 &\quad + \sum_{n=1}^k \int_{-t}^{T-t} [a_n \cos(n\omega_0 x) + b_n \sin(n\omega_0 x)] \\
 &\quad \cdot S(x+t)\sin(H\pi x)dx \\
 &= \frac{1}{2}a_0 [S_{**}(H, -t, T-t) + S_{**}(H, -t, T-t)] \\
 &\quad + \sum_{n=1}^k a_n \int_{-t}^{T-t} S(x+t)\cos(n\omega_0 x)\sin(H\pi x)dx \\
 &\quad + \sum_{n=1}^k b_n \int_{-t}^{T-t} S(x+t)\sin(n\omega_0 x)\sin(H\pi x)dx \dots \dots (7)-1
 \end{aligned}$$

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$$= \frac{1}{2} a_0 [S_{s,c}(H, -t, T-t) + S_{c,s}(H, -t, T-t)] \\ + \alpha_s(t) + \beta_s(t) \dots \dots \dots (7)-2$$

in which, $\alpha_s(t)$ and $\beta_s(t)$ are respectively regarded
as "sine waveform function" of the cosine and sine of
5 $S(t)$, and the value of which are respectively as
follows:

$$\alpha_s(t) = \sum_{n=1}^k a_n \int_{-t}^{T-t} S(x+t) \cos(n \omega_0 x) \sin(H \pi x) dx \dots \dots (8)-1$$

$$\beta_s(t) = \sum_{n=1}^k b_n \int_{-t}^{T-t} S(x+t) \sin(n \omega_0 x) \sin(H \pi x) dx \dots \dots (8)-2$$

because:

$$\begin{aligned} 10 \quad & \int_{-t}^{T-t} S(x+t) \cos(n \omega_0 x) \sin(H \pi x) dx \\ &= \int_0^T S(x') \cos[n \omega_0 (x' - t)] \sin[H \pi (x' - t)] dx \\ &= \int_0^T S(x) \cos(n \omega_0 x - n \omega_0 t) \sin(H \pi x - H \pi t) dx \\ &= \int_0^T S(x) [\cos(n \omega_0 x) \cos(n \omega_0 t) + \sin(n \omega_0 x) \sin(n \omega_0 t)] \\ & \quad \cdot [\sin(H \pi x) \cos(H \pi t) - \sin(H \pi t) \cos(H \pi x)] dx \end{aligned}$$

$$\begin{aligned} 15 \quad &= \cos(n \omega_0 t) \cos(H \pi t) \int_0^T S(x) \cos(n \omega_0 x) \sin(H \pi x) dx \\ & \quad - \cos(n \omega_0 t) \sin(H \pi t) \int_0^T S(x) \cos(n \omega_0 x) \cos(H \pi x) dx \\ & \quad + \sin(n \omega_0 t) \cos(H \pi t) \int_0^T S(x) \sin(n \omega_0 x) \sin(H \pi x) dx \\ & \quad - \sin(n \omega_0 t) \sin(H \pi t) \int_0^T S(x) \sin(n \omega_0 x) \cos(H \pi x) dx \end{aligned}$$

(9)-1

In the same manner, it can be obtained that:

$$\begin{aligned}
 & \int_{-t}^{T-t} S(x+t) \sin(n\omega_0 t) \sin(H\pi x) dx \\
 &= \cos(n\omega_0 t) \cos(H\pi t) \int_0^T S(x) \sin(n\omega_0 x) \sin(H\pi x) dx \\
 & \quad - \cos(n\omega_0 x) \sin(H\pi x) \int_0^T S(x) \sin(n\omega_0 t) \cos(H\pi t) dx \\
 & \quad - \sin(n\omega_0 t) \cos(H\pi t) \int_0^T S(x) \cos(n\omega_0 x) \sin(H\pi x) dx \\
 & \quad + \sin(n\omega_0 x) \sin(H\pi x) \int_0^T S(x) \cos(n\omega_0 t) \cos(H\pi t) dx
 \end{aligned}
 \tag{9}-2$$

When substituting equations (9)-1 and (9)-2 in equations (8)-1 and (8)-2, respectively for

10 $\alpha_*(t) + \beta_*(t)$, thus, we can obtain:

for $\alpha_*(t) + \beta_*(t)$, thus, we can obtain:

$$\begin{aligned}
 \alpha_*(t) + \beta_*(t) &= \sum_{n=1}^k \{ [a_n \cos(n\omega_0 t) - b_n \sin(n\omega_0 t)] \\
 & \quad \cdot \cos(H\pi t) \int_0^T S(x) \cos(n\omega_0 x) \sin(H\pi x) dx \} \\
 & \quad + \sum_{n=1}^k \{ [-a_n \cos(n\omega_0 t) + b_n \sin(n\omega_0 t)] \\
 & \quad \cdot \sin(H\pi t) \int_0^T S(x) \cos(n\omega_0 x) \cos(H\pi x) dx \} \\
 & \quad + \sum_{n=1}^k \{ [a_n \sin(n\omega_0 t) + b_n \cos(n\omega_0 t)] \\
 & \quad \cdot \cos(H\pi t) \int_0^T S(x) \sin(n\omega_0 x) \sin(H\pi x) dx \} \\
 & \quad + \sum_{n=1}^k \{ [-a_n \sin(n\omega_0 t) - b_n \cos(n\omega_0 t)] \\
 & \quad \cdot \sin(H\pi t) \int_0^T S(x) \sin(n\omega_0 x) \cos(H\pi x) dx \}
 \end{aligned}
 \tag{10}$$

Assign $T=m(\Delta T)$; $\Delta T \rightarrow 0$, $m \rightarrow \infty$ $m \in \mathbb{N} \cup \{0\}$. In equations (5) ~ (10), each variable t which is contained in interval $[0, T]$ is assigned as $j(\Delta T)$ ($j=0, 1, \dots, m$), i.e. $t=j(\Delta T)$, thus,

$$\begin{aligned} 5 \quad & \int_0^T S(x) \cos(n \omega_0 t) \sin(H \pi x) dx \\ & = \sum_{j=0}^{m-1} \int_{j(\Delta T)}^{(j+1)\Delta T} S(x) \cos(n \omega_0 x) \sin(H \pi x) dx \dots \dots \dots (11) \end{aligned}$$

Since interval $[j(\Delta T), (j+1)\Delta T]$ is extremely small, the $S(x)$ of the two end points which are connected to this interval (i.e. coordinates $(x_1, s(x_1))$ and $(x_2, s(x_2))$) is a straight line; here we use $\bar{S}_j(x)$ to express this straight line, thus:

$$\begin{aligned} \bar{S}_j(x) &= \frac{S((j+1)\Delta T) - S(j(\Delta T))}{\Delta T} x \\ &\quad + (j+1) \cdot S(j(\Delta T)) - j \cdot S((j+1)\Delta T) \\ &= S'(j(\Delta T)) \cdot x + (j+1) \cdot S(j(\Delta T)) \\ 15 \quad &\quad - j \cdot S((j+1)\Delta T) \dots \dots \dots (12) \end{aligned}$$

Substitute equation (12) in equation (11), we can obtain an approximate expression as follows:

$$\begin{aligned} & \int_0^T S(x) \cos(n \omega_0 x) \sin(H \pi x) dx \\ & \doteq \sum_{j=0}^{m-1} [S'(j(\Delta T)) \int_{j(\Delta T)}^{(j+1)\Delta T} x \cos(n \omega_0 x) \sin(H \pi x) dx] \\ 20 \quad & + \sum_{j=0}^{m-1} \{[(j+1) \cdot S(j(\Delta T)) - j \cdot S((j+1)\Delta T)] \\ & \cdot \int_{j(\Delta T)}^{(j+1)\Delta T} \cos(n \omega_0 x) \sin(H \pi x) dx \dots \dots \dots (13) \end{aligned}$$

In the same manner, it can be obtained that:

$$\begin{aligned}
 & \int_0^T S(x) \cos(n \omega_0 x) \cos(H \pi x) dx \\
 & \doteq \sum_{j=0}^{m-1} [S'(j(\Delta T)) \int_{j(\Delta T)}^{(j+1)\Delta T} x \cos(n \omega_0 x) \cos(H \pi x) dx] \\
 & + \sum_{j=0}^{m-1} \{[(j+1) \cdot S(j(\Delta T)) - j \cdot S((j+1) \Delta T)] \\
 5 \quad & \cdot \int_{j(\Delta T)}^{(j+1)\Delta T} \cos(n \omega_0 x) \cos(H \pi x) dx\} \dots \dots \dots (13)
 \end{aligned}$$

$$\begin{aligned}
 & \int_0^T S(x) \sin(n \omega_0 x) \sin(H \pi x) dx \\
 & \doteq \sum_{j=0}^{m-1} [S'(j(\Delta T)) \int_{j(\Delta T)}^{(j+1)\Delta T} x \sin(n \omega_0 x) \sin(H \pi x) dx] \\
 & + \sum_{j=0}^{m-1} \{[(j+1) \cdot S(j(\Delta T)) - j \cdot S((j+1) \Delta T)] \\
 & \cdot \int_{j(\Delta T)}^{(j+1)\Delta T} \sin(n \omega_0 x) \sin(H \pi x) dx\} \dots \dots \dots (13)-1
 \end{aligned}$$

$$\begin{aligned}
 10 \quad & \int_0^T S(x) \sin(n \omega_0 x) \cos(H \pi x) dx \\
 & \doteq \sum_{j=0}^{m-1} [S'(j(\Delta T)) \int_{j(\Delta T)}^{(j+1)\Delta T} x \sin(n \omega_0 x) \cos(H \pi x) dx] \\
 & + \sum_{j=0}^{m-1} \{[(j+1) \cdot S(j(\Delta T)) - j \cdot S((j+1) \Delta T)] \\
 & \cdot \int_{j(\Delta T)}^{(j+1)\Delta T} \sin(n \omega_0 x) \cos(H \pi x) dx\} \dots \dots \dots (13)-2
 \end{aligned}$$

Then, assign that:

$$15 \quad Q_{xn}(CS, j) = \int_{j(\Delta T)}^{(j+1)\Delta T} x \cos(n \omega_0 x) \sin(H \pi x) dx \dots \dots \dots (14)-1$$

$$Q_{xn}(CC, j) = \int_{j(\Delta T)}^{(j+1)\Delta T} x \cos(n \omega_0 x) \cos(H \pi x) dx \dots \dots \dots (14)-2$$

$$Q_{xn}(SS, j) = \int_{j(\Delta T)}^{(j+1)\Delta T} x \sin(n \omega_0 x) \sin(H \pi x) dx \dots \dots \dots (14)-3$$

$$Q_{xn}(SC, j) = \int_{j(\Delta T)}^{(j+1)\Delta T} x \sin(n\omega_0 x) \cos(H\pi x) dx \dots \dots \dots (14)-4$$

$$Q_n(CS, j) = \int_{j(\Delta T)}^{(j+1)\Delta T} \cos(n\omega_0 x) \sin(H\pi x) dx \dots \dots \dots (14)-5$$

$$Q_n(CC, j) = \int_{j(\Delta T)}^{(j+1)\Delta T} \cos(n\omega_0 x) \cos(H\pi x) dx \dots \dots \dots (14)-6$$

$$Q_n(SS, j) = \int_{j(\Delta T)}^{(j+1)\Delta T} \sin(n\omega_0 x) \sin(H\pi x) dx \dots \dots \dots (14)-7$$

$$5 \quad Q_n(SC, j) = \int_{j(\Delta T)}^{(j+1)\Delta T} \sin(n\omega_0 x) \cos(H\pi x) dx \dots \dots \dots (14)-8$$

Then, assign that:

$$C\bar{S}C_n(t) = [a_n \cos(n\omega_0 t) - b_n \sin(n\omega_0 t)] \cos(H\pi t) \dots \dots \dots (15)-1$$

$$\bar{C}SS_n(t) = [-a_n \cos(n\omega_0 t) + b_n \sin(n\omega_0 t)] \sin(H\pi t) \dots \dots \dots (15)-2$$

$$SCC_n(t) = [a_n \sin(n\omega_0 t) + b_n \cos(n\omega_0 t)] \cos(H\pi t) \dots \dots \dots (15)-3$$

$$10 \quad \bar{S}\bar{C}S_n(t) = [-a_n \sin(n\omega_0 t) - b_n \cos(n\omega_0 t)] \sin(H\pi t) \dots \dots \dots (15)-4$$

in which, the first sign "C" of the $C\bar{S}C_n(t)$ at the left side of the equation means "positive Cos", therefore, in the brackets at the right side of the equation (15)-1, the first item is "+a_n cos(n\omega_0 t)";

15 the second sign " $\bar{S}$ " of the $C\bar{S}C_n(t)$ at the left side of the equation means "negative Sin", therefore the second item in the brackets at the right side of the equation is "-b_n sin(n\omega_0 t)"; the third sign "C" of the $C\bar{S}C_n(t)$ expresses the "Cos(H\pi t)" at the right

20 side of the equation; the lower mark "n" represents each n at the right side of the equation. The rest of $\bar{C}SS_n(t)$, $SCC_n(t)$ and $\bar{S}\bar{C}S_n(t)$ may be inferred by analogy.

Now, substitute equations (14)-1 to (14)-8

25 in equations (13)-1 to (13)-4 respectively, and then substitute in equation (11), together with equations

(15)-1 to (15)-4 in equation (10); thus, the following approximate expressions can be obtained:

$$\begin{aligned}
 \alpha_*(t) + \beta_*(t) \doteq & \sum_{n=1}^k \{ \bar{C}S_n(t) \sum_{j=0}^{m-1} [S'(j(\Delta T))Q_{xn}(CS, j) \\
 & + [(j+1) \cdot S(j(\Delta T)) - j \cdot S((j+1)\Delta T)]Q_n(CS, j)] \} \\
 & + \sum_{n=1}^k \{ \bar{C}SS_n(t) \sum_{j=0}^{m-1} [S'(j(\Delta T))Q_{xn}(CC, j) \\
 & + [(j+1) \cdot S(j(\Delta T)) - j \cdot S((j+1)\Delta T)]Q_n(CC, j)] \} \\
 & + \sum_{n=1}^k \{ \bar{S}CC_n(t) \sum_{j=0}^{m-1} [S'(j(\Delta T))Q_{xn}(SS, j) \\
 & + [(j+1) \cdot S(j(\Delta T)) - j \cdot S((j+1)\Delta T)]Q_n(SS, j)] \} \\
 & + \sum_{n=1}^k \{ \bar{S}CS_n(t) \sum_{j=0}^{m-1} [S'(j(\Delta T))Q_{xn}(SC, j) \\
 & + [(j+1) \cdot S(j(\Delta T)) - j \cdot S((j+1)\Delta T)]Q_n(SC, j)] \} \\
 & \dots\dots\dots (16)
 \end{aligned}$$

In the approximate expression (16), there is contained a significant meaning, i.e. $\alpha_*(t) + \beta_*(t)$ can be expressed by means of $4k$ items, this will be outlined further.

In comparing equation (6) with approximate expression (7)-2, we can obtain an approximate expression as:

$$\begin{aligned}
 \alpha_*(t) + \beta_*(t) \doteq & D_{..}(H, -t, 0) + D_{..}(H, -t, 0) + E_{..}(H, 0, T-t) \\
 & + E_{..}(H, 0, T-t) - \frac{1}{2}a_0[S_{..}(H, -t, T-t) \\
 & + S_{..}(H, -t, T-t)] \dots\dots\dots (17)
 \end{aligned}$$

by means of equations (2)-1 and (2)-2, and because $D(x, t) = L(x)S(x+t)$ and $E(x, t) = R(x)S(x+t)$, it can be obtained that:

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$$(H\pi)^3 D_{..}(H, -t, 0)$$

$$= \sum_{i=1}^{\infty} \left\{ \frac{(-1)^{i-1}}{(H\pi)^{2i-3}} [D_x^{(2i-1)}(0, t) \sin(0 \cdot H\pi) \right.$$

$$\left. - D_x^{(2i-1)}(-t, t) \sin((-t)H\pi) \right\}$$

$$= H\pi D_x'(-t, t) \sin(H\pi t)$$

$$5 \quad + \sum_{i=2}^{\infty} \left\{ \frac{(-1)^{i-1}}{(H\pi)^{2i-3}} D_x^{(2i-1)}(-t, t) \sin(H\pi t) \right\}$$

$$= H\pi [L'(-t)S(0) + L(-t)S'(0)] \sin(H\pi t) + \text{DER}_{..}(t)$$

..... (18)-1

$$(H\pi)^3 D_{..}(H, -t, 0)$$

$$= \sum_{i=0}^{\infty} \left\{ \frac{(-1)^i}{(H\pi)^{2i-2}} [D_x^{(2i)}(0, t) \cos(0 \cdot H\pi) \right.$$

$$10 \quad \left. + D_x^{(2i)}(-t, t) \cos(H\pi t) \right\}$$

$$= (H\pi)^2 [D(0, t) - D(-t, t) \cos(H\pi t)] - [D_x''(0, t)$$

$$- D_x''(-t, t) \cos(H\pi t)] + \sum_{i=2}^{\infty} \left\{ \frac{(-1)^i}{(H\pi)^{2i-2}} [D_x^{(2i)}(0, t) \right.$$

$$\left. - D_x^{(2i)}(-t, t) \cos(H\pi t) \right\}$$

$$= (H\pi)^2 [L(0)S(t) - L(-t)S(0) \cos(H\pi t)]$$

$$15 \quad - [L''(0)S(t) + 2L'(0)S'(t) + L(0)S''(t)]$$

$$+ [L''(-t)S(0) + 2L'(-t)S'(0) + L(-t)S''(0)]$$

• $\cos(H\pi t) + \text{DER}_{..}(t)$ (18)-2

$$(H\pi)^3 E_{..}(H, 0, T-t)$$

$$\begin{aligned}
 &= \sum_{i=1}^{\infty} \left\{ \frac{(-1)^{i-1}}{(H\pi)^{2i-3}} [E_x^{(2i-1)}(T-t, t) \sin(H\pi T - H\pi t) \right. \\
 &\quad \left. - E_x^{(2i-1)}(0, t) \sin(0, H, \pi)] \right\} \\
 &= H\pi E_x'(T-t, t) \sin(H\pi T - H\pi t) \\
 &+ \sum_{i=2}^{\infty} \left\{ \frac{(-1)^{i-1}}{(H\pi)^{2i-3}} E_x^{(2i-1)}(T-t, t) \sin(H\pi T - H\pi t) \right\} \\
 &= H\pi [R'(T-t)S(T) + R(T-t)S'(T)] \\
 &\quad \cdot \sin(H\pi T - H\pi t) + EER_{..}(t) \dots \dots \dots (18)-3
 \end{aligned}$$

$$(H\pi)^3 E_{..}(H, 0, T-t)$$

$$\begin{aligned}
 &= \sum_{i=0}^{\infty} \left\{ \frac{(-1)^i}{(H\pi)^{2i-2}} [E_x^{(2i)}(T-t, t) \cos(H\pi T - H\pi t) \right. \\
 &\quad \left. - E_x^{(2i)}(0, t) \cos(0, H, \pi)] \right\} \\
 &= (H\pi)^2 [E(T-t, t) \cos(H\pi T - H\pi t) - E(0, t)] \\
 &\quad - [E_x''(T-t, t) \cos(H\pi T - H\pi t) - E_x''(0, t)] \\
 &+ \sum_{i=2}^{\infty} \left\{ \frac{(-1)^i}{(H\pi)^{2i-2}} [E_x^{(2i)}(T-t, t) \cos(H\pi T - H\pi t) \right. \\
 &\quad \left. - E_x^{(2i)}(0, t)] \right\} \\
 &= (H\pi)^2 [R(T-t)S(T) \cos(H\pi T - H\pi t) - R(0)S(t)] \\
 &\quad - [R''(T-t)S(T) + 2R'(T-t)S'(T) + R(T-t)S''(T)] \\
 &\quad \cdot \cos(H\pi T - H\pi t) + [R''(0)S(t) + 2R'(0)S'(t) \\
 &\quad + R(0)S''(t)] + EER_{..}(t) \dots \dots \dots (18)-4
 \end{aligned}$$

$$(H\pi)^3 S_{s,c}(H, -t, T-t)$$

$$= \sum_{i=1}^{\infty} \left\{ \frac{(-1)^{i-1}}{(H\pi)^{2i-3}} [S^{(2i-1)}(T) \sin(H\pi T - H\pi t) \right.$$

$$\left. - S^{(2i-1)}(0) \sin((-t)H\pi) \right\}$$

$$= H\pi [S'(T) \sin(H\pi T - H\pi t) + S'(0) \sin(H\pi t)]$$

$$5 \quad + \text{SER}_{s,c}(t) \dots \dots \dots (18)-5$$

$$(H\pi)^3 S_{s,c}(H, -t, T-t)$$

$$= \sum_{i=0}^{\infty} \left\{ \frac{(-1)^i}{(H\pi)^{2i-2}} [S^{(2i)}(T) \cos(H\pi T - H\pi t) \right.$$

$$\left. - S^{(2i)}(0) \cos(H\pi t) \right\}$$

$$= (H\pi)^2 [S(T) \cos(H\pi T - H\pi t) - S(0) \cos(H\pi t)]$$

$$10 \quad - [S''(T) \cos(H\pi T - H\pi t) - S''(0) \cos(H\pi t)]$$

$$+ \text{SER}_{s,c}(t) \dots \dots \dots (18)-6$$

In the equations from (18)-1 to (18)-6,

$$\text{DER}_{s,c}(t) = \sum_{i=2}^{\infty} \left\{ \frac{(-1)^{i-1}}{(H\pi)^{2i-3}} D_x^{(2i-1)}(-t, t) \sin(H\pi t) \right\} \dots \dots \dots (19)-1$$

$$\text{EER}_{s,c}(t) = \sum_{i=2}^{\infty} \left\{ \frac{(-1)^i}{(H\pi)^{2i-2}} [D_x^{(2i)}(0, t) - D_x^{(2i)}(-t, t) \right.$$

$$15 \quad \left. \cdot \cos(H\pi t) \right\} \dots \dots \dots (19)-2$$

$$\text{EER}_{s,c}(t) = \sum_{i=2}^{\infty} \left\{ \frac{(-1)^{i-1}}{(H\pi)^{2i-3}} E_x^{(2i-1)}(T-t, t) \sin(H\pi T - H\pi t) \right\}$$

$$\dots \dots \dots (19)-3$$

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$$\begin{aligned} \text{EER}_{..}(t) = \sum_{i=2}^{\infty} \left\{ \frac{(-1)^i}{(H\pi)^{2i-2}} [E_x^{(2i)}(T-t, t) \cos(H\pi T - H\pi t) \right. \\ \left. - E_x^{(2i)}(0, t)] \right\} \dots \dots \dots (19)-4 \end{aligned}$$

$$\begin{aligned} \text{SER}_{..}(t) = \sum_{i=2}^{\infty} \left\{ \frac{(-1)^{i-1}}{(H\pi)^{2i-3}} [S^{(2i-1)}(T) \sin(H\pi T - H\pi t) \right. \\ \left. + S^{(2i-1)}(0) \sin(H\pi t)] \right\} \dots \dots \dots (19)-5 \end{aligned}$$

$$\begin{aligned} 5 \quad \text{SER}_{..}(t) = \sum_{i=2}^{\infty} \left\{ \frac{(-1)^i}{(H\pi)^{2i-2}} [S^{(2i)}(T) \cos(H\pi T - H\pi t) \right. \\ \left. - S^{(2i)}(0) \cos(H\pi t)] \right\} \dots \dots \dots (19)-6 \end{aligned}$$

Now, multiply both the left side and the right side of the approximate expression (17) by $(H\pi)^3$, and substitute (18)-1 to (18)-6 to obtain the following:

$$\begin{aligned} 10 \quad Y_{..1}S(t) + Y_{..2}S'(t) + Y_{..3}S''(t) \\ = Z_{..1}S(0) + Z_{..2}S'(0) + Z_{..3}S''(0) + W_{..1}S(T) + W_{..2}S''(T) \\ + W_{..3}S''(T) + (H\pi)^3 [\alpha_{..}(t) + \beta_{..}(t)] - \text{DER}_{..}(t) \\ - \text{DER}_{..}(t) - \text{EER}_{..}(t) - \text{EER}_{..}(t) + \frac{1}{2}a_0 [\text{SER}_{..}(t)] \\ + \frac{1}{2}a_0 [\text{SER}_{..}(t)] \\ 15 \quad = Z_{..1}S(0) + Z_{..2}S'(0) + Z_{..3}S''(0) + W_{..1}S(T) + W_{..2}S'(T) \\ + W_{..3}S''(T) + (H\pi)^3 [\alpha_{..}(t) + \beta_{..}(t)] + \text{ER}_{..}(t) \dots \dots \dots (20) \end{aligned}$$

in which,

$$\begin{aligned} \text{ER}_{..}(t) = -\text{DER}_{..}(t) - \text{DER}_{..}(t) - \text{EER}_{..}(t) - \text{EER}_{..}(t) \\ = \frac{1}{2}a_0 [\text{SER}_{..}(t) + \text{SER}_{..}(t)] \dots \dots \dots (21) \end{aligned}$$

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$$Y_{s1} = (H\pi)^2 L(0) - L''(0) + R''(0) - (H\pi)^2 R(0) \dots (22)-1$$

$$Y_{s2} = 2R'(0) - 2L'(0) \dots (22)-2$$

$$Y_{s3} = R(0) - L(0) \dots (22)-3$$

$$Z_{s1} = -H\pi L'(-t) \sin(H\pi t) - [L''(-t) - (H\pi)^2 L(-t)$$

$$+ (\frac{1}{2}a_0 - 1)(H\pi)^2] \cos(H\pi t) \dots (23)-1$$

$$Z_{s2} = -H\pi L(-t) \sin(H\pi t) - 2L'(-t) \cos(H\pi t)$$

$$+ \frac{1}{2}a_0 H\pi \sin(H\pi t) \dots (23)-2$$

$$Z_{s3} = -L(-t) \cos(H\pi t) - \frac{1}{2}a_0 \cos(H\pi t) \dots (23)-3$$

$$W_{s1} = -H\pi R'(T-t) \sin(H\pi T - H\pi t) - [R''(T-t)$$

$$- (H\pi)^2 R(T-t) + (\frac{1}{2}a_0 - 1)(H\pi)^2]$$

$$\cdot \cos(H\pi T - H\pi t) \dots (24)-1$$

$$W_{s2} = (\frac{1}{2}a_0 - H\pi R(T-t)) \sin(H\pi T - H\pi t)$$

$$- 2R'(T-t) \cos(H\pi T - H\pi t) \dots (24)-2$$

$$W_{s3} = R(T-t) \cos(H\pi T - H\pi t) - \frac{1}{2}a_0 \cos(H\pi T - H\pi t) \dots (24)-3$$

15 If to increase H value gradually, the value of $ER_s(t)$ is relatively reducing. As soon as the value of H is increased to a certain extent, the value of $ER_s(t)$ is reduced to become of little significance. If we select properly a "left auxiliary function" $L(x)$ and

20 a "right auxiliary function" $R(x)$ so that $R(0)=L(0)$ and $R'(0)=L'(0)$ but $R''(0) \neq L''(0)$ (for example, select $L(x)=x^2$, $R(x)=-x^2$; or $L(x)=\sin^2 x$, $R(x)=-\sin^2 x$, thus, $R(0)=L(0)$ and $R'(0)=L'(0)$ but $R''(0) \neq L''(0)$), thus we can obtain (when H is extremely large) the

25 following:

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$$S(t) \doteq \frac{1}{[R''(0) - L''(0)]} \{Z_{.1}S(0) + Z_{.2}S'(0) + Z_{.3}S''(0) - W_{.1}S(T) + W_{.2}S'(T) + W_{.3}S''(T) + (H\pi)^3 [\alpha_s(t) + \beta_s(t)]\} \dots \dots \dots (25)$$

In the above approximate expression, $\alpha_s(t) + \beta_s(t)$ can be expressed by means of $4k$ items (this will be outlined further). Therefore, when $S(t)$ is an acoustic signal function it can be expressed by means of $4k+6$ items (the other six items are $Z_{.1}S(0)$, $Z_{.2}S'(0)$, $Z_{.3}S''(0)$, $W_{.1}S(T)$, $W_{.2}S'(T)$, $W_{.3}S''(T)$). That is meant that $4k+6$ groups of memory will be sufficient for the storage of an acoustic signal $S(t)$. In an embodiment of the present invention, $2k+6$ sets of memories (in an embodiment of the present invention, each set contains 4 bytes) is capable of storing such an acoustic signal $S(t)$.

III. "COSINE WAVEFORM FUNCTION" AND ITS CALCULATION:

$$\text{Function } A_c(S,t) = \int_{-t}^{T-t} P(x)S(x+t)\cos(H\pi x)dx \dots \dots \dots (26)$$

is called a "cosine waveform function" of $S(t)$; in $A_c(S,t)$ the lower mark "c" means "cosine", and the others are same as those in $A_c(S,t)$, $P(x)$ is an "auxiliary function" as defined in equation (3), $0 \leq t \leq T$, $0 < T \leq M$, H is any real number.

According to the definition of equation (3), $A_c(S,t)$ can be converted to :

$$\begin{aligned} A_c(S,t) &= \int_{-t}^0 L(x)S(x+t)\cos(H\pi x)dx + \int_0^{T-t} R(x)S(x+t) \\ &\quad \cdot \cos(H\pi x)dx \\ &= D_{cc}(H, -t, 0) + D_{cc}(H, -t, 0) + E_{cc}(H, 0, T-t) \\ &\quad + E_{cc}(H, 0, T-t)E_{cc}(H, 0, T-t) + E_{cc}(H, 0, T-t); \end{aligned}$$

when substitute equation (1)-3, thus:

$$A_e(S,t) = D_{ee}(H, -t, 0) + D_{ec}(H, -t, 0) + E_{ee}(H, 0, T-t) \\ + E_{ec}(H, 0, T-t) \dots \dots \dots (27)$$

in which , $D(x,t) = L(x)S(x+t)$ and $E(x,t) = R(x)S(x+t)$; D and E are a function which contains two variables.

5 In equation (4)-2, if the value of k that we take is so sufficient that $P_k(x) \rightarrow P(x)$, thus:

$$A_e(S,t) \doteq \frac{1}{2} a_0 \int_{-t}^{T-t} S(x+t) \cos(H \pi x) dx \\ + \sum_{n=1}^k \int_{-t}^{T-t} [a_n \cos(n \omega_0 x) + b_n \sin(n \omega_0 x)] \\ \cdot S(x+t) \cos(H \pi x) dx \\ 10 = \frac{1}{2} a_0 [S_{ee}(H, -t, T-t) + S_{ec}(H, -t, T-t)] \\ + \alpha_e(t) + \beta_e(t) \dots \dots \dots (28)$$

in which, $\alpha_e(t)$ and $\beta_e(t)$ are respectively called as "cosine waveform function" of the cosine and sine of $S(t)$, and the value of which are respectively as:

$$15 \quad \alpha_e(t) = \sum_{n=1}^k a_n \int_{-t}^{T-t} S(x+t) \cos(n \omega_0 x) \cos(H \pi x) dx \dots \dots \dots (29)-1$$

$$\beta_e(t) = \sum_{n=1}^k b_n \int_{-t}^{T-t} S(x+t) \sin(n \omega_0 x) \cos(H \pi x) dx \dots \dots \dots (29)-2$$

Same as the derivation in equations (9)-1 and (9)-2, we can obtain:

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$$\begin{aligned}
& \int_{-t}^{T-t} S(x+t) \cos(n \omega_0 x) \cos(H \pi x) dx \\
&= \cos(n \omega_0 t) \cos(H \pi t) \int_0^T S(x) \cos(n \omega_0 x) \cos(H \pi x) dx \\
&+ \cos(n \omega_0 t) \sin(H \pi t) \int_0^T S(x) \cos(n \omega_0 x) \sin(H \pi x) dx \\
&+ \sin(n \omega_0 t) \cos(H \pi t) \int_0^T S(x) \sin(n \omega_0 x) \cos(H \pi x) dx \\
&+ \sin(n \omega_0 t) \sin(H \pi t) \int_0^T S(x) \sin(n \omega_0 x) \sin(H \pi x) dx \\
&\dots\dots\dots (30)-1
\end{aligned}$$

$$\begin{aligned}
& \int_{-t}^{T-t} S(x+t) \sin(n \omega_0 x) \cos(H \pi x) dx \\
&= \cos(n \omega_0 t) \cos(H \pi t) \int_0^T S(x) \sin(n \omega_0 x) \cos(H \pi x) dx \\
&+ \cos(n \omega_0 t) \sin(H \pi t) \int_0^T S(x) \sin(n \omega_0 x) \sin(H \pi x) dx \\
&- \sin(n \omega_0 t) \cos(H \pi t) \int_0^T S(x) \cos(n \omega_0 x) \cos(H \pi x) dx \\
&- \sin(n \omega_0 t) \sin(H \pi t) \int_0^T S(x) \cos(n \omega_0 x) \sin(H \pi x) dx \\
&\dots\dots\dots (30)-2
\end{aligned}$$

When substitute (30)-1 and (30)-2 in (29)-1 and (29)-2 for $\alpha_0(t) + \beta_0(t)$, we can obtain:

$$\begin{aligned}
15 \quad \alpha_0(t) + \beta_0(t) &= \sum_{n=1}^k \{ [a_n \cos(n \omega_0 t) - b_n \sin(n \omega_0 t)] \cos(H \pi t) \\
&\quad \cdot \int_0^T S(x) \cos(n \omega_0 x) \cos(H \pi x) dx \}
\end{aligned}$$

$$\begin{aligned}
& - 21 - \\
& + \sum_{n=1}^k \{ [a_n \cos(n \omega_0 t) - b_n \sin(n \omega_0 t)] \sin(H \pi t) \\
& \cdot \int_0^T S(x) \cos(n \omega_0 x) \sin(H \pi x) dx \} \\
& + \sum_{n=1}^k \{ [a_n \sin(n \omega_0 t) + b_n \cos(n \omega_0 t)] \cos(H \pi t) \\
& \cdot \int_0^T S(x) \sin(n \omega_0 x) \cos(H \pi x) dx \} \\
& + \sum_{n=1}^k \{ [a_n \sin(n \omega_0 t) + b_n \cos(n \omega_0 t)] \sin(H \pi t) \\
& \cdot \int_0^T S(x) \sin(n \omega_0 x) \sin(H \pi x) dx \} \dots \dots \dots (31)
\end{aligned}$$

Same as the derivation in approximate expression (16), we can obtain an approximate expression as the following:

$$\begin{aligned}
10 \quad \alpha_c(t) + \beta_c(t) & \doteq \sum_{n=1}^k \{ \bar{C} \bar{S} C_n(t) \sum_{j=0}^{m-1} [S'(j(\Delta T)) Q_{xn}(CC, j) \\
& + [(j+1) \cdot S(j(\Delta T)) - j \cdot S((j+1) \Delta T)] Q_n(CC, j)] \} \\
& + \sum_{n=1}^k \{ \bar{C} \bar{S} S_n(t) \sum_{j=0}^{m-1} [S'(j(\Delta T)) Q_{xn}(CS, j) \\
& + [(j+1) \cdot S(j(\Delta T)) - j \cdot S((j+1) \Delta T)] Q_n(CS, j)] \} \\
& + \sum_{n=1}^k \{ \bar{S} C C_n(t) \sum_{j=0}^{m-1} [S'(j(\Delta T)) Q_{xn}(SC, j) \\
15 \quad & + [(j+1) \cdot S(j(\Delta T)) - j \cdot S((j+1) \Delta T)] Q_n(SC, j)] \} \\
& + \sum_{n=1}^k \{ \bar{S} C S_n(t) \sum_{j=0}^{m-1} [S'(j(\Delta T)) Q_{xn}(SS, j) \\
& + [(j+1) \cdot S(j(\Delta T)) - j \cdot S((j+1) \Delta T)] Q_n(SS, j)] \} \\
& \dots \dots \dots (32)
\end{aligned}$$

in which;

$$\bar{C}\bar{S}C_n(t) = [a_n \cos(n\omega_0 t) - b_n \sin(n\omega_0 t)] \cos(H\pi t) \dots \dots \dots (33)-1$$

$$\bar{C}\bar{S}S_n(t) = [a_n \cos(n\omega_0 t) - b_n \sin(n\omega_0 t)] \sin(H\pi t) \dots \dots \dots (33)-2$$

$$SCC_n(t) = [a_n \sin(n\omega_0 t) + b_n \cos(n\omega_0 t)] \cos(H\pi t) \dots \dots \dots (33)-3$$

$$5 \quad SCS_n(t) = [a_n \sin(n\omega_0 t) + b_n \cos(n\omega_0 t)] \sin(H\pi t) \dots \dots \dots (33)-4$$

In the above equations, $\bar{C}\bar{S}C_n(t)$, $\bar{C}\bar{S}S_n(t)$, $SCC_n(t)$ and $SCS_n(t)$ are respectively the same as those in the equations (15)-1 to (15)-4 ((33)-1 and (15)-1 are indeed the same).

- 10 Same as approximate expression (16), the approximate expression (32) provides a significant meaning, that is $\alpha_0(t) + \beta_0(t)$ can be expressed by means of 4k items. This will be outlined further.

15 In comparing equation (27) with equation (28), it can be obtained that:

$$\begin{aligned} \alpha_0(t) + \beta_0(t) &\doteq D_{ee}(H, -t, 0) + D_{ee}(H, -t, 0) + E_{ee}(H, 0, T-t) \\ &+ E_{ee}(H, 0, T-t) - \frac{1}{2} a_0 [S_{ee}(H, -t, T-t) \\ &+ S_{ee}(H, -t, T-t)] \dots \dots \dots (34) \end{aligned}$$

By means of (2)-3 and (2)-4, and because $D(x, t) = L(x)S(x+t)$ and $E(x, t) = R(x)S(x, t)$, we can obtain that:

$$\begin{aligned} &(H\pi)^2 D_{ee}(H, -t, 0) \\ &= \sum_{i=0}^{\infty} \left\{ \frac{(-1)^i}{(H\pi)^{2i-1}} [D_x^{(2i)}(0, t) \sin(0 \cdot H\pi) \right. \\ &\quad \left. - D_x^{(2i)}(-t, t) \sin((-t)H\pi)] \right\} \\ &= H\pi L(-t)S(0) \sin(H\pi t) + DER_{ee}(t) \dots \dots \dots (35)-1 \end{aligned}$$

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$$(H\pi)^2 D_{ee}(H, -t, 0)$$

$$= \sum_{i=1}^{\infty} \left\{ \frac{(-1)^{i-1}}{(H\pi)^{2i-2}} [D_x^{(2i-1)}(0, t) \cos(0 \cdot H\pi) \right. \\ \left. - D_x^{(2i-1)}(-t, t) \cos(H\pi t)] \right\}$$

$$= L'(0)S(t) + L(0)S'(t) - [L'(-t)S(0)$$

$$+ L(-t)S'(0)] \cos(H\pi t) + DER_{ee}(t) \dots \dots \dots (35)-2$$

$$(H\pi)^2 E_{ee}(H, 0, T-t)$$

$$= \sum_{i=0}^{\infty} \left\{ \frac{(-1)^i}{(H\pi)^{2i-1}} [E_x^{(2i)}(T-t, t) \sin(H\pi T - H\pi t) \right. \\ \left. - E_x^{(2i)}(0, t) \sin(0 \cdot H\pi)] \right\}$$

$$= H\pi R(T-t)S(T) \sin(H\pi T - H\pi t) + EER_{ee}(t) \dots \dots \dots (35)-3$$

$$10 \quad (H\pi)^2 E_{ee}(H, 0, T-t)$$

$$= \sum_{i=1}^{\infty} \left\{ \frac{(-1)^{i-1}}{(H\pi)^{2i-2}} [E_x^{(2i-1)}(T-t, t) \cos(H\pi T - H\pi t) \right. \\ \left. - E_x^{(2i-1)}(0, t) \cos(0 \cdot H\pi)] \right\}$$

$$= [R'(T-t)S(T) + R(T-t)S'(T)] \cos(H\pi T - H\pi t)$$

$$- [R'(0)S(t) + R(0)S'(t)] + EER_{ee}(t) \dots \dots \dots (35)-4$$

$$15 \quad (H\pi)^2 S_{ee}(H, -t, T-t)$$

$$= \sum_{i=0}^{\infty} \left\{ \frac{(-1)^i}{(H\pi)^{2i-1}} [S^{(2i)}(T) \sin(H\pi T - H\pi t) \right. \\ \left. + S^{(2i)}(0) \sin(H\pi t)] \right\}$$

$$= H\pi [S(T) \sin(H\pi T - H\pi t) + S(0) \sin(H\pi t)]$$

$$+ SER_{ee}(t) \dots \dots \dots (35)-5$$

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$$\begin{aligned}
& (H\pi)^2 S_{ee}(H, -t, T-t) \\
&= \sum_{i=1}^{\infty} \left\{ \frac{(-1)^{i-1}}{(H\pi)^{2i-1}} [S^{(2i-1)}(T) \cos(H\pi T - H\pi t) \right. \\
&\quad \left. - S^{(2i-1)}(0) \cos(H\pi t)] \right\} \\
&= S'(T) \cos(H\pi T - H\pi t) - S'(0) \cos(H\pi t) + \text{SER}_{ee}(t) \\
&\dots\dots\dots (35)-6
\end{aligned}$$

5

in which:

$$\text{DER}_{ee}(t) = \sum_{i=1}^{\infty} \left[\frac{(-1)^i}{(H\pi)^{2i-1}} D_x^{(2i)}(-t, t) \sin(H\pi t) \right] \dots\dots\dots (36)-1$$

$$\begin{aligned}
\text{DER}_{ee}(t) &= \sum_{i=2}^{\infty} \left\{ \frac{(-1)^{i-1}}{(H\pi)^{2i-2}} [D_x^{(2i-1)}(0, t) - D_x^{(2i-1)}(-t, t) \cos(H\pi t)] \right. \\
&\dots\dots\dots (36)-2
\end{aligned}$$

10

$$\text{EER}_{ee}(t) = \sum_{i=1}^{\infty} \left[\frac{(-1)^i}{(H\pi)^{2i-1}} E_x^{(2i)}(T-t, t) \sin(H\pi T - H\pi t) \right] \dots\dots (36)-3$$

$$\begin{aligned}
\text{EER}_{ee}(t) &= \sum_{i=2}^{\infty} \left\{ \frac{(-1)^{i-1}}{(H\pi)^{2i-2}} [E_x^{(2i-1)}(T-t, t) \cos(H\pi T - H\pi t) \right. \\
&\quad \left. - E_x^{(2i-1)}(0, t)] \right\} \dots\dots\dots (36)-4
\end{aligned}$$

$$\begin{aligned}
\text{SER}_{ee}(t) &= \sum_{i=1}^{\infty} \left\{ \frac{(-1)^i}{(H\pi)^{2i-1}} [S^{(2i)}(T) \sin(H\pi T - H\pi t) \right. \\
&\quad \left. + S^{(2i)}(0) \sin(H\pi t)] \right\} \dots\dots\dots (36)-5
\end{aligned}$$

15

$$\begin{aligned}
\text{SER}_{ee}(t) &= \sum_{i=2}^{\infty} \left\{ \frac{(-1)^{i-1}}{(H\pi)^{2i-2}} [S^{(2i-1)}(T) \cos(H\pi T - H\pi t) \right. \\
&\quad \left. - S^{(2i-1)}(0) \cos(H\pi t)] \right\} \dots\dots\dots (36)-6
\end{aligned}$$

Multiply the both sides of the equations (24) by $(H\pi)^2$, and substitute (35)-1 to (35)-6 respectively, thus, we can obtain:

$$\begin{aligned}
 & Y_{c1}S(t) + Y_{c2}S'(t) \\
 5 \quad & = Z_{c1}S(0) + Z_{c2}S'(0) + W_{c1}S(T) + W_{c2}S'(T) \\
 & \quad - \text{DER}_{cs}(t) + (H\pi)^2 [\alpha_c(t) + \beta_c(t)] - \text{DER}_{cc}(t) \\
 & \quad - \text{EER}_{cs}(t) - \text{EER}_{cc}(t) + \frac{1}{2}a_0 [\text{SER}_{cs}(t) + \text{SER}_{cc}(t)] \\
 & = Z_{c1}S(0) + Z_{c2}S'(0) + W_{c1}S(T) + W_{c2}S'(T) \\
 & \quad + (H\pi)^2 [\alpha_c(t) + \beta_c(t)] + \text{ER}_c(t) \dots \dots \dots (37)
 \end{aligned}$$

10 in which,

$$\begin{aligned}
 \text{ER}_c(t) &= -\text{DER}_{cs}(t) - \text{DER}_{cc}(t) - \text{EER}_{cs}(t) - \text{EER}_{cc}(t) \\
 & \quad + \frac{1}{2}a_0 [\text{SER}_{cs}(t) + \text{SER}_{cc}(t)] \dots \dots \dots (38)
 \end{aligned}$$

$$Y_{c1} = -L'(0) + R'(0) \dots \dots \dots (39)-1$$

$$Y_{c2} = -L(0) + R(0) \dots \dots \dots (39)-2$$

$$15 \quad Z_{c1} = \left[\frac{1}{2}a_0 - L(-t) \right] H\pi \sin(H\pi t) + L'(-t) \cos(H\pi t) \dots \dots \dots (40)-1$$

$$Z_{c2} = \left[-\frac{1}{2}a_0 + L(-t) \right] \cos(H\pi t) \dots \dots \dots (40)-2$$

$$\begin{aligned}
 W_{c1} &= \left[\frac{1}{2}a_0 - R(T-t) \right] H\pi \sin(H\pi T - H\pi t) \\
 & \quad - R'(T-t) \cos(H\pi T - H\pi t) \dots \dots \dots (41)-1
 \end{aligned}$$

$$W_{c2} = \left[\frac{1}{2}a_0 - R(T-t) \right] \cos(H\pi T - H\pi t) \dots \dots \dots (41)-2$$

When H value is increasing gradually, the value of $ER_0(t)$ is relatively reducing. As soon as H value is increased to a certain extent, $ER_0(t)$ becomes of little significance. When we take such "left
 5 auxiliary function" $L(x)$ and "right auxiliary function" $R(x)$ that $R(0)=L(0)$ but $R'(0) \neq L'(0)$ (for example, we select $L(x)=x$, and $R(x)=0$; or, select $L(x)=\sin x$ and $R(x)=-x$), thus we can obtain (when the value of H is extremely large):

$$10 \quad S(t) \doteq \frac{1}{R'(0) - L'(0)} \{ Z_{01} S(0) + Z_{02} S'(0) + W_{01} S(T) \\ + W_{02} S'(T) + (H\pi)^2 [\alpha_0(t) + \beta_0(t)] \} \dots \dots \dots (42)$$

In the above approximate expression (42), $\alpha_0(t) + \beta_0(t)$ can be expressed by means of 4k items (this will be explained further); therefore, if $S(t)$ is an acoustic
 15 signal function, it can be expressed by means of 4k+4 items (the additional 4 items are $Z_{01} S(0)$, $Z_{02} S'(0)$, $W_{01} S(T)$, $W_{02} S'(T)$). Actually, in an embodiment of the present invention, 2k+4 items are sufficient for such an expression. This will be described further.

20 IV. ERROR:

In addition to $ER_0(t)$ and $ER_1(t)$, there is still another error in expressions (25) and (42) which is caused to happen when $P(x)$ is substituted by Fourier series $P_k(x)$. Letting:

$$25 \quad P(x) = P_k(x) + EP_k(x)$$

in which $EP_k(t)$ is called Fourier error.

thus,

$$P(x) = \lim_{k \rightarrow \infty} P_k(x)$$

that is, $\lim_{k \rightarrow \infty} EP_k(t) = 0$

In actual practice, it is not possible to obtain an infinitely great for k , and the finite value that we take for k has a great concern with the "left auxiliary function" $L(x)$ and the "right auxiliary function" $R(x)$. For example, given that: $L(x)=x$ and $R(x)=0$, thus $P_{50}(x)$ has a very close approximation to $P(x)$ when 50 is taken for k . Although $P(x)-P_{50}(x)$ is very small, it is still not infinitely small. For accuracy's sake $P(x)-P_{50}(x)$ must be taken into account.

10 With respect to equation (5) regarding the definition $A_*(s,t)$:

$$\begin{aligned} A_*(s,t) &= \int_{-t}^{T-t} P(x)S(x+t)\sin(H\pi x)dx \\ &= \int_{-t}^{T-t} P_k(x)S(x+t)\sin(H\pi x)dx \\ &\quad + \int_{-t}^{T-t} EP_k(t)S(x+t)\sin(H\pi x)dx \end{aligned}$$

$$\begin{aligned} 15 \quad &= \frac{1}{2}a_0[S_{..}(H,-t,T-t)+S_{..}(H,-t,T-t)] + \alpha_*(t) \\ &\quad + \beta_*(t) + \int_{-t}^{T-t} EP_k(t)S(x+t)\sin(H\pi x)dx; \end{aligned}$$

in which, $\int_{-t}^{T-t} EP_k(t)S(x+t)\sin(H\pi x)dx$ is called "Fourier sine integral error of $S(t)$ " and expressed by $SE_*(t)$, that is :

$$20 \quad SE_*(t) = \int_{-t}^{T-t} EP_k(t)S(x+t)\sin(H\pi x)dx$$

letting:

$$G(x,t) = EP_k(x)S(x+t)$$

according to equations (1)-1, (2)-1 and (2)-2, it is obtained that:

$$SE_s(t) = G_{s..}(H, -t, T-t) + G_{s..}(H, -t, T-t) \cdots (43)-1$$

thus,

$$\begin{aligned} 5 \quad A_s(s, t) = & \frac{1}{2} a_0 [S_{s..}(H, -t, T-t) + S_{s..}(H, -t, T-t)] \\ & + \alpha_s(t) + \beta_s(t) + G_{s..}(H, -t, T-t) \\ & + G_{s..}(H, -t, T-t) \cdots \cdots \cdots (44) \end{aligned}$$

Letting:

$$SE_s(t) = \int_{-t}^{T-t} EP_k(t) S(x+t) \cos(H \pi x) dx$$

10 thus:

$$SE_s(t) = G_{s..}(H, -t, T-t) + G_{s..}(H, -t, T-t) \cdots (43)-2$$

and thus:

$$\begin{aligned} A_s(s, t) = & \frac{1}{2} a_0 [S_{s..}(H, -t, T-t) + S_{s..}(H, -t, T-t)] \\ & + \alpha_s(t) + \beta_s(t) + G_{s..}(H, -t, T-t) \\ 15 \quad & + G_{s..}(H, -t, T-t) \cdots \cdots \cdots (45) \end{aligned}$$

In comparing equation (6) with equation (44), it can be obtained that:

$$\begin{aligned} \alpha_s(t) + \beta_s(t) = & D_{s..}(H, -t, 0) + D_{s..}(H, -t, 0) + E_{s..}(H, 0, T-t) \\ & + E_{s..}(H, 0, T-t) - \frac{1}{2} a_0 [S_{s..}(H, -t, T-t) \\ 20 \quad & + S_{s..}(H, -t, T-t)] - G_{s..}(H, -t, T-t) \\ & - G_{s..}(H, -t, T-t) \cdots \cdots \cdots (46) \end{aligned}$$

In comparing equation (46) with expression (17), (46) is an identical equation and (17) is an approximate expression.

In comparing equations (27) with (45), it can be obtained that:

$$\begin{aligned}
 \alpha_e(t) + \beta_e(t) = & D_{ee}(H, -t, 0) + D_{ee}(H, -t, 0) \\
 & + E_{ee}(H, 0, T-t) + E_{ee}(H, 0, T-t) \\
 5 \quad & - \frac{1}{2} a_0 [S_{ee}(H, -t, T-t) + S_{ee}(H, -t, T-t)] \\
 & - G_{ee}(H, -t, T-t) - G_{ee}(H, -t, T-t) \dots \dots \dots (47)
 \end{aligned}$$

In comparing (47) with (34), (47) is an identical equation and (34) is an approximate expression.

Since:

$$\begin{aligned}
 10 \quad & (H\pi)^3 G_{ee}(H, -t, T-t) \\
 & = \sum_{i=0}^{\infty} \left\{ \frac{(-1)^i}{(H\pi)^{2i-2}} [G_x^{(2i)}(T-t, t) \cos(H\pi T - H\pi t) \right. \\
 & \quad \left. - G_x^{(2i)}(-t, t) \cos(H\pi t)] \right\} \\
 & = (H\pi)^2 [G(T-t, t) \cos(H\pi T - H\pi t) \\
 & \quad - G(-t, t) \cos(H\pi t)] - [G_x''(T-t, t) \cos(H\pi T - H\pi t) \\
 15 \quad & - G_x''(-t, t) \cos(H\pi t)] + \sum_{i=2}^{\infty} \left\{ \frac{(-1)^i}{(H\pi)^{2i-2}} [G_x^{(2i)}(T-t, t) \right. \\
 & \quad \left. \cdot \cos(H\pi T - H\pi t) - G_x^{(2i)}(-t, t) \cos(H\pi t)] \right\} \\
 & = (H\pi)^2 [EP_k(T-t)S(T) \cos(H\pi T - H\pi t) \\
 & \quad - EP_k(-t)S(0) \cos(H\pi t)] - \{ [EP_k''(T-t)S(T) \\
 & \quad + 2EP_k'(T-t)S'(T) + EP_k(T-t)S''(T)] \\
 20 \quad & \cdot \cos(H\pi T - H\pi t) - [EP_k''(-t)S(0) + 2EP_k'(-t)S'(0) \\
 & \quad + EP_k(-t)S''(0)] \cos(H\pi t) \} + GER_{ee}(t) \dots \dots \dots (48)-1
 \end{aligned}$$

$$\begin{aligned}
& (H\pi)^3 G_{..}(H, -t, T-t) \\
&= \sum_{i=1}^{\infty} \left\{ \frac{(-1)^{i-1}}{(H\pi)^{2i-3}} [G_x^{(2i-1)}(T-t, t) \sin(H\pi T - H\pi t) \right. \\
&\quad \left. + G_x^{(2i-1)}(-t, t) \sin(H\pi t)] \right\} \\
&= (H\pi) \{ [EP_k'(T-t)S(T) + EP_k(T-t)S'(T)] \\
5 \quad & \cdot \sin(H\pi T - H\pi t) + [EP_k'(-t)S(0) + EP_k(-t)S'(0)] \\
& \cdot \sin(H\pi t)] + GER_{..}(t) \dots \dots \dots (48)-2
\end{aligned}$$

in which:

$$\begin{aligned}
& EP_k''(T-t) = P''(T-t) - P_k''(T-t) = R''(T-t) - P_k''(T-t) \quad (49)-1 \\
& EP_k'(T-t) = R'(T-t) - P_k'(T-t) \dots \dots \dots (49)-2 \\
10 \quad & EP_k(T-t) = R(T-t) - P_k(T-t) \dots \dots \dots (49)-3 \\
& EP_k''(-t) = P''(-t) - P_k''(-t) = L''(-t) - P_k''(-t) \dots \dots (49)-4 \\
& EP_k'(-t) = L'(-t) - P_k'(-t) \dots \dots \dots (49)-5 \\
& EP_k(-t) = L(-t) - P_k(-t) \dots \dots \dots (49)-6
\end{aligned}$$

$$\begin{aligned}
& GER_{..}(t) = \sum_{i=2}^{\infty} \left\{ \frac{(-1)^i}{(H\pi)^{2i-2}} [G_x^{(2i)}(T-t, t) \cos(H\pi T - H\pi t) \right. \\
15 \quad & \left. - G_x^{(2i)}(-t, t) \cos(H\pi t)] \right\} \dots \dots \dots (50)-1
\end{aligned}$$

$$\begin{aligned}
& GER_{..}(t) = \sum_{i=2}^{\infty} \left\{ \frac{(-1)^{i-1}}{(H\pi)^{2i-3}} [G_x^{(2i-1)}(T-t, t) \sin(H\pi T - H\pi t) \right. \\
& \left. + G_x^{(2i-1)}(-t, t) \sin(H\pi t)] \right\} \dots \dots \dots (50)-2
\end{aligned}$$

Substitute (49)-1 ~ (49)-6 into (48)-1, (48)-2, then multiply both sides of the equation (46) by $(H\pi)^3$ and then substitute (48)-1, (48)-2 or together with (18)-1 ~ (18)-6 into the equation of (46) after it is multiplied by $(H\pi)^3$. Thus, it is obtained that:

$$\begin{aligned}
& Y_{.1}S(t) + Y_{.2}S'(t) + Y_{.3}S''(t) \\
& = \{Z_{.1} - (H\pi)^2 [L(-t) - P_k(-t)] \cos(H\pi t) \\
& \quad - [L''(-t) - P_k''(-t)] \cos(H\pi t) + (H\pi) [L'(-t) \\
& \quad - P_k'(-t)] \sin(H\pi t)\} S(0) + \{Z_{.2} + 2[L''(-t) - P_k''(-t)] \\
& \quad \cdot \cos(H\pi t) + (H\pi) [L(-t) - P_k(-t)] \sin(H\pi t)\} S'(0) \\
& \quad + \{Z_{.3} + [L(-t) - P_k(-t)] \cos(H\pi t)\} S''(0) \\
& \quad + \{W_{.1} + (H\pi)^2 [R(T-t) - P_k(T-t)] \cos(H\pi T - H\pi t) \\
& \quad - [R''(T-t) - P_k''(T-t)] \cos(H\pi T - H\pi t) \\
& \quad + (H\pi) [R'(T-t) - P_k'(T-t)] \sin(H\pi T - H\pi t)\} S(T) \\
& \quad + \{W_{.2} - 2[R''(T-t) - P_k''(T-t)] \cos(H\pi T - H\pi t) \\
& \quad + (H\pi) [R(T-t) - P_k(T-t)] \sin(H\pi T - H\pi t)\} S'(T) \\
& \quad + \{W_{.3} - [R(T-t) - P_k(T-t)] \cos(H\pi T - H\pi t)\} S''(T) \\
& \quad + (H\pi)^3 [\alpha_*(t) + \beta_*(t)] + ER_*(t) + GER_{..}(t) + GER_{..}(t) \\
& \quad \dots\dots\dots (51)
\end{aligned}$$

15 Thus, when H is extremely great, $ER_*(t) + GER_{..}(t) + GER_{..}(t)$ is extremely small; Letting $L(0) = R(0)$ and $L'(0) = R'(0)$, but $L''(0) \neq R''(0)$, (51) can be rewritten as:

$$\begin{aligned}
& S(t) \doteq \frac{1}{R''(0) - L''(0)} \{U_{.1}S(0) + U_{.2}S'(0) + U_{.3}S''(0) \\
& \quad + V_{.1}S(T) + V_{.2}S'(T) + V_{.3}S''(T) \\
& \quad + (H\pi)^3 [\alpha_*(t) + \beta_*(t)]\} \dots\dots\dots (52)
\end{aligned}$$

in which,

$$U_{s1} = Z_{s1} - (H\pi)^2 [L(-t) - P_k(-t)] \cos(H\pi t) - [L''(-t) - P_k''(-t)] \cos(H\pi t) + (H\pi) [L'(-t) - P_k'(-t)] \sin(H\pi t) \dots (53)-1$$

$$U_{s2} = Z_{s2} + 2[L''(-t) - P_k''(-t)] \cos(H\pi t) + (H\pi) [L(-t) - P_k(-t)] \sin(H\pi t) \dots (53)-2$$

$$U_{s3} = Z_{s3} + [L(-t) - P_k(-t)] \cos(H\pi t) \dots (53)-3$$

$$V_{s1} = W_{s1} + (H\pi)^2 [R(T-t) - P_k(T-t)] \cos(H\pi T - H\pi t) - [R''(T-t) - P_k''(T-t)] \cos(H\pi T - H\pi t) + (H\pi) [R'(T-t) - P_k'(T-t)] \sin(H\pi T - H\pi t) \dots (53)-4$$

$$V_{s2} = W_{s2} - 2[R''(T-t) - P_k''(T-t)] \cos(H\pi T - H\pi t) + (H\pi) [R(T-t) - P_k(T-t)] \sin(H\pi T - H\pi t) \dots (53)-5$$

$$V_{s3} = W_{s3} - [R(T-t) - P_k(T-t)] \cos(H\pi T - H\pi t) \dots (56)-6$$

Therefore, when H is extremely great, $L(0) = R(0)$ but $L'(0) \neq R'(0)$, thus,

$$S(t) \doteq \frac{1}{R'(0) - L'(0)} \{U_{s1}S(0) + U_{s2}S'(0) + V_{s1}S(T) + V_{s2}S'(T) + (H\pi)^2 [\alpha_c(t) + \beta_c(t)]\} \dots (54)$$

in which:

$$U_{s1} = Z_{s1} - [L'(-t) - P_k'(-t)] \cos(H\pi t) + H\pi [L(-t) - P_k(-t)] \sin(H\pi t) \dots (55)-1$$

$$U_{s2} = Z_{s2} - [L(-t) - P_k(-t)] \cos(H\pi t) \dots (55)-2$$

$$V_{s1} = W_{s1} + [R'(T-t) - P_k'(T-t)] \cos(H\pi T - H\pi t) + H\pi [R(T-t) - P_k(T-t)] \sin(H\pi T - H\pi t) \dots (55)-3$$

$$V_{s2} = W_{s2} + [R(T-t) - P_k(T-t)] \cos(H\pi T - H\pi t) \dots (55)-4$$

V. SOUND RECORDING AND REPRODUCTION PARAMETER:

The $Q_{xn}(CS,j)$, $Q_{xn}(CC,j)$, $Q_{xn}(SS,j)$ and $Q_{xn}(SC,j)$ in equations (14)-1~(14)-4, and the $Q_n(CS,j)$, $Q_n(CC,j)$, $Q_n(SS,j)$ and $Q_n(SC,j)$ in equations (14)-5~
 5 (14)-8 are generally called "n times sound recording parameter at location j"; these sound recording parameters are further expressed by $Q_{xn}(CS,j)$, ... $Q_{xn}(SC,j)$, and $Q_n(CS,j)$, ... $Q_n(SC,j)$

The $\bar{CSC}_n(t)$, $\bar{CSS}_n(t)$... in equations (15)-1
 10 ~ (15)-4 and (33)-1~(33)-4 (wherein (15)-1 is identical to (33)-1) are called "sound reproduction parameter at location t"; these sound reproduction parameters are further expressed by $\bar{CSC}_n(t)$, $\bar{CSS}_n(t)$... etc.

The $U_{.1} \sim U_{.3}$, $V_{.1} \sim V_{.3}$, $U_{.1}$, $U_{.2}$, $V_{.1}$ and $V_{.2}$
 15 in equations (53)-1~(53)-6 and (55)-1~(55)-4 are called "End point sound reproduction parameter at location t" (It is a kind of sound reproduction parameter); these sound reproduction parameters are
 20 further expressed by $Z_{.1}$, ... etc., respectively.

Since the foregoing sound recording and reproduction parameters have nothing to do with $S(t)$ ($S(t)$ is an acoustic signal to store), they can be calculated and pre-stored in ROM for ready use.

25 VI. WAVEFORM DATA:

In approximate expressions (13)-1~(13)-4,

$$\int_0^T S(x) \cos(n \omega_0 x) \sin(H \pi x) dx ;$$

$$\int_0^T S(x) \cos(n \omega_0 x) \cos(H \pi x) dx ;$$

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$$\int_0^T S(x) \sin(n \omega_0 x) \sin(H \pi x) dx ; \text{ and}$$

$$\int_0^T S(x) \sin(n \omega_0 x) \cos(H \pi x) dx ;$$

These are called "n times waveform data" of S(t). The calculation of these data can be understood directly from equations (13)-1~(13)-4. It is to sample m times from S(t) in interval [0,T] and proceed a calculation each time a sample S(j(ΔT)) (j=0,1,⋯,m-1, ΔT=T/m) is drawn.

Because sampling is proceeded from n to k, after m times of sampling on S(t) is completed, a 4k number is obtained. Therefore, a 4k waveform data can be obtained. As shown in expressions (16) and (32), $\alpha_+(t) + \beta_+(t)$ and $\alpha_-(t) + \beta_-(t)$ finally contain only 4k items, in which each item is a product of a waveform data and a sound reproduction parameter, and each waveform data can be obtained for storage in RAM after acoustic signal S(t) ($t \in [0, T]$) is completely presented.

There are total 4k sets of RAM which are equivalent to a recording tape. The process to obtain a waveform data is a process to record a sound. For reproduction of sound, it is to read out waveform data from each set of RAM and multiply the corresponding sound reproduction parameter, as shown in expressions (16) or (32), by the waveform data thus obtained so as to seek for $\alpha_+(t) + \beta_+(t)$ or $\alpha_-(t) + \beta_-(t)$. The result thus obtained is substituted into expression (52) (When L(x) and R(x) are selected to permit $R(0)=L(0)$, $R'(0)=L'(0)$ but $L''(0) \neq R''(0)$) or

expression (54) (When $L(x)$ and $R(x)$ are selected to permit $R(0)=L(0)$ but $R'(0) \neq L'(0)$ to seek for $S(t)$).

METHOD OF THE INVENTION

The method of the present invention to
 5 record and reproduce a sound will be described by way of example as hereinafter. Either expression (52) or expression (54) can be used for performing the method of the present invention. Hereby expression (54) is taken for explanation, and letting:

10 $L(x) = x;$
 $R(x) = 0;$
 $[-M, M] = [-2, 2],$ i.e. $M = 2$ seconds;
 $T = 1$ second;
 $H = 64,000;$
 15 $m = 64,000.$

thus, according to the definition of $P(x)$ as defined in equation (3), when it is expanded by Fourier series in interval $[-2, 2]$, it can be obtained that:

$$a_n = \frac{1}{2} \int_{-2}^0 x \, dx = -1;$$

$$20 \quad a_n = \frac{1}{2} \int_{-2}^0 x \cos(n \omega_0 x) \, dx = \frac{1}{2(n \omega_0)^2} [1 - (-1)^n];$$

$$b_n = \frac{1}{2} \int_{-2}^0 x \sin(n \omega_0 x) \, dx = -\frac{(-1)^n}{n \omega_0};$$

$$\text{in which, } \omega_0 = \frac{2\pi}{2M} = \frac{\pi}{2}.$$

After $P(x)$ is expanded by Fourier series,
 and 50 is taken for n , thus:

25 $k = 50$

In the above, $m=64,000$ represents that acoustic signal $S(t)$ in interval $[0,1]$ ($T=1$ second) has been sampled for 64,000 times, that is to sample from $S(t)$ at a sampling frequency of 64KHz. Now,
 5 during reproduction of sound, assume time point t of each sound reproduction is just the same as the original sampling time point $\frac{r}{64,000}$ ($r=0,1,\dots,63,999$), thus:

$$\sin(H\pi t) = \sin(64,000 \times \pi \times \frac{r}{64,000}) = \sin(r\pi) = 0$$

$$\begin{aligned} 10 \quad \cos(H\pi t) &= \cos(64,000 \times \pi \times \frac{r}{64,000}) = \cos(r\pi) \\ &= (-1)^r; r=64,000t \end{aligned}$$

Assume the time point of each sound reproduction

$$t = \frac{1}{2} \left(\frac{r}{64,000} + \frac{r+1}{64,000} \right) \text{ thus:}$$

$$\sin(H\pi t) = \sin(r\pi + \frac{\pi}{2}) = (-1)^r; r=64,000t$$

$$15 \quad \cos(H\pi t) = \cos(r\pi + \frac{\pi}{2}) = 0$$

Now, the former is selected.

According to the above selection, expression (54) can be rewritten as:

$$\begin{aligned} S(t) &\doteq (-1)^r \{ P_k'(-t)S(0) + [\frac{1}{2} + P_k(-t)]S'(0) - P_k'(1-t) \\ 20 \quad &\cdot S(1) - [\frac{1}{2} + P_k(1-t)]S'(1) \} + (64,000\pi)^2 [\alpha_+(t) + \beta_+(t)] \\ &\dots\dots\dots(56) \end{aligned}$$

in which,

$$\begin{aligned}
 \alpha_c(t) + \beta_c(t) = & \sum_{n=1}^{50} \{ \bar{C}SC_n(t) \sum_{j=1}^{63999} [S(j\Delta T)Q_{xn}(CC, j) \\
 & + [(j+1)S(j\Delta T) - j \cdot S((j+1)\Delta T)] \\
 & \cdot Q_n(CC, j)] \} + \sum_{n=1}^{50} \{ SCC_n(t) \sum_{j=0}^{63999} [S'(j\Delta T) \\
 & \cdot Q_{xn}(SC, j) + [(j+1)S(j\Delta T) \\
 & - j \cdot S((j+1)\Delta T)] Q_n(SC, j)] \} \dots \dots \dots (57)
 \end{aligned}$$

$$\bar{C}SC_n(t) = \left[\frac{1 - (-1)^n}{2(n\omega_0)^2} \cos(n\omega_0 t) + \frac{(-1)^n}{n\omega_0} \sin(n\omega_0 t) \right] (-1)^r \dots (58)-1$$

$$SCC_n(t) = \left[\frac{1 - (-1)^n}{2(n\omega_0)^2} \sin(n\omega_0 t) - \frac{(-1)^n}{n\omega_0} \cos(n\omega_0 t) \right] (-1)^r \dots (58)-2$$

$$Q_{xn}(CC, j) = \int_{j(\Delta T)}^{(j+1)\Delta T} x \cos(n\omega_0 x) \cos(64,000 \pi x) dx \dots \dots \dots (59)-1$$

$$10 \quad Q_{xn}(SC, j) = \int_{j(\Delta T)}^{(j+1)\Delta T} x \sin(n\omega_0 x) \cos(64,000 \pi x) dx \dots \dots \dots (59)-2$$

$$Q_n(CC, j) = \int_{j(\Delta T)}^{(j+1)\Delta T} \cos(n\omega_0 x) \cos(64,000 \pi x) dx \dots \dots \dots (59)-3$$

$$Q_n(SC, j) = \int_{j(\Delta T)}^{(j+1)\Delta T} \sin(n\omega_0 x) \cos(64,000 \pi x) dx \dots \dots \dots (59)-4$$

$$r=64,000t, \quad \omega_0 = \frac{\pi}{2}, \quad \Delta T = \frac{1}{64,000}, \quad S'(j\Delta T) = \frac{S((j+1)\Delta T) - S(j\Delta T)}{\Delta T}$$

Because ΔT is not infinitely small, the $S'(j\Delta T)$
 15 here differs from the $S'(j\Delta T)$ in expression (16) or
 (32).

The expression (56) is taken for the
 present embodiment. In expression (57) a number of $2k$

$=2 \times 50 = 100$ (i.e. $2k=100$ waveform data) is sufficient to express $\alpha_n(t) + \beta_n(t)$.

As per above example, the method of the present invention is outlined hereinafter.

5 1. SOUND RECORDING PARAMETER AND "SOUND RECORDING PARAMETER MEMORY"

In the present embodiment, $Q_{xn}(CC, j)$, $Q_{xn}(SC, j)$, $Q_n(CC, j)$ and $Q_n(SC, j)$ as what indicated in (59)-1 ~ (59)-4 are sound recording parameters. Because $n=1, 2, \dots, 50$, and $j=0, 1, \dots, 63999$, there are total $4 \times 50 \times 64000 = 1.28 \times 10^7$ recording parameters. These parameters are calculated through computer and stored in ROM which we call "Sound recording parameter memory".

15 Hereby, $MQ_{xn}(CC, j)$, $MQ_{xn}(SC, j)$, $MQ_n(CC, j)$ and $MQ_n(SC, j)$ are designated as memories for $Q_{xn}(CC, j)$, $Q_{xn}(SC, j)$, $Q_n(CC, j)$ and $Q_n(SC, j)$ respectively.

2. SOUND REPRODUCTION PARAMETER AND "SOUND REPRODUCTION PARAMETER MEMORY"

20 (1) Main sound reproduction parameter

In the present embodiment, the "main sound reproduction parameter" indicates $C\bar{S}C_n(t)$ and $SCC_n(t)$ as shown in equations (58)-1 and (58)-2. Because $n=1, 2, \dots, 50$, and $t = \frac{0}{64,000}, \frac{1}{64,000}, \dots$, therefore, there are total $2 \times 50 \times 64,000 = 6.4 \times 10^6$ parameters. These parameters are calculated through computer and stored in ROM which we call "main sound reproduction parameter memory". Hereby, $MC\bar{C}S_n(t)$ and $MSCC_n(t)$ are designated as memories for $C\bar{C}S_n(t)$ and $SCC_n(t)$ respectively.

30

(2) End point sound reproduction parameter

In the present embodiment, "end point sound

reproduction parameter" indicates

$$(-1)^r P_k'(-t), (-1)^r \left[\frac{1}{2} + P_k(-t) \right], -(-1)^r P_k'(1-t)$$

and $-(-1)^r \left[\frac{1}{2} + P_k(1-t) \right]$ as shown in expression (56).

Because $t = \frac{0}{64,000}, \frac{1}{64,000}, \dots, \frac{63,999}{64,000}$;

5 therefore, there are total $4 \times 64,000 = 2.56 \times 10^5$ parameters. These parameters are calculated through computer and stored in ROM which we call "end point sound reproduction parameter memory", in which $r=64,000t$, Hereby, letting:

$$\begin{aligned} 10 \quad u_1(t) &= (-1)^r P_k'(t); \\ u_2(t) &= (-1)^r \left[\frac{1}{2} + P_k(-t) \right]; \\ v_1(t) &= -(-1)^r P_k'(1-t); \text{ and} \\ v_2(t) &= -(-1)^r \left[\frac{1}{2} + P_k(1-t) \right]. \end{aligned}$$

Thus, $Mu_1(t)$, $Mu_2(t)$, $Mv_1(t)$ and $Mv_2(t)$ are
15 designated as memories for $u_1(t)$, $u_2(t)$, $v_1(t)$, and $v_2(t)$ respectively.

3. WAVEFORM DATA, WAVEFORM DATA MEMORY (RECORDING TAPE) AND SOUND RECORDING METHOD

In the following description, a sign $\langle X \rangle$
20 will be used, in which X represents a certain memory, and $\langle X \rangle$ represents the data in the memory X . Further, in case Y is a memory, thus:

$$Y \leftarrow \langle X \rangle$$

It means to store the data from memory X to memory Y .
25 In general condition, the right side of the arrow " $\leftarrow$ " represents a number, and the left side represents a memory. For example,

$$Y \leftarrow \langle X_1 \rangle + \langle X_2 \rangle \cdot \langle X_3 \rangle + 3$$

It means to store in memory Y the number which is obtained from the product of the data in memories X_2 and X_3 , plus the data in memory X_1 and plus 3.

- 5 (1). Waveform data and waveform data memory (recording tape)

Letting:

$$\begin{aligned} WD_1(n) = & \sum_{j=0}^{63999} \{S'(j\Delta T)Q_{xn}(CC,j) + [(j+1)S(j\Delta T) \\ & - jS((j+1)\Delta T)]Q_n(CC,j)\} \cdots \cdots (60)-1 \end{aligned}$$

$$\begin{aligned} 10 \quad WD_2(n) = & \sum_{j=0}^{63999} \{S'(j\Delta T)Q_{xn}(SC,j) + [(j+1)S(j\Delta T) \\ & - jS((j+1)\Delta T)]Q_{xn}(SC,j)\} \cdots \cdots (60)-2 \end{aligned}$$

thus, (57)-1 can be rewritten as:

$$\begin{aligned} \alpha_e(t) + \beta_e(t) = & \sum_{n=1}^{50} [CSC_n(t) \cdot WD_1(n) + SCC_n(t) \\ & \cdot WD_2(n)] \cdots \cdots (57)-2 \end{aligned}$$

- 15 in which $WD_1(n)$ and $WD_2(n)$ are called waveform data. Because $n=1,2,\dots,50$; there are total $2 \times 50 = 100$ waveform data.

When $MWD_1(n)$ and $MWD_2(n)$ are respectively designated as RAM (random access memories) for $WD_1(n)$ and $WD_2(n)$, there are totally $2 \times 50 = 100$ sets of RAM here. If each set of RAM contains 4 sets of Bytes (1 Byte = 8 Bits), there will be totally 400 Bytes. According to the present embodiment, $T=1$. Because acoustic signal $S(t)$ is 1 second, a 1 second of

acoustic signal can be stored by means of 400 Bytes.

The foregoing $MWD_1(n)$ and $MWD_2(n)$ are called "waveform data memories", they are used as a recording tape.

5 (2). Storage method (Sound recording method)

A "derivative circuit" shall be prepared (the derivative circuit will be described further in Hardware Structure) to give an output for the voltage signal $S'(t)$ of the derivative function of t as soon as an acoustic voltage signal $S(t)$ enters. One or two A/D converters shall also be prepared. When two A/D converters are used, they are respectively for converting $S(t)$ and $S'(t)$ into digital signals. When single A/D converter is used, $S(t)$ and $S'(t)$ are commonly converted into digital signals therethrough. The sound recording method according to the present invention is outlined hereinafter:

(i) clear $MWD_1(n)$ and $MWD_2(n)$, then, sample $S(t)$ and $S'(t)$ when $t = \frac{0}{64,000}$ (i.e. $t=0$). The samples from $S(t)$ and $S'(t)$ are $S(0)$ and $S'(0)$. Pre-store $S(0)$ and $S'(0)$ in two sets of Data RAM which are designated $MS(0)$ and $MS'(0)$.

(ii) Sample $S(t)$ when $t = \frac{1}{64,000}$, and the sample is $S(\Delta T)$; $\Delta T = \frac{1}{64,000}$. After converting into digital signal through A/D converter, the following calculations and operations are performed in proper sequence:

$$\begin{aligned} MWD_1(1) &\leftarrow \langle MWD_1(1) \rangle + S'(0 \cdot \Delta T) Q_{x1}(CC, 0) \\ &\quad + [S(0 \cdot \Delta T) - 0 \cdot S(1 \cdot \Delta T)] Q_1(CC, 0) \end{aligned}$$

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$$\begin{aligned} \text{MWD}_1(2) &\leftarrow \langle \text{MWD}_1(2) \rangle + S' (0 \cdot \Delta T) Q_{x2}(CC, 0) \\ &\quad + [S(0 \cdot \Delta T) - 0 \cdot S(1 \cdot \Delta T)] Q_2(CC, 0) \\ &\quad \vdots \end{aligned}$$

$$\begin{aligned} \text{MWD}_1(50) &\leftarrow \langle \text{MWD}_1(50) \rangle + S' (0 \cdot \Delta T) Q_{x50}(CC, 0) \\ &\quad + [S(0 \cdot \Delta T) - 0 \cdot S(1 \cdot \Delta T)] Q_{50}(CC, 0) \end{aligned}$$

5

$$\begin{aligned} \text{MWD}_2(1) &\leftarrow \langle \text{MWD}_2(1) \rangle + S' (0 \cdot \Delta T) Q_{x1}(SC, 0) \\ &\quad + [S(0 \cdot \Delta T) - 0 \cdot S(1 \cdot \Delta T)] Q_1(SC, 0) \end{aligned}$$

$$\begin{aligned} \text{MWD}_2(2) &\leftarrow \langle \text{MWD}_2(2) \rangle + S' (0 \cdot \Delta T) Q_{x2}(SC, 0) \\ &\quad + [S(0 \cdot \Delta T) - 0 \cdot S(1 \cdot \Delta T)] Q_2(SC, 0) \\ &\quad \vdots \end{aligned}$$

$$\text{MWD}_2(50) \leftarrow \langle \text{MWD}_2(50) \rangle + S' (0 \cdot \Delta T) Q_{x50}(SC, 0)$$

10

$$+ [S(0 \cdot \Delta T) - 0 \cdot S(1 \cdot \Delta T)] Q_{50}(SC, 0)$$

(ii) when $t = \frac{2}{64,000}, \frac{3}{64,000}, \dots, \frac{64,000}{64,000}$ repeat

the process of (i), the final data in $\text{MWD}_1(n)$ and $\text{MWD}_2(n)$ ($n=1, 2, \dots, 50$) are the waveform data.

And, the samples of $S(1)$ and $S'(1)$ which are

15 obtained when $t = \frac{64,000}{64,000} = 1$ are respectively stored in two Data RAM $\text{MS}(1)$ and $\text{MS}'(1)$.

Thus, the final data in $\text{MWD}_1(n)$, $\text{MWD}_2(n)$ ($n=1, 2, \dots, 50$), $\text{MS}(0)$, $\text{MS}'(0)$. $\text{MS}(1)$ and $\text{MS}'(1)$ represents a one second acoustic signal $S(t)$.

20

In the above calculations and operations, every procedure must be completed within $\frac{1}{64,000}$ second = 15,625ns, and which is performed by means of addition circuit and multiplication circuit matching with timing circuit. This will be described further.

4. METHOD OF RESTORATION (METHOD FOR REPRODUCTION OF SOUND)

The method to reproduce sound in accordance with the present invention is outlined hereinafter.

5 (1) Read out the data from MS(0) directly
when $t = \frac{0}{64,000} = 0$ this data is S(0).

(2) When $t = \frac{1}{64,000}$, do the following calculations:

(i) First calculate the following:

$$10 \quad \langle \text{MC}\bar{\text{S}}\text{C}_1 (\frac{1}{64,000}) \rangle \times \langle \text{MWD}_1 (1) \rangle$$

$$\langle \text{MC}\bar{\text{S}}\text{C}_2 (\frac{1}{64,000}) \rangle \times \langle \text{MWD}_1 (2) \rangle$$

$$\langle \text{MC}\bar{\text{S}}\text{C}_3 (\frac{1}{64,000}) \rangle \times \langle \text{MWD}_1 (3) \rangle$$

$$\vdots$$

$$\langle \text{MC}\bar{\text{S}}\text{C}_{50} (\frac{1}{64,000}) \rangle \times \langle \text{MWD}_1 (50) \rangle$$

$$\langle \text{MSCC}_1 (\frac{1}{64,000}) \rangle \times \langle \text{MWD}_2 (1) \rangle$$

$$15 \quad \langle \text{MSCC}_2 (\frac{1}{64,000}) \rangle \times \langle \text{MWD}_2 (2) \rangle$$

$$\langle \text{MSCC}_3 (\frac{1}{64,000}) \rangle \times \langle \text{MWD}_2 (3) \rangle$$

$$\vdots$$

$$\langle \text{MSCC}_{50} (\frac{1}{64,000}) \rangle \times \langle \text{MWD}_2 (50) \rangle$$

(i) Then, calculate the following:

$$(64,000 \pi)^2 \sum_{n=1}^{50} \{ \langle \text{MCSC}_n(\frac{1}{64,000}) \rangle \times \langle \text{MWD}_1(n) \rangle \\ + \langle \text{MSCC}_n(\frac{1}{64,000}) \rangle \times \langle \text{MWD}_2(n) \rangle$$

(ii) And then, calculate the following:

$$\begin{aligned} 5 \quad & \langle \text{Mu}_1(\frac{1}{64,000}) \rangle \times \langle \text{MS}(0) \rangle + \langle \text{Mu}_2(\frac{1}{64,000}) \rangle \\ & \times \langle \text{MS}'(0) \rangle + \langle \text{Mv}_1(\frac{1}{64,000}) \rangle \times \langle \text{MS}(1) \rangle \\ & + \langle \text{Mv}_2(\frac{1}{64,000}) \rangle \times \langle \text{MS}'(1) \rangle \end{aligned}$$

(iv) Calculate the sum of the result obtained from (i) and (ii), and the sum thus obtained
10 is: $S(\frac{1}{64,000})$.

(3) Repeat the calculation (2) when
 $t = \frac{2}{64,000}, \frac{3}{64,000}, \dots, \frac{63,999}{64,000}$ thus, we can obtained
respectively: $S(\frac{2}{64,000}), S(\frac{3}{64,000}), \dots, S(\frac{63,999}{64,000})$.

(4) Read out the data in MS(1) directly
15 when $t = \frac{64,000}{64,000} = 1$ hour, which data is S(1).

Every procedure above-described shall also be completed within 15,625ns. This will be described further in Hardware Structure.

HARDWARE STRUCTURE OF THE INVENTION

An embodiment of hardware structure in accordance with the present invention for the operation of the foregoing method will be fully understood from the following detailed description, with reference to the annexed drawings, in which:

1. Brief Description of the Drawings:

Fig. 1 is a schematic drawing, illustrating the contents of (a) and (b) which are respectively stored in $MQ_{xn}(CC,j)$ and $MQ_n(CC,j)$ ($j=0,1,\dots,63999$) according to address sequence;

Fig. 2 is a schematic drawing, illustrating the contents of (a) and (b) which are respectively stored in $MQ_{xn}(SC,j)$ and $MQ_n(SC,j)$ ($j=0,1,\dots,63999$) according to address sequence;

Fig. 3 is a schematic drawing, illustrating the contents of (a) and (b) which are respectively stored in $MC\bar{S}C_n(j\Delta T)$ and $MSCC_n(j\Delta T)$ ($j=0,1,\dots,63999$, $\Delta T = \frac{1}{64,000}$) according to address sequence;

Fig. 4 is a schematic drawing, illustrating the contents stored in a hybrid memory of $Mu_1(j\Delta T)$, $Mu_2(j\Delta T)$, $Mv_1(j\Delta T)$, $Mv_2(j\Delta T)$ ($j=1,2,\dots,63999$, $\Delta T = \frac{1}{64,000}$) according to address sequence;

Fig. 5 is a circuit diagram of a "derivative circuit" according to the present invention, in which an output of $S'(t)$ is provided through terminal b when an input of acoustic signal $S(t)$ enters through terminal a (t is differentiated);

Fig. 6 is a computing circuit for the calculation of $64,000[(DS_2) - (DS_1)] \times (DQ_x) + [j(DS_1) - (j-1)(DS_2)] \times (DQ) + (DW)$;

In which (DS_1) , (DS_2) , (DQ_x) , (DQ) and (DW) represent the data in Data Bus DS_1 , DS_2 , DQ_x , DQ and DW (the others may be inferred by analog); $j=0,1,\dots, 63999$; the value of j is counted by Counter 100. The
5 calculation result is finally sent for output through $D0$ (beyond the dotted line);

Fig. 7 is a computing circuit (sound recording circuit) diagram for computing the waveform data $WD_1(n)$ and $WD_2(n)$ of acoustic signal $S(t)$, the
10 result of which are sent through DW_1 and DW_2 respectively for output;

Fig. 8 is a read-write control circuit diagram for $MWD_1(n)$ and $MWD_2(n)$;

Fig. 9 is a computing circuit diagram for
15 the calculation of
 $(DES_1) \times (DUV_1) + (DES_2) \times (DUV_2) + (DES_3) \times (DUV_3) + (DES_4) \times (DUV_4)$

Fig. 10 is a circuit diagram which can continuously complete the following operation;

(1) to calculate $(DW) \times (DP)$
20 (2) to read the data from accumulator 18 and add to the product obtained from (1) for further storage in accumulator 18 again, or simultaneously to multiply the result by a constant $(64,000\pi)^2$ for further output through $D0$;

25 Fig. 11 is a partly view of a restoration circuit (sound reproduction circuit) diagram for the restoration of acoustic signal $S(t)$;

Fig. 12 is a complete restoration circuit diagram for the restoration of acoustic signal $S(t)$;

30 Fig. 13 is a complete "storage/restoration circuit" diagram;
and

Fig. 14 is a control block diagram, in which a microprocessor is added to control the storage
35 /restoration circuit.

Description of the designated numerals:

- 010 : $MQ_{xn}(CC, j)$. 021 : $MQ_n(SC, j)$.
 011 : $MQ_{xn}(SC, j)$. 030 : $MC\bar{S}C_n(j \Delta T)$.
 020 : $MQ_n(CC, j)$. 031 : $MSCC_n(j \Delta T)$.
 5 04 : hybrid memory of $Mu_1(j \Delta T)$, $Mu_2(j \Delta T)$, $Mv_1(j \Delta T)$, $Mv_2(j \Delta T)$.

 in the above, $j=0, 1, \dots, 63999$; $\Delta T = \frac{1}{64,000}$.
 050 : $MWD_1(n)$; $n=1, 2, \dots, 50$.
 0500~050q : q+1 segments of $MWD_1(n)$, each
 10 segment contains 50 sets (because $n=1, 2, \dots, 50$).
 051: $MWD_2(n)$; $n=1, 2, \dots, 50$.
 0510-051q : q+1 segments of $MWD_2(n)$, each
 segment contains 50 sets (because $n=1, 2, \dots, 50$).
 060, 063 : subtracter for subtracting the data
 15 at input terminal DI_1 from the data at input terminal
 DI_2 for further output through DO .
 061 : subtracter for subtracting 1 from the
 data at input terminal DI .
 070-074, 0750-0753, 076, 077 : multiplier for
 20 the calculation of $(DI_1) \times (DI_2)$.
 080 and 083 : adder for the calculation of (DI_1)
 $+(DI_2)+(DI_3)$.
 081 : adder for the calculation of $(DI_1)+(DI_2)+$
 $(DI_3)+(DI_4)$.
 25 082 : adder for the calculation of $(DI_1)+(DI_2)$.
 090 : circuit for providing constant "64,000".
 091 : circuit for providing constant " $(64,000$
 $\pi)^2$ ".
 100 : counter for counting the value of "j",
 30 in which CK is a count pulse input end, and CR is a
 clear end.
 101-107 : to provide address data for counter
 of memory device, in which CK is a count pulse input
 end, and CR is a clear end.

- 11 : "derivative circuit".
- 110,111 : high gain operational amplifier.
- 112-114 : resistors.
- 115 : inductor.
- 5 120,121 : electronic switch for use in
sampling acoustic signal $S(t)$, in which Cr is the ON
-OFF control end, and it becomes ON when Cr is High
or it becomes OFF when Cr is Low.
- 130,131 : A/D converter.
- 10 14 : D/A converter.
- 150 : hybrid memory of MS' (0) and MS' (1).
- 151 : hybrid memory of MS(0) and MS(1).
- 160,161,1620,1621,1630,1631,1640,1641,1650,1651:
buffers.
- 15 17 : shift register, in which the output data
at D0 is the last input data at DI.
- 18 : accumulator for use in the process of the
restoration of acoustic signal $S(t)$.
- 19 : power amplifier.
- 20 20 : speaker.
- 210,211 : OR gate group.
- 22 : timer (or called as "sound recording timer")
for use in the process of the storage of acoustic
signal $S(t)$.
- 25 23 : timer (or called as "sound reproduction
timer") for use in the process of the reproduction of
acoustic signal $S(t)$.
- 24 : microprocessor.
- 25 : keyboard.
- 30 26 : digital display.
- 27,270,271 : circuits as illustrated in Fig. 6.
- 28 : circuit as illustrated in Fig. 7.
- 29 : circuit as illustrated in Fig. 8.
- 30 : circuit as illustrated in Fig. 9.
- 35 31,310,311 : circuits as illustrated in Fig. 10.

32 : circuit as illustrated in Fig. 11.

33 : circuit as illustrated in Fig. 12.

34 : circuit as illustrated in Fig. 13.

2. Detailed Description of the Drawings:

5 1). Figs. 1 through 4

As previously described, these drawings illustrate the contents in the memories concerned.

2). Fig. 5

It is a "derivative circuit". As
 10 illustrated, assume the resistance of resistors 112-114 are R_{11} , R_{12} and R_1 ohm respectively; the inductance of inductor 115 is L Henry. For the selection of operational amplifiers 110 and 111, the following three terms must be taken into account: (1)
 15 The relative relation among amplifier's output voltage e_o , voltage e_b at input connecting point and amplifier's gain K must be $e_o = -Ke_b$; (2) Amplifier's current $i_b \div 10^{-9}$ is negligible; and (3) Amplifier's open-circuit gain is generally at D-C and can be as
 20 high as 10^8 .

With respect to amplifier 110, assume its input voltage is e_{in} (i.e. the voltage at terminal a in Fig. 5), the voltage at input connecting point is e_{x1} , the voltage at both inducing ends is e_L , output
 25 voltage is e_{y1} (i.e. the voltage at terminal y_1 in Fig. 5), input current is i_1 , feedback current is i_2 . Because the current at amplifier 110 is as small as 10^{-9} , it is negligible and can be regarded as 0.

thus,

$$30 \quad i_1 + i_2 \div 0$$

and

$$i_1 = \frac{e_{in} - e_{x1}}{R_{11}} \div \frac{e_{in}}{R_{11}} \quad (\text{because } e_{y1} = -Ke_{x1},$$

and K is extremely great, therefore $e_{x1} \rightarrow 0$)

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$$i_2 = \frac{1}{L} \int_0^t e_L dt$$

$$i_1' \doteq \frac{1}{R_{i1}} e_{in}'$$

$$i_2' = \frac{1}{L} e_L$$

$$i_1' + i_2' \doteq \frac{1}{L} e_L + \frac{1}{R_{i1}} e_{in}' \doteq 0$$

5 that is,

$$e_L \doteq -\frac{L}{R_{i1}} e_{in}'$$

the voltage e_L at both inducing ends can also be expressed by:

$$e_L = e_{y1} - e_{x1} \doteq e_{y1}$$

10 therefore:

$$e_{y1} \doteq -\frac{L}{R_{r1}} e_{in}'$$

With respect to amplifier 111, the input voltage of amplifier 111 is the output voltage e_{y1} of amplifier 110. Assume the voltage at its input
 15 connecting point is e_{x2} , the output voltage is e_{y2} , the input current is i_3 , the feedback current is i_4 , thus:

$$i_3 + i_4 \doteq 0$$

$$i_3 = \frac{e_{y1} - e_{x2}}{R_{i2}} \doteq \frac{e_{y1}}{R_{i2}}$$

20
$$i_4 = \frac{e_{y2} - e_{x2}}{R_f} \doteq \frac{e_{y2}}{R_f}$$

$$\frac{e_{y1}}{R_{i2}} + \frac{e_{y2}}{R_f} \doteq 0$$

therefore,

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$$e_{yz} = -\frac{R_t}{R_{tz}} e_{y1}$$

When said e_{y1} is substituted,

$$e_{y2} \doteq \frac{R_f}{R_{i2}} \times \frac{L}{R_{i1}} e_{in}'$$

When the value of R_{i1} , R_{i2} , R_f and L are selected to let

$$\frac{R_f}{R_{i2}} \times \frac{L}{R_{i1}} = 1$$

thus,

$$e_{y2} \doteq e_{in}'$$

In the above expression, e_{y2} is the output through terminal b in Fig. 5, and e_{in} is the input through terminal a. In case the input through terminal a is an acoustic signal $S(t)$, the output through terminal b becomes $S'(t)$, and this is a derivative of time for $S(t)$.

Because the input resistance in regular operational amplifiers is generally infinitely great, amplifier 110 still can be regarded as in an open-circuit status when amplifier 111 is connected.

3). Fig. 6

As foregoing statement, Fig. 6 is a computing circuit for the calculation of :
 $64,000[(DS_2) - (DS_1)] \times (DQ_x) + [j(DS_1) - (j-1)(DS_2)] \times (DQ) + (DW)$

When the data at Data Bus DW, DS_1 , DS_2 , DQ_x and DQ become stable and a High signal enters through Enable terminal EN, the result from said calculation will be sent for output through terminal D0 after a duration delayed by the circuit itself. Before each calculation or before adding High to EN, a pulse input is sent through terminal CK to drive counter 100 to produce a new value of "j". Further, an input signal of clear must be sent through terminal CR while proceeding with first calculation process,

permitting the value of "j" to start from 0.

4). Fig. 7

Therein illustrated is a computing circuit for the calculation of waveform data of acoustic signal $S(t)$, and the operation of which is outlined hereinafter.

(1) Acoustic signal $S(1)$ enters from terminal S through "derivative circuit" 11, to provide electronic switch 121 with $S'(t)$.

10 (2) At the same time, $S(t)$ enters electronic switch 120 directly.

(3) $S(t)$ and $S'(t)$ are continuously sampled for converting into digital signals by A/D converters 130 and 131 respectively (the frequency at 15 C_r is 64,000Hz) when the instant is High at terminal C_r .

(4) $S'(0)$ and $S'(1)$ from the digital signals of $S'(t)$ that A/D converter 131 provides will be stored in memory 150 when the total time 20 length of $S(t)$ is one second. The address data of memory 150 is provided by counter 101. Under this condition, a pulse enters clock input terminal CK_3 of counter 101 per every second, and "write control terminal" W_1 enters an input of High to complete 25 storage operation when address data and $S'(0)$ or $S'(1)$ that A/D converter 131 provides become stable.

(5) $S(0)$ and $S(1)$ from the digital signals of $S(t)$ that A/D converter 130 provides are stored in memory 151. The address data of memory 151 is 30 provided by counter 102. Similarly, a pulse enters CK_4 per every second, and "write control terminal" W_2 enters an input of High to complete storage operation when address data and digital signal $S(0)$, $S(1)$ become stable.

35 (6) 17 is a shift register. When a first

High enters terminal SF the input data from terminal DI is shifted to a register prepared in 17. As soon as a second High enters terminal SF the data in said register is shifted to terminal D0 and the data at DI is shifted to said register. Therefore, the data at terminals DS₂, DS₁, in circuit blocks 270 and 271 are constantly the same: the data at DS is existing S(t), and the data at DS₁ is the last S(t). That is to say: DS₁ is S((j-1)ΔT) when DS₂ is S(jΔT), in which j=0, 1, ..., 63,999; $\Delta T = \frac{1}{64,000}$.

(7) 270 and 271 are the circuit 27 as illustrated in Fig. 6.

(8) 010 is MQ_{xn}(CC,j); 011 is MQ_{xn}(SC,j); 020 is MQ_n(CC,j); 021 is MQ_n(SC,j). Counter 103 provides address data for these memories, and "Read control terminals" are concomitantly controlled by R₃.

(9) According to the description of Fig. 6, it is apparent that the data presented in DW₁ and DW₂ after last S(t) is presented (i.e. after termination of 1 second) are the waveform data:

$$\sum_{j=0}^{63999} \{S'(j\Delta T)Q_{xn}(CC,j) + [(j+1)S(j\Delta T) - jS((j+1)\Delta T)]Q_n(CC,j)\};$$

and

$$\sum_{j=0}^{63999} \{S'(j\Delta T)Q_{xn}(SC,j) + [(j+1)S(j\Delta T) - jS((j+1)\Delta T)]Q_n(SC,j)\};$$

in which, $S'(j\Delta T) = 64,000[S((j+1)\Delta T) - S(j\Delta T)]$

$\Delta T = \frac{1}{64,000}$ (please refer to equation (57)-1); n=1,2, ..., 50. Therefore, DW₁ and DW₂ will respectively provide an output of 50 waveform data.

5). Fig. 8

Therein illustrated is a read-write control circuit for controlling $MWD_1(n)$ and $MWD_2(n)$, and the operation of which is outlined hereinafter:

- 5 (1) $MWD_1(n)$ 050 and $MWD_2(n)$ 051 are respectively partitioned into $q+1$ segments 0500-050 q and 0510-051 q , in which each segment includes 50 sets permitting each set to store therein a $WD_1(n)$ and a $WD_2(n)$ ($n=1,2,\dots,50$).
- 10 (2) The read and write control terminals of 050 are R_1 and W_2 respectively, and of 051 are R_1 and W_2 respectively.
- 15 (3) Counters 104 and 105 provide address data for 050 and 051 respectively, wherein 104 provides higher address data and 105 provides lower address data. CK_1 and CK_2 are count pulse input terminals of 104 and 105 respectively, and CR is the common clear terminal.
- 20 (4) Higher address are the address of every segment of 0500, 0501, 0502, ..., 050 q and 0510, 0511, 0512, ..., 051 q , and lower address are the address of every set of said every segment (each segment has 50 sets, therefore, lower address contains 5 Bits).
- 25 (5) Address data can be freely set in advance (therefore, 104 and 105 here are special counters). During setting, the data to set is added to terminal ADS, and thereafter, a setting signal is added to terminal Sr.
- 30 (6) Because address data can be freely set in advance, it is possible to start reading and writing from any segment in 050 and 051.
- (7) For address data free setting, an external microprocessor is provided for selection control (by means of keyboard operation).
- 35 (8) An acoustic signal $S(t)$ is stored in

said every segment of 050 and 051. When a one-hour acoustic signal is divided into 3600 segments and every segment equals to 1 second, 050 and 051 must have 3600 segments (for higher address 14 Bits is required) sufficient for the storage of the waveform data of an one-hour acoustic signal.

(9) The circuit in Fig. 8 is actually equivalent to a "recording tape".

6). Fig. 9

As previously described, the circuit herein is a computing circuit for the calculation of :
 $(DES_1) \times (DUV_1) + (DES_2) \times (DUV_2) + (DES_3) \times (DUV_3) + (DES_4) \times (DUV_4)$

Because 0750-0751 are multipliers and 081 is an adder, they are provided for the calculation of above expression. During computation, a High is added to terminal EN after the data in Data Bus DES_1 , DUV_1 ... become stable. After a delayed duration through the circuit, the result thus obtained is sent for output through terminal D0.

7). Fig. 10

The operational sequence of the circuit herein is outlined hereinafter:

(1) The data to process are sent to terminals DW and DP.

(2) After the data at DW and DP become stable, High is added to terminals EN_1 and R. After delayed duration through the circuit, an output of $(DW) \times (DP)$ is added from D0 of multiplier 076 to DI of adder 082, and the data in accumulator 18 is read out and added to DI of adder 082.

(3) After the data at DI_1 and DI_2 of adder 082 become stable, High is added to EN_2 and the sum from its two input terminals is sent for output through D0 of adder 082.

(4) After the output from adder 082 becomes

stable, High is added to terminal W so as to store the sum from (3) back to accumulator 18.

(5) Repeat the operation from (1) through (4) for 50 times.

5 (6) Then, add High to ST so as to register "final result" in buffer 166.

(7) 091 is a circuit to provide constant $(64,000\pi)^2$. When High is finally added to EN_3 , said "final result" can be multiplied by $(64,000\pi)^2$
10 before output (since 077 is a multiplier).

8). Fig. 11 and Fig. 12

As previously described, Fig. 11 is a part of a restoration circuit which can restore an acoustic signal $S(t)$, and Fig. 12 is a complete
15 restoration circuit (sound reproduction circuit). Both drawings are concomitantly described hereinafter.

(1) In Fig. 12, 32 designates Fig. 11; In Fig. 11 designates Fig. 9, and 310 and 311 designate 31 in Fig. 10.

20 (2) In Fig. 12, 04 designates hybrid memory of $Mu_1(j\Delta T)$, $Mu_2(j\Delta T)$, $Mv_1(j\Delta T)$ and $Mv_2(j\Delta T)$; 107 designates a counter to provide address data. From the allocation of the storage contents in Fig. 4, when 4 pcs. of data is continuously read out from 04
25 each time, such 4 pcs. of data are $u_1(j\Delta T)$, $u_2(j\Delta T)$, $v_1(j\Delta T)$ and $v_2(j\Delta T)$ ($j=1,2,\dots,63999$; $\Delta T=\frac{1}{64,000}$).

After ST_2 , ST_3 , ST_4 and ST_5 in Fig. 11 become synchronous and are respectively added with High in proper sequence, said 4 pcs. of data can then be
30 registered in Buffers 1621, 1631, 1641 and 1651 properly.

(3) Terminal DES is connected to terminal DES of circuit 28 in Fig. 7 (see Fig. 13). In Fig. 7, the following operations are performed in proper

sequence:

- CK₃ is added with a pulse;
 R₁ is added with High;
 ST₁ is added with High — under this
 5 condition, S' (0) is presented at DES;
 CK₄ is added with a pulse;
 R₂ is added with High;
 ST₂ is added with High — under this
 condition, S(0) is presented at DES;
 10 Repeat above operation twice permitting S'
 (1) and S(1) to be presented at DES in proper sequence.
 (4) Return to Fig. 11 now. According to (3),
 4 pcs. of data S' (0), S(0), S' (1) and S(1) can be
 continuously presented through DES. When ST₂, ST₃,
 15 ST₄ and ST₅ become synchronous and are added with
 High in proper sequence, said 4 pcs. of data can then
 be registered in buffers 1620, 1630, 1640 and 1650
 respectively.
 (5) After output data from buffers 1620,
 20 1621, 1630, 1631, and etc., become stable, EN₄ (in Fig.
 11) is added with High, and then output can be sent
 through 30 (see Fig. 9): $u_1(j\Delta T)S'(0) + u_2(j\Delta T) \cdot S(0)$
 $+ v_1(j\Delta T)S'(1) + v_2(j\Delta T)S(1)$.
 (6) 310 and 311 in Fig. 11 designates 31 in
 25 Fig. 10; 030, 031 in Fig. 12 designate $MC\bar{S}C_n(j\Delta T)$
 and $MSCC_n(j\Delta T)$ ($j=1,2,\dots,63999$; $\Delta T = \frac{1}{64,000}$), the
 allocation of the contents of which is as shown in Fig.
 3. Counter 106 provides address data for 030 and 031.
 Therefore, when pulse enters CK₁ in Fig. 12 and High
 30 is given to terminal R₁ after the address data each
 time provided become stable, $C\bar{S}C_1(j\Delta T)$, $C\bar{S}C_2(j\Delta T)$,
 $\dots$ and $SCC_1(j\Delta T)$, $SCC_2(j\Delta T)$, $\dots$ are respectively
 continuously presented through terminals DP₁ and DP₂
 (see the allocation of the contents of 030 and 031 in

Fig. 3).

(7) DW_1 and DW_2 in Fig. 11 or Fig. 12 are respectively connected to DW_1 and DW_2 of circuit 29 in Fig. 8 (see Fig. 13), and DW_1 and DW_2 of circuit 29 (Fig. 8) are data input output terminals of $MWD_1(n)$ 050 and $MWD_2(n)$ 051. Therefore, what are presented through DW_1 and DW_2 here (Fig. 11 or Fig. 12) are waveform data of $S(t)$. According to the description for Fig. 10, the output through 310 and 311 are respectively as:

$$(64,000\pi)^2 \sum_{n=1}^{50} [\langle MCSC_n(j\Delta T) \rangle \times \langle MWD_1(n) \rangle]; \text{ and}$$

$$(64,000\pi)^2 \sum_{n=1}^{50} [\langle MSCC_n(j\Delta T) \rangle \times \langle MWD_2(n) \rangle]$$

in which, $j=1,2,\dots, 63999$.

(8) Because 083 is an adder, the output from 083 is the sum of the output from 310, 311 and 30, and such sum is $S(j\Delta T)$. Under this condition, $S(j\Delta T)$ is a digital signal which can be converted into analog signal through D/A converter.

9). Fig. 13

Therein illustrated is a "storage/restoration circuit" which incorporates the circuit which stores $S(t)$ and the circuit which restores $S(t)$, and the operation of which is outlined hereinafter.

(1) In the drawing, 28 designates the circuit in Fig. 7, 33 designates the circuit in Fig. 12, 29 designates the circuit in Fig. 8, and in which S is an acoustic signal input terminal, ADS and Sr are equivalent to that in Fig. 8.

(2) 22 designates a timer for use in the calculation of waveform data of $S(t)$ (i.e. during sound recording); 23 designates a timer for use in

the restoration of $S(t)$ (i.e. in reproduction of sound); in which TEN_1 is an Enable terminal to drive timer 22 to operate, and TEN_2 is an Enable terminal to drive timer 23 to operate.

5 (3) Timer 22 includes $T_1 - T_{21}$ total 21 output control terminals; Timer 23 includes $T_1 - T_{32}$ total 32 output control terminals. Each output control terminal of timers 22 and 23 completes a circuit operation each after every output of High
10 (pulse) signal therethrough. The sequence of output from timers 22 and 23 and the duration of each output therefrom are respectively designed according to the above-described operational routine of the circuit.

 (4) Because timers 22 and 23 are of known
15 art and not within the scope of the present invention, the circuit of which will not be described here. However, further detail will be available when it is required.

10). Fig. 14

20 As previously described, Fig. 14 is a control block diagram, in which a microprocessor is provided to control storage/restoration circuit. It is detailed hereinafter.

 (1) In the drawing, 34 is the circuit in Fig.
25 13; 25 designates a keyboard; 26 designates a digital display.

 (2) 24 designates a microprocessor, the I/O of which includes:

 one set of output lines DSP_1 for sending a
30 7 digits data to digital display 26;

 one set of scanning output lines DSP_2 for selecting digit place to display when DSP_1 provides a 7 digits data to digital display 26;

 one set of output lines ADS for providing
35 the address data of $MWD_1(n)$ and $MWD_2(n)$ to circuit 34;

one output line TEN_1 for selecting timer 22 of circuit 34 to operate;

one output line S_r for providing a control signal when the address data in $MWD_1(n)$ and $MWD_2(n)$ are set through ADS;

one sets of "read keyboard scanning line" DK_1 for providing scanning data to keyboard 25 during keyboard reading; and

one sets of "key-entry identification lines" DK_2 to judge and identify any key-entry then DK_1 provides scanning data to keyboard 25.

(3) Digital display 26 provides two functions. One is to display the address data preset in $MWD_1(n)$ and $MWD_2(n)$ so that an user can know where to start recording or reproduction; the other is to display the duration of time during sound recording or reproduction so that an user can know how long has been consumed in sound recording or reproduction.

(4) Keyboard 25 provides three functions. The first function is to set address data in $MWD_1(n)$ and $MWD_2(n)$; the second function is to select TEN_1 or TEN_2 to be High (both can not be High at the same time) for sound recording or reproduction; the third function is to select the mode of display through digital display 26 (to display address data, or duration of time in sound recording or reproduction).

(5) Microprocessor 24 is of a known art and not within the scope of the present invention, the hardware and software structure of which will not be described here. However, further detail will be available when it is required.

CLAIMS

1. A method for the storage access of acoustic signal $S(t)$ defined within $[0, T]$ ($t \in [0, T]$), including:

a first procedure to define an "auxiliary function" $P(x)$ as:

$$P(x) = \begin{cases} L(\alpha) & ; \text{ when } x \in [-M, 0] \\ R(\alpha) & ; \text{ when } x \in [0, M] \end{cases}$$

in which $M > 0$, $0 \leq t \leq M$, $L(x)$ is "left auxiliary function", $R(x)$ is "right auxiliary function", $R(0) = L(0)$;

a second procedure to express acoustic signal $S(t)$ by means of approximate expression as:

$$S(t) \doteq \frac{1}{R''(0) - L''(0)} \{ U_{.1} S(0) + U_{.2} S'(0) + U_{.3} S''(0) \\ + V_{.1} S(T) + V_{.2} S'(T) + V_{.3} S''(T) \\ + (H\pi)^3 [\alpha_{.}(t) + \beta_{.}(t)] \} \dots \dots \dots (52)$$

in which H is a number of high absolute value, $U_{.1} S(0)$, $U_{.2} S'(0)$, $U_{.3} S''(0)$, $V_{.1} S(T)$, $V_{.2} S'(T)$ and $V_{.3} S''(T)$ are as described in the expressions (53)-1 - (53)-6 of the specification, and $\alpha_{.}(t) + \beta_{.}(t)$ is as described in expression (16);

a third procedure to calculate $Q_{xn}(CS, j)$, $Q_{xn}(CC, j)$, $Q_{xn}(SS, j)$, $Q_{xn}(SC, j)$, $Q_n(CS, j)$, $Q_n(CC, j)$, $Q_n(SS, j)$ and $Q_n(SC, j)$ ($n=1, 2, \dots, k$; $j=0, 1, \dots, m-1$; k is the highest number of harmonic wave after expansion of $P(x)$ through Fourier series; m is the number of segments which are partitioned from interval $[0, T]$) and to store the result thus obtained in permanent memory $MQ_{xn}(CS, j)$, $MQ_{xn}(CC, j)$, $MQ_{xn}(SS, j)$, $MQ_{xn}(SC, j)$, $MQ_n(CS, j)$, $MQ_n(CC, j)$, $MQ_n(SS, j)$ and $MQ_n(SC, j)$ respectively, in which $Q_{xn}(CS, j)$, $Q_{xn}(CC, j)$, $Q_{xn}(SS, j)$, $Q_{xn}(SC, j)$, $Q_n(CS, j)$, $Q_n(CC, j)$, $Q_n(SS, j)$ and $Q_n(SC, j)$

are as described in the equations (14)-1~(14)-8 of the specification;

a fourth procedure to prepare 4k sets of Data RAM $MWD_1(n)$, $MWD_2(n)$, $MWD_3(n)$, $MWD_4(n)$ and 6 sets of Data RAM $MS(0)$, $MS'(0)$, $MS''(0)$, $MS(T)$, $MS'(T)$ and $MS''(T)$, in which $n=1,2,\dots,k$; and

a fifth procedure to proceed with following jobs:

(1) clearing $MWD_1(n)$, $MWD_2(n)$, $MWD_3(n)$, $MWD_4(n)$ to zero;

(2) sampling $S(t)$, $S'(t)$ and $S''(t)$ to have samples $S(0)$, $S'(0)$ and $S''(0)$ when $t=0 \cdot \Delta T$ ($\Delta T = \frac{T}{m}$), and storing $S(0)$, $S'(0)$ and $S''(0)$ in $MS(0)$, $MS'(0)$ and $MS''(0)$ respectively;

(3) sampling $S(t)$ to have sample $S(j \Delta T)$ when $t=j \cdot \Delta T$ ($j=1,2,\dots,m$, $\Delta T = \frac{T}{m}$), and then proceeding:

$$\begin{aligned}
 MWD_1(1) &\leftarrow \langle MWD_1(1) \rangle + S'((j-1)\Delta T) \\
 &\quad \times \langle MQ_{x1}(cs, j-1) \rangle + [js((j-1)\Delta T) - \\
 &\quad (j-1)S(j\Delta T)] \times \langle MQ_1(cs, j-1) \rangle; \\
 MWD_1(2) &\leftarrow \langle MWD_1(2) \rangle + S'((j-1)\Delta T) \\
 &\quad \times \langle MQ_{x2}(cs, j-1) \rangle + [js((j-1)\Delta T) - \\
 &\quad (j-1)S(j\Delta T)] \times \langle MQ_2(cs, j-1) \rangle; \\
 &\quad \vdots \\
 MWD_1(n) &\leftarrow \langle MWD_1(n) \rangle + S'((j-1)\Delta T) \\
 &\quad \times \langle MQ_{xn}(cs, j-1) \rangle + [js((j-1)\Delta T) - \\
 &\quad (j-1)S(j\Delta T)] \times \langle MQ_n(cs, j-1) \rangle;
 \end{aligned}$$

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$$\begin{aligned} \text{MWD}_2(1) \leftarrow & \langle \text{MWD}_2(1) \rangle + S'((j-1)\Delta T) \\ & \times \langle \text{MQ}_{x1}(cc, j-1) \rangle + [js((j-1)\Delta T) - \\ & (j-1)S(j\Delta T)] \times \langle \text{MQ}_1(cc, j-1) \rangle ; \end{aligned}$$

$$\begin{aligned} \text{MWD}_2(2) \leftarrow & \langle \text{MWD}_2(2) \rangle + S'((j-1)\Delta T) \\ & \times \langle \text{MQ}_{x2}(cc, j-1) \rangle + [js((j-1)\Delta T) - \\ & (j-1)S(j\Delta T)] \times \langle \text{MQ}_2(cc, j-1) \rangle ; \end{aligned}$$

$$\begin{aligned} & \vdots \qquad \qquad \qquad \vdots \\ \text{MWD}_2(n) \leftarrow & \langle \text{MWD}_2(n) \rangle + S'((j-1)\Delta T) \\ & \times \langle \text{MQ}_{xn}(cc, j-1) \rangle + [js((j-1)\Delta T) - \\ & (j-1)S(j\Delta T)] \times \langle \text{MQ}_n(cc, j-1) \rangle ; \end{aligned}$$

$$\begin{aligned} \text{MWD}_3(1) \leftarrow & \langle \text{MWD}_3(1) \rangle + S'((j-1)\Delta T) \\ & \times \langle \text{MQ}_{x1}(ss, j-1) \rangle + [js((j-1)\Delta T) - \\ & (j-1)S(j\Delta T)] \times \langle \text{MQ}_1(ss, j-1) \rangle ; \end{aligned}$$

$$\begin{aligned} \text{MWD}_3(2) \leftarrow & \langle \text{MWD}_3(2) \rangle + S'((j-1)\Delta T) \\ & \times \langle \text{MQ}_{x2}(ss, j-1) \rangle + [js((j-1)\Delta T) - \\ & (j-1)S(j\Delta T)] \times \langle \text{MQ}_2(ss, j-1) \rangle ; \end{aligned}$$

$$\begin{aligned} & \vdots \qquad \qquad \qquad \vdots \\ \text{MWD}_3(n) \leftarrow & \langle \text{MWD}_3(n) \rangle + S'((j-1)\Delta T) \\ & \times \langle \text{MQ}_{xn}(ss, j-1) \rangle + [js((j-1)\Delta T) - \\ & (j-1)S(j\Delta T)] \times \langle \text{MQ}_n(ss, j-1) \rangle ; \end{aligned}$$

$$\begin{aligned} \text{MWD}_4(1) \leftarrow & \langle \text{MWD}_4(1) \rangle + S'((j-1)\Delta T) \\ & \times \langle \text{MQ}_{x1}(sc, j-1) \rangle + [js((j-1)\Delta T) - \\ & (j-1)S(j\Delta T)] \times \langle \text{MQ}_1(sc, j-1) \rangle ; \end{aligned}$$

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$$\begin{aligned}
MWD_4(2) &\leftarrow \langle MWD_4(2) \rangle + S'((j-1)\Delta T) \\
&\quad \times \langle MQ_{x_2}(sc, j-1) \rangle + [js(j-1)\Delta T - \\
&\quad (j-1)S(j\Delta T)] \times \langle MQ_2(sc, j-1) \rangle ; \\
&\quad \vdots \\
MWD_4(n) &\leftarrow \langle MWD_4(n) \rangle + S'((j-1)\Delta T) \\
&\quad \times \langle MQ_{x_2}(sc, j-1) \rangle + [js(j-1)\Delta T - \\
&\quad (j-1)S(j\Delta T)] \times \langle MQ_n(sc, j-1) \rangle ;
\end{aligned}$$

in which,

$$S'((j-1)\Delta T) = \frac{S(j\Delta T) - S((j-1)\Delta T)}{\Delta T} ;$$

(4) storing samples $S(T)$, $S'(T)$ and $S''(T)$ in $MS(T)$, $MS'(T)$ and $MS''(T)$ respectively when $t = m\Delta T = T$.

2. A method for the storage access of acoustic signal $S(t)$ defined within $[0, T]$ ($t \in [0, T]$), including:

a first procedure to define an "auxiliary function" $P(x)$ as:

$$P(x) = \begin{cases} L(x) & ; \text{ when } x \in [-M, 0] \\ R(x) & ; \text{ when } x \in [0, M] \end{cases}$$

in which $M > 0$, $0 \leq t \leq M$, $L(x)$ is "left auxiliary function", $R(x)$ is "right auxiliary function", $R(x)$ is "right auxiliary function", $R(0) = L(0)$;

a second procedure to express acoustic signal $S(t)$ by means of approximate expression as:

$$\begin{aligned}
S(t) \doteq \frac{1}{R'(0) - L'(0)} & \{ U_{s1} S(0) + U_{s2} S'(0) + V_{s1} S(T) \\
& + V_{s2} S'(T) + (H\pi)^2 [\alpha_c(t) + \beta_c(t)] \} \dots (54)
\end{aligned}$$

in which, H is a number of high absolute value, $U_{.1}S(0)$, $U_{.2}S'(0)$, $V_{.1}S(T)$, $V_{.2}S'(T)$ are as described in the equations (55)-1 - (55)-4, and $\alpha_{.}(t) + \beta_{.}(t)$ is as described in the approximate expressoin (32) of the specification;

a third procedure to calculate $Q_{xn}(CS,j)$, $Q_{xn}(CC,j)$, $Q_{xn}(SS,j)$, $Q_{xn}(SC,j)$, $Q_n(CS,j)$, $Q_n(CC,j)$, $Q_n(SS,j)$ and $Q_n(SC,j)$ ($n=1,2,\dots,k$; $j=0,1,\dots,m-1$; k is the highest number of harmonic wave after expansion of $P(x)$ through Fourier series; m is the number of segments which are partitioned from interval $[0,T]$) and to store the result thus obtained in permanent memory $MQ_{xn}(CS,j)$, $MQ_{xn}(CC,j)$, $MQ_{xn}(SS,j)$, $MQ_{xn}(SC,j)$, $MQ_n(CS,j)$, $MQ_n(CC,j)$, $MQ_n(SS,j)$ and $MQ_n(SC,j)$, respectively, in which $Q_{xn}(CS,j)$, $Q_{xn}(CC,j)$, $Q_{xn}(SS,j)$, $Q_{xn}(SC,j)$, $Q_n(CS,j)$, $Q_n(CC,j)$, $Q_n(SS,j)$ and $Q_n(SC,j)$ are as described in the equations (14)-1 - (14)-8 of the specification;

a fourth procedure to prepare $4k$ sets of Data RAM $MWD_1(n)$, $MWD_2(n)$, $MWD_3(n)$, $MWD_4(n)$ and 4 sets of Data RAM $MS(0)$, $MS'(0)$, $MS(T)$, $MS'(T)$, in which $n=1,2,\dots,k$; and

a fifth procedure to proceed with following jobs:

(1) clearing $MWD_1(n)$, $MWD_2(n)$, $MWD_3(n)$, $MWD_4(n)$ to zero;

(2) sampling $S(t)$ and $S'(t)$ to have samples $S(0)$ and $S'(0)$ when $t=0 \cdot \Delta T$ ($\Delta T = \frac{T}{m}$), and storing $S(0)$ and $S'(0)$ in $MS(0)$ and $MS'(0)$ respectively;

(3) sampling $S(t)$ to have sample $S(j\Delta T)$ when $t=j \cdot \Delta T$ ($j=1,2,\dots,m$, $\Delta T = \frac{T}{m}$), and then proceeding:

$$\begin{aligned} \text{MWD}_1(1) &\leftarrow \langle \text{MWD}_1(1) \rangle + S'((j-1)\Delta T) \\ &\quad \times \langle \text{MQ}_{x1}(cs, j-1) \rangle + [js((j-1)\Delta T) - \\ &\quad (j-1)S(j\Delta T)] \times \langle \text{MQ}_1(cs, j-1) \rangle ; \end{aligned}$$

$$\begin{aligned} \text{MWD}_1(2) &\leftarrow \langle \text{MWD}_1(2) \rangle + S'((j-1)\Delta T) \\ &\quad \times \langle \text{MQ}_{x2}(cs, j-1) \rangle + [js((j-1)\Delta T) - \\ &\quad (j-1)S(j\Delta T)] \times \langle \text{MQ}_2(cs, j-1) \rangle ; \end{aligned}$$

$$\begin{aligned} &\quad \vdots \qquad \qquad \qquad \vdots \\ \text{MWD}_1(n) &\leftarrow \langle \text{MWD}_1(n) \rangle + S'((j-1)\Delta T) \\ &\quad \times \langle \text{MQ}_{xn}(cs, j-1) \rangle + [js((j-1)\Delta T) - \\ &\quad (j-1)S(j\Delta T)] \times \langle \text{MQ}_n(cs, j-1) \rangle ; \end{aligned}$$

$$\begin{aligned} \text{MWD}_2(1) &\leftarrow \langle \text{MWD}_2(1) \rangle + S'((j-1)\Delta T) \\ &\quad \times \langle \text{MQ}_{x1}(cc, j-1) \rangle + [js((j-1)\Delta T) - \\ &\quad (j-1)S(j\Delta T)] \times \langle \text{MQ}_1(cc, j-1) \rangle ; \end{aligned}$$

$$\begin{aligned} \text{MWD}_2(2) &\leftarrow \langle \text{MWD}_2(2) \rangle + S'((j-1)\Delta T) \\ &\quad \times \langle \text{MQ}_{x2}(cc, j-1) \rangle + [js((j-1)\Delta T) - \\ &\quad (j-1)S(j\Delta T)] \times \langle \text{MQ}_2(cc, j-1) \rangle ; \end{aligned}$$

$$\begin{aligned} \text{MWD}_2(n) &\leftarrow \langle \text{MWD}_2(n) \rangle + S'((j-1)\Delta T) \\ &\quad \times \langle \text{MQ}_{xn}(cc, j-1) \rangle + [js((j-1)\Delta T) - \\ &\quad (j-1)S(j\Delta T)] \times \langle \text{MQ}_n(cc, j-1) \rangle ; \end{aligned}$$

$$\begin{aligned} \text{MWD}_3(1) &\leftarrow \langle \text{MWD}_3(1) \rangle + S'((j-1)\Delta T) \\ &\quad \times \langle \text{MQ}_{x1}(ss, j-1) \rangle + [js((j-1)\Delta T) - \\ &\quad (j-1)S(j\Delta T)] \times \langle \text{MQ}_1(ss, j-1) \rangle ; \end{aligned}$$

$$\begin{aligned} \text{MWD}_3(2) &\leftarrow \langle \text{MWD}_3(2) \rangle + S'((j-1)\Delta T) \\ &\quad \times \langle \text{MQ}_{x2}(ss, j-1) \rangle + [js((j-1)\Delta T) - \\ &\quad (j-1)S(j\Delta T)] \times \langle \text{MQ}_2(ss, j-1) \rangle ; \end{aligned}$$

$$\begin{aligned}
MWD_3(n) &\leftarrow \langle MWD_3(n) \rangle + S'((j-1)\Delta T) \\
&\quad \times \langle MQ_{xn}(ss, j-1) \rangle + [js((j-1)\Delta T) - \\
&\quad (j-1)S(j\Delta T)] \times \langle MQ_n(ss, j-1) \rangle ; \\
MWD_4(1) &\leftarrow \langle MWD_4(1) \rangle + S'((j-1)\Delta T) \\
&\quad \times \langle MQ_{x1}(sc, j-1) \rangle + [js((j-1)\Delta T) - \\
&\quad (j-1)S(j\Delta T)] \times \langle MQ_1(sc, j-1) \rangle ; \\
MWD_4(2) &\leftarrow \langle MWD_4(2) \rangle + S'((j-1)\Delta T) \\
&\quad \times \langle MQ_{x2}(sc, j-1) \rangle + [js((j-1)\Delta T) - \\
&\quad (j-1)S(j\Delta T)] \times \langle MQ_2(sc, j-1) \rangle ; \\
MWD_4(n) &\leftarrow \langle MWD_4(n) \rangle + S'((j-1)\Delta T) \\
&\quad \times \langle MQ_{xn}(sc, j-1) \rangle + [js((j-1)\Delta T) - \\
&\quad (j-1)S(j\Delta T)] \times \langle MQ_n(sc, j-1) \rangle ;
\end{aligned}$$

in which,

$$S'((i-1)\Delta T) = \frac{S(j\Delta T) - S((j-1)\Delta T)}{\Delta T} ;$$

(4) storing samples $S(T)$ and $S'(T)$ in $MS(T)$ and $MS'(T)$ respectively when $t = m\Delta T = T$.

3. A method according to claim 1 or 2, which includes a process, as described in said second procedure, to express the stored acoustic signal $S(t)$ as the approximate expression of (52) or (54) in the specification.

4. A method according to claim 1 or 2, which includes a technical process as described in said third procedure.

5. A method according to claim 1 or 2, which includes a process as described in said fourth procedure.

6. A method according to claim 1 or 2, which includes a process as described in said fifth procedure.

7. A method according to claim 1 or 2 which is characterized by its process in defining an "auxiliary function" $P(x)$ as expressed in equation (3); expressing $P(x)$ by means of Fourier series $P_k(x)$ in which k is the number of times of the highest harmonic wave in Fourier series, and considering

$$\int_{-t}^0 L(x)S(x+t)\sin(H\pi x)dx + \int_0^{T-t} R(x)S(x+t)\sin(H\pi x)dx$$

$$\doteq \int_{-t}^{T-t} P_k(x)S(x+t)\sin(H\pi x)dx ;$$

or

$$\int_{-t}^0 L(x)S(x+t)\cos(H\pi x)dx + \int_0^{T-t} R(x)S(x+t)\cos(H\pi x)dx$$

$$\doteq \int_{-t}^{T-t} P_k(\alpha)S(x+t)\cos(H\pi x)dx ;$$

as well as selecting "left auxiliary function" $L(x)$ and "right auxiliary function" properly so as to obtain an approximate expression (52) or (54) for $S(t)$.

8. A method according to claim 7, which is to alternatively select "left auxiliary function" $L(x)$ and "right auxiliary function" $R(x)$ so as to obtain a respective approximate expression for $S(t)$.

9. A method according to claim 1 or 2,

which is characterized by its process in continuously sampling acoustic signal $S(t)$ within interval $[0, T]$ before its termination so as to complete the calculation of :

$$\int_0^T S(x) \cos(n \omega_0 x) \sin(H \pi x) dx ;$$

$$\int_0^T S(x) \cos(n \omega_0 x) \cos(H \pi x) dx ;$$

$$\int_0^T S(x) \sin(n \omega_0 x) \sin(H \pi x) dx ; \text{ and}$$

$$\int_0^T S(x) \sin(n \omega_0 x) \cos(H \pi x) dx ;$$

in which $n=1, 2, \dots, k$; k is the number of times of the highest harmonic wave obtained from the expansion of $P(x)$ through Fourier series; $\omega = \frac{2\pi}{T}$; H is a number of high absolute value.

10. A method according to claim 1, which includes a process to replace approximate expression (52) by:

$$\begin{aligned} S(t) \doteq & \frac{1}{R''(0) - L''(0)} \{ Z_{.1} S(0) + Z_{.2} S'(0) + Z_{.3} S''(0) \\ & + W_{.1} S(T) + W_{.2} S'(T) + W_{.3} S''(T) + (H\pi)^3 [\alpha_{.}(t) + \beta_{.}(t)] \} \\ & \dots\dots\dots (25) \end{aligned}$$

in which, H is a number of high absolute value; $Z_{.1}$, $Z_{.2}$, $Z_{.3}$, $W_{.1}$, $W_{.2}$, $W_{.3}$ are respectively as illustrated in equations (23)-1 - (23)-3 and (24)-1 - (24)-3; and $\alpha_{.}(t) + \beta_{.}(t)$ is as illustrated in approximate expression (16).

11. A method according to claim 2, which, includes a process to replace approximate expression (54) by:

$$S(t) \doteq \frac{1}{R'(0) - L'(0)} \{ Z_{c1} S(0) + Z_{c2} S'(0) + W_{c1} S(T) + W_{c1} S'(T) + (H\pi)^2 [\alpha_c(t) + \beta_c(t)] \} \dots \dots \dots (42)$$

in which, H is a number which has a high absolute value; Z_{c1} , Z_{c2} , and W_{c1} , W_{c2} are respectively as illustrated in equations (40)-1, (40)-2, (41)-1 and (41)-2; and $\alpha_c(t) + \beta_c(t)$ is as illustrated in approximate expression (32).

12. A method according to claim 9, which is characterized by its process in representing acoustic signal $S(t)$ by means of a value which is obtained from its calculation, said value being:

$$\int_0^T S(x) \cos(n\omega_0 x) \sin(H\pi x) dx ;$$

$$\int_0^T S(x) \cos(n\omega_0 x) \cos(H\pi x) dx ;$$

$$\int_0^T S(x) \sin(n\omega_0 x) \sin(H\pi x) dx ;$$

$$\int_0^T S(x) \sin(n\omega_0 x) \cos(H\pi x) dx ;$$

in which, H is a number of high absolute value; $n=1, 2, \dots, k$; k is the number of times of the highest harmonic wave obtained from the expansion of "auxiliary function" $P(x)$ through Fourier series;

$$\omega_0 = \frac{2\pi}{T} .$$

13. A method according to claim 1, which includes a process to restore an acoustic signal $S(t)$ defined within $[0, T]$ by utilizing the waveform data stored in $MWD_1(n)$, $MWD_2(n)$, $MWD_3(n)$ and $MWD_4(n)$ ($n=1, 2, \dots, k$; k is the number of times of the highest harmonic wave obtained from the expansion of "auxiliary function" $P(x)$), said process being performed according to the following procedures:

(1). to calculate the value of $U_{.1}$, $U_{.2}$, $U_{.3}$, $V_{.1}$, $V_{.2}$ and $V_{.3}$ of the approximate expression (52) and store respective result in permanent memories $MU_{.1}(t)$, $MU_{.2}(t)$, $MU_{.3}(t)$, $MV_{.1}(t)$, $MV_{.2}(t)$ and $MV_{.3}(t)$;

(2). to calculate the value of $\bar{C}\bar{S}C_n(t)$, $\bar{C}\bar{S}S_n(t)$, $\bar{S}\bar{C}C_n(t)$ and $\bar{S}\bar{C}S_n(t)$ ($t=0 \cdot \Delta T, 1 \cdot \Delta T, \dots (m-1) \Delta T$; $\Delta T = \frac{T}{m}$; m is a number of great positive integer) of the equation (15)-1 - (15)-4 in the specification and to store respective result in permanent memories $MC\bar{S}C_n(t)$, $M\bar{C}S\bar{S}_n(t)$, $MSCC_n(t)$ and $M\bar{S}\bar{C}C_n(t)$ respectively;

(3). to execute following jobs:

(1) to clear $MWD_1(n) \sim MWD_4(n)$ to zero; $n=1, 2, \dots, k$;

(2) to read out the data in $MS(0)$ directly when $t=0$ so as to obtain $S(0)$;

(3) to start following calculations when $t=j \Delta T$ ($j=1, 2, \dots, m-1, \Delta T = \frac{T}{m}$) at first to calculate.

$$\phi_{1n} = \langle MC\bar{S}C_n(j \Delta T) \rangle \times \langle MWD_1(n) \rangle ;$$

$$\phi_{2n} = \langle M\bar{C}S\bar{S}_n(j \Delta T) \rangle \times \langle MWD_2(n) \rangle ;$$

$$\phi_{3n} = \langle MSCC_n(j \Delta T) \rangle \times \langle MWD_3(n) \rangle ;$$

$$\phi_{4n} = \langle M\bar{S}\bar{C}C_n(j \Delta T) \rangle \times \langle MWD_4(n) \rangle ;$$

in which, $n=1,2,\dots,k$;

then, to calculate:

$$\phi = (H\pi) \sum_{n=1}^k (\phi_{1n} + \phi_{2n} + \phi_{3n} + \phi_{4n})$$

and then, to calculate:

$$\begin{aligned} \theta = & \langle MU_{.1}(j\Delta T) \rangle \times \langle MS(0) \rangle + \langle MU_{.2}(j\Delta T) \rangle \\ & \times \langle MS'(0) \rangle + \langle MU_{.3}(j\Delta T) \rangle \times \langle MS''(0) \rangle \\ & + \langle MV_{.1}(j\Delta T) \rangle \times \langle MS(T) \rangle + \langle MV_{.2}(j\Delta T) \rangle \\ & + \langle MS'(T) \rangle + \langle MV_{.3}(j\Delta T) \rangle \times \langle MS''(T) \rangle \end{aligned}$$

and final, to calculate $\psi + \theta$, hereby $\psi + \theta$ equals to $S(j\Delta T)$;

(4) to read out the data in $MS(T)$ directly when $t=m\Delta T=T$ so as to obtain $S(T)$.

14. A method according to claim 2, which includes a process to restore an acoustic signal $S(t)$ defined within $[0,T]$ by utilizing the waveform data stored in $MWD_1(n)$, $MWD_2(n)$, $MWD_3(n)$ and $MWD_4(n)$ ($n=1,2,\dots,k$; k is the number of times of the highest harmonic wave obtained from the expansion of "auxiliary function" $P(x)$), said process being performed according to the following procedures:

(1) to calculate the value of $U_{.1}$, $U_{.2}$, v_1 and $V_{.2}$ of the approximate expression (54) and store respective result in permanent memories $MU_{.1}(t)$, $MU_{.2}(t)$, $MV_{.1}(t)$ and $MV_{.2}(t)$;

(2) to calculate the value of $C\bar{S}C_n(t)$, $C\bar{S}S_n(t)$, $SCC_n(t)$ and $SCS_n(t)$ ($t=0\cdot\Delta T, 1\cdot\Delta T, \dots, (m-1)\Delta T$;

$\Delta T = \frac{T}{m}$; m is a number of great positive integer) of

the equations (33)-1 - (33)-4 in the specification

and to store respective result in permanent memories $MC\bar{S}C_n(t)$, $MC\bar{S}S_n(t)$, $MSCC_n(t)$ and $MSCS_n(t)$ respectively:

(3) to execute following jobs:

(i) to clear $MWD_1(n) \sim MWD_4(n)$ to zero; $n = 1, 2, \dots, k$;

(ii) to read out the data in $MS(0)$ directly when $t=0$ so as to obtain $S(0)$;

(iii) to start following calculations when $t = j \Delta T$ ($j=1, 2, \dots, m-1$; $\Delta T = \frac{T}{m}$):

at first to calculate:

$$\phi_{1n} = \langle MC\bar{S}C_n(t) \rangle \times \langle MWD_1(n) \rangle ;$$

$$\phi_{2n} = \langle MC\bar{S}S_n(t) \rangle \times \langle MWD_2(n) \rangle ;$$

$$\phi_{3n} = \langle MSCC_n(t) \rangle \times \langle MWD_3(n) \rangle ;$$

$$\phi_{4n} = \langle MSCS_n(t) \rangle \times \langle MWD_4(n) \rangle ;$$

it which, $n=1, 2, \dots, k$;

then, to calculate:

$$\psi = (H\pi)^2 \sum_{n=1}^k (\phi_{1n} + \phi_{2n} + \phi_{3n} + \phi_{4n})$$

and then, to calculate:

$$\begin{aligned} \theta = & \langle MU_{e1}(j\Delta T) \rangle \times \langle MS(0) \rangle + \langle MU_{e2}(j\Delta T) \rangle \\ & \times \langle MS'(0) \rangle + \langle MV_{e1}(j\Delta T) \rangle \times \langle MS(T) \rangle \\ & + \langle MV_{e2}(j\Delta T) \rangle \times \langle MS'(T) \rangle ; \end{aligned}$$

and final, to calculate: $\psi + \theta$, herein

$$\psi + \theta = S(j\Delta T);$$

(iv) to read out the data in $MS(T)$ directly when $t = m \Delta T = T$ so as to obtain $S(T)$.

15. A method according to claim 13 or 14, which includes a process as described in said procedure (1).

16. A method according to claim 13 or 14, which includes a process as described in said procedure (2).

17. A method according to claim 13 or 14, which includes a process as described in said procedure (3).

18. A method according to claim 13 or 14, which includes a process as described in the job (iii) of said procedure (3).

19. A method according to claim 1 through 18, which includes a process to let $m=|H|$ ($|H|$ is the absolute value of H) and to let $-j\Delta T$ ($j=0,1,\dots,m, \Delta T=\frac{T}{m}$) during restoration of acoustic signal $S(t)$, so as to have $\bar{C}SS_n(t)$, $\bar{S}\bar{C}S_n(t)$ in the equations (15)-2, (15)-4 or $C\bar{S}S_n(t)$, $SCS_n(t)$ in the equations (33)-2, (33)-4 of the specification be constantly 0.

20. A method according to claim 1 through 18, which includes a process to let $m=|H|$ ($|H|$ is the absolute value of H) and to let $t=\frac{1}{2} [j\Delta T+(j+1)\Delta T]$ ($j=0,1,2,\dots,m; \Delta T=\frac{T}{m}$) during restoration of acoustic signal $S(t)$, so as to have $C\bar{S}C_n(t)$, $SCC_n(t)$ in the equations (15)-1, (15)-3 or $C\bar{S}C_n(t)$, $SCC_n(t)$ in equations (33)-1, (33)-3 be constantly 0.

21. A method according to claim 19, which includes a process to let $m = \tau |H|$ (τ is a positive integer ≥ 2).

22. A method according to claim 20, which includes a process to let $m = \tau |H|$ (τ is a positive integer ≥ 2).

23. The equipment according to claim 1 or 2, which includes:

k.m sets of permanent memories $MQ_{xn}(CS, j)$
for the storage of $Q_{xn}(CS, j)$;

k.m sets of permanent memories $MQ_{xn}(CC, j)$
for the storage of $Q_{xn}(CC, j)$;

k.m sets of permanent memories $MQ_{xn}(SS, j)$
for the storage of $Q_{xn}(SS, j)$;

k.m sets of permanent memories $MQ_{xn}(SC, j)$
for the storage of $Q_{xn}(SC, j)$;

k.m sets of permanent memories $MQ_n(CS, j)$
for the storage of $Q_n(CS, j)$;

k.m sets of permanent memories $MQ_n(CC, j)$
for the storage of $Q_n(CC, j)$;

k.m sets of permanent memories $MQ_n(SS, j)$
for the storage of $Q_n(SS, j)$;

k.m sets of permanent memories $MQ_n(SC, j)$
for the storage of $Q_n(SC, j)$;

4k sets of RAM $MWD_1(n)$, $MWD_2(n)$, $MWD_3(n)$
and $MWD_4(n)$ respectively for the storage of waveform
data $WD_1(n)$, $WD_2(n)$, $WD_3(n)$ and $WD_4(n)$ of the
acoustic signal $S(t)$;

6 sets of RAM $MS(0)$, $MS'(0)$, $MS''(0)$, $MS(T)$,
 $MS'(T)$ and $MS''(T)$, or 4 sets of RAM $MS(0)$, $MS'(0)$,
 $MS(T)$ and $MS'(T)$ respectively for the storage of $S(0)$,
 $S'(0)$, $S''(0)$, $S(T)$, $S'(T)$ and $S''(T)$, or $S(0)$, S'
 (0) , $S(T)$ and $S'(T)$;

one set of circuit for performing the operation of :

$$\begin{aligned}
 MWD_1(n) &\leftarrow \langle MWD_1(n) \rangle + S'((j-1)\Delta T) \\
 &\quad \times \langle MQ_{xn}(CS, j-1) \rangle + [jS((j-1)\Delta T) \\
 &\quad - (j-1)S(j\Delta T)] \times \langle MQ_n(CS, j-1) \rangle \\
 MWD_2(n) &\leftarrow \langle MWD_2(n) \rangle + S'((j-1)\Delta T) \\
 &\quad \times \langle MQ_{xn}(CC, j-1) \rangle + [jS((j-1)\Delta T) \\
 &\quad - (j-1)S(j\Delta T)] \times \langle MQ_n(CC, j-1) \rangle \\
 MWD_3(n) &\leftarrow \langle MWD_3(n) \rangle + S'((j-1)\Delta T) \\
 &\quad \times \langle MQ_{xn}(SS, j-1) \rangle + [jS((j-1)\Delta T) \\
 &\quad - (j-1)S(j\Delta T)] \times \langle MQ_n(SS, j-1) \rangle \\
 MWD_4(n) &\leftarrow \langle MWD_4(n) \rangle + S'((j-1)\Delta T) \\
 &\quad \times \langle MQ_{xn}(SC, j-1) \rangle + [jS((j-1)\Delta T) \\
 &\quad - (j-1)S(j\Delta T)] \times \langle MQ_n(SC, j-1) \rangle
 \end{aligned}$$

in which, k is the number of times of the highest harmonic wave obtained from the "auxiliary function" $P(x)$ of the equation (3) after its expansion through Fourier series; $n=1, 2, \dots, k$; $j=0, 1, \dots, m-1$; $S(t)$ is an acoustic signal defined within $[0, T]$; $\Delta T = \frac{T}{m}$;

$$S'((j-1)\Delta T) = [S(j\Delta T) - S((j-1)\Delta T)] / \Delta T ;$$

one or more A/D converters; and

one "primary derivative circuit", or one "primary derivative circuit" and one "secondary derivative circuit".

24. An equipment for performing the method as claimed in claim 13 or 14, including:

$4k \times m$ sets of permanent memories $MCSC_n(j\Delta T)$,

$\bar{M}\bar{C}\bar{S}S_n(j\Delta T)$, $M\bar{S}C\bar{C}_n(j\Delta T)$ and $M\bar{S}\bar{C}\bar{S}_n(j\Delta T)$ for the storage of $C\bar{S}C_n(j\Delta T)$, $\bar{C}S\bar{S}_n(j\Delta T)$, $S\bar{C}C_n(j\Delta T)$ and $\bar{S}\bar{C}S_n(j\Delta T)$; or permanent memories $M\bar{C}\bar{S}C_n(j\Delta T)$, $M\bar{C}\bar{S}S_n(j\Delta T)$, $M\bar{S}C\bar{C}_n(j\Delta T)$ and $M\bar{S}\bar{C}\bar{S}_n(j\Delta T)$ for the storage of $C\bar{S}C_n(j\Delta T)$, $\bar{C}S\bar{S}_n(j\Delta T)$, $S\bar{C}C_n(j\Delta T)$ and $S\bar{C}S_n(j\Delta T)$;

6m sets of permanent memories $MU_{.1}(j\Delta T)$, $MU_{.2}(j\Delta T)$, $MU_{.3}(j\Delta T)$, $MV_{.1}(j\Delta T)$, $MV_{.2}(j\Delta T)$ and $MV_{.3}(j\Delta T)$ for the storage of $U_{.1}$, $U_{.2}$, $U_{.3}$, $V_{.1}$, $V_{.2}$ and $V_{.3}$ when t in expression (52) $= j\Delta T$; or 4 sets of 4m sets of permanent memories $MU_{.1}(j\Delta T)$, $MU_{.2}(j\Delta T)$, $MV_{.1}(j\Delta T)$, $MV_{.2}(j\Delta T)$ for the storage of $U_{.1}$, $U_{.2}$, $V_{.1}$ and $V_{.2}$ when t in expression (54) $= j\Delta T$;

one set of computing circuit for calculating ϕ_{1n} , ϕ_{2n} , ϕ_{3n} and ϕ_{4n} in which

$$\begin{aligned}\phi_{1n} &= \langle \bar{M}\bar{C}\bar{S}S_n(j\Delta T) \rangle \times \langle MWD_1(n) \rangle, \phi_{2n} = \langle \bar{M}\bar{C}\bar{S}S_n(j\Delta T) \rangle \\ &\times \langle MWD_2(n) \rangle \text{ or } \langle \bar{M}\bar{C}\bar{S}S_n(j\Delta T) \rangle \times \langle MWD_2(n) \rangle, \phi_{3n} = \\ &\langle M\bar{S}C\bar{C}_n(j\Delta T) \rangle \times \langle MWD_3(n) \rangle, \phi_{4n} = \langle M\bar{S}C\bar{C}_n(j\Delta T) \rangle \times \\ &\langle MWD_4(n) \rangle \text{ or } \langle M\bar{S}\bar{C}\bar{S}_n(j\Delta T) \rangle \times \langle MWD_4(n) \rangle ;\end{aligned}$$

one set of computing circuit for calculating ψ value, in which

$$\begin{aligned}\psi &= (H\pi)^3 \sum_{n=1}^k (\phi_{1n} + \phi_{2n} + \phi_{3n} + \phi_{4n}) \text{ or} \\ &(H\pi)^2 \sum_{n=1}^k (\phi_{1n} + \phi_{2n} + \phi_{3n} + \phi_{4n});\end{aligned}$$

one set of computing circuit for calculating θ value, in which

$$\begin{aligned}
\theta = & \langle MU_{.1}(j\Delta T) \rangle \times \langle MS(0) \rangle + \langle MU_{.2}(j\Delta T) \rangle \times \langle MS'(0) \rangle \\
& + \langle MU_{.3}(j\Delta T) \rangle \times \langle MS''(T) \rangle \text{ or } \langle MU_{.1}(j\Delta T) \rangle \times \langle MS(0) \rangle \\
& + \langle MU_{.2}(j\Delta T) \rangle \times \langle MS'(0) \rangle + \langle MV_{.1}(j\Delta T) \rangle \times \langle MS(T) \rangle \\
& + \langle MV_{.2}(j\Delta T) \rangle \times \langle MS'(T) \rangle ;
\end{aligned}$$

one set of computing circuit for calculating $\psi + \theta$;

one D/A converter for converting the digital signal of $\psi + \theta$ into an analog signal;

a power amplifier to amplify the output of said D/A converter; and

a speaker;

wherein said k , n , j , ΔT are same as that claimed in claim 23, and said H is a number of high absolute value.

25. An equipment which is to incorporate the equipment as claimed in claim 23 with the equipment as claimed in claim 24.

26. A controlling device including a microprocessor for controlling the equipment as claimed in claim 25 to select the operation of the equipment as claimed in claim 23 or the operation of the equipment as claimed in claim 24.

27. The controlling device as claimed in claim 26, wherein said microprocessor is capable of performing the free setting of the initial address of $MWD_1(n) \sim MWD_4(n)$ of the equipment as claimed in claim 23 or 24.

28. The controlling device as claimed in claim 26, wherein said microprocessor includes a display for the indication of the duration of time and the data of the initial address preset in $MWD_1(n) \sim MWD_4(n)$ during the operation of the equipment as claimed in claim 23 or 24.

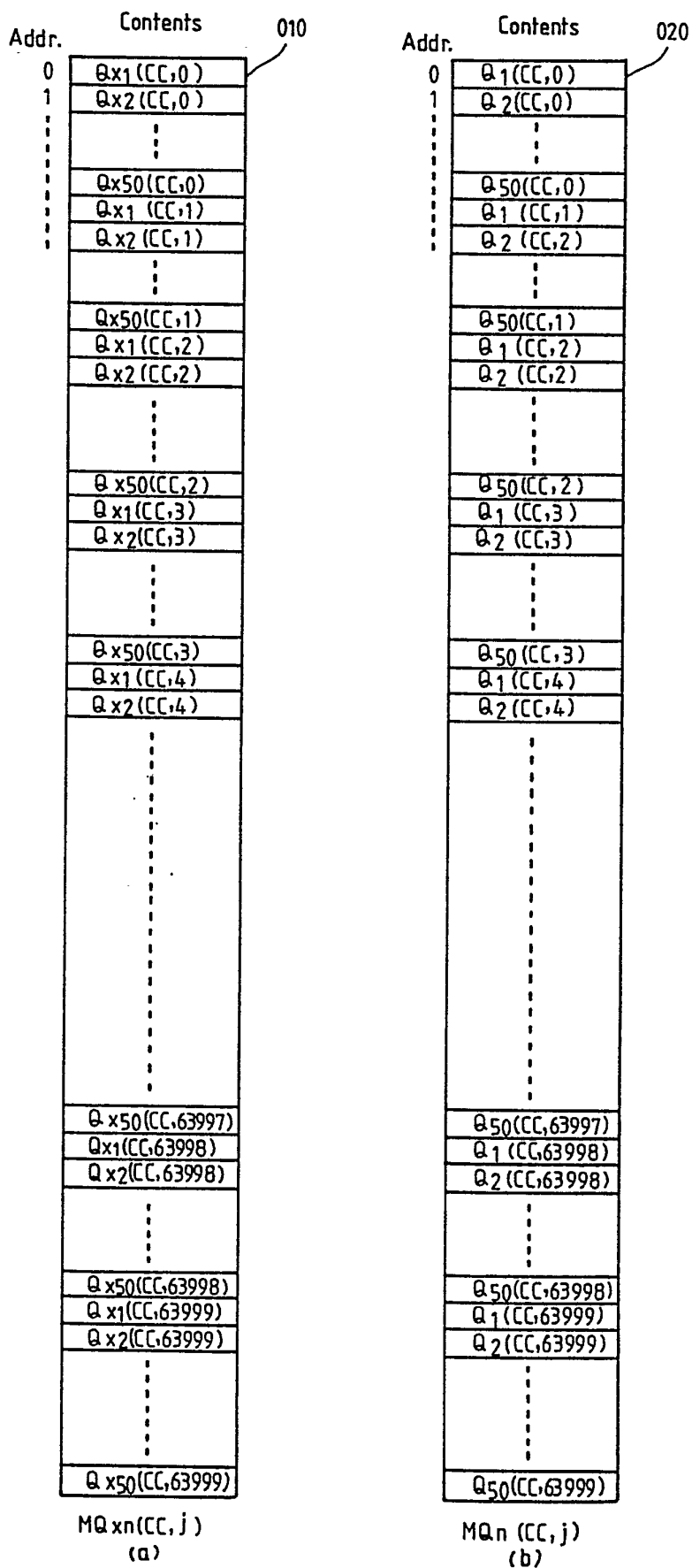


Fig. 1

Addr.	Contents	011
0	$Q_{x1}(SC,0)$	└─┘
1	$Q_{x2}(SC,0)$	
⋮	⋮	
⋮	$Q_{x50}(SC,0)$	
⋮	$Q_{x1}(SC,1)$	
⋮	$Q_{x2}(SC,1)$	
⋮	⋮	
⋮	$Q_{x50}(SC,1)$	
⋮	$Q_{x1}(SC,2)$	
⋮	$Q_{x2}(SC,2)$	
⋮	⋮	
⋮	$Q_{x50}(SC,2)$	
⋮	$Q_{x1}(SC,3)$	
⋮	$Q_{x2}(SC,3)$	
⋮	⋮	
⋮	$Q_{x50}(SC,3)$	
⋮	$Q_{x1}(SC,4)$	
⋮	$Q_{x2}(SC,4)$	
⋮	⋮	
⋮	$Q_{x50}(SC,63997)$	
⋮	$Q_{x1}(SC,63998)$	
⋮	$Q_{x2}(SC,63998)$	
⋮	⋮	
⋮	$Q_{x50}(SC,63998)$	
⋮	$Q_{x1}(SC,63999)$	
⋮	$Q_{x2}(SC,63999)$	
⋮	⋮	
⋮	$Q_{x50}(SC,63999)$	

$MQ_{xn}(SC,j)$
(a)

Addr.	Contents	021
0	$Q_1(SC,0)$	└─┘
1	$Q_2(SC,0)$	
⋮	⋮	
⋮	$Q_{50}(SC,0)$	
⋮	$Q_1(SC,1)$	
⋮	$Q_2(SC,2)$	
⋮	⋮	
⋮	$Q_{50}(SC,1)$	
⋮	$Q_1(SC,2)$	
⋮	$Q_2(SC,2)$	
⋮	⋮	
⋮	$Q_{50}(SC,2)$	
⋮	$Q_1(SC,3)$	
⋮	$Q_2(SC,3)$	
⋮	⋮	
⋮	$Q_{50}(SC,3)$	
⋮	$Q_1(SC,4)$	
⋮	$Q_2(SC,4)$	
⋮	⋮	
⋮	$Q_{50}(SC,63997)$	
⋮	$Q_1(SC,63998)$	
⋮	$Q_2(SC,63998)$	
⋮	⋮	
⋮	$Q_{50}(SC,63998)$	
⋮	$Q_1(SC,63999)$	
⋮	$Q_2(SC,63999)$	
⋮	⋮	
⋮	$Q_{50}(SC,63999)$	

$MQ_n(SC,j)$
(b)

Fig. 2

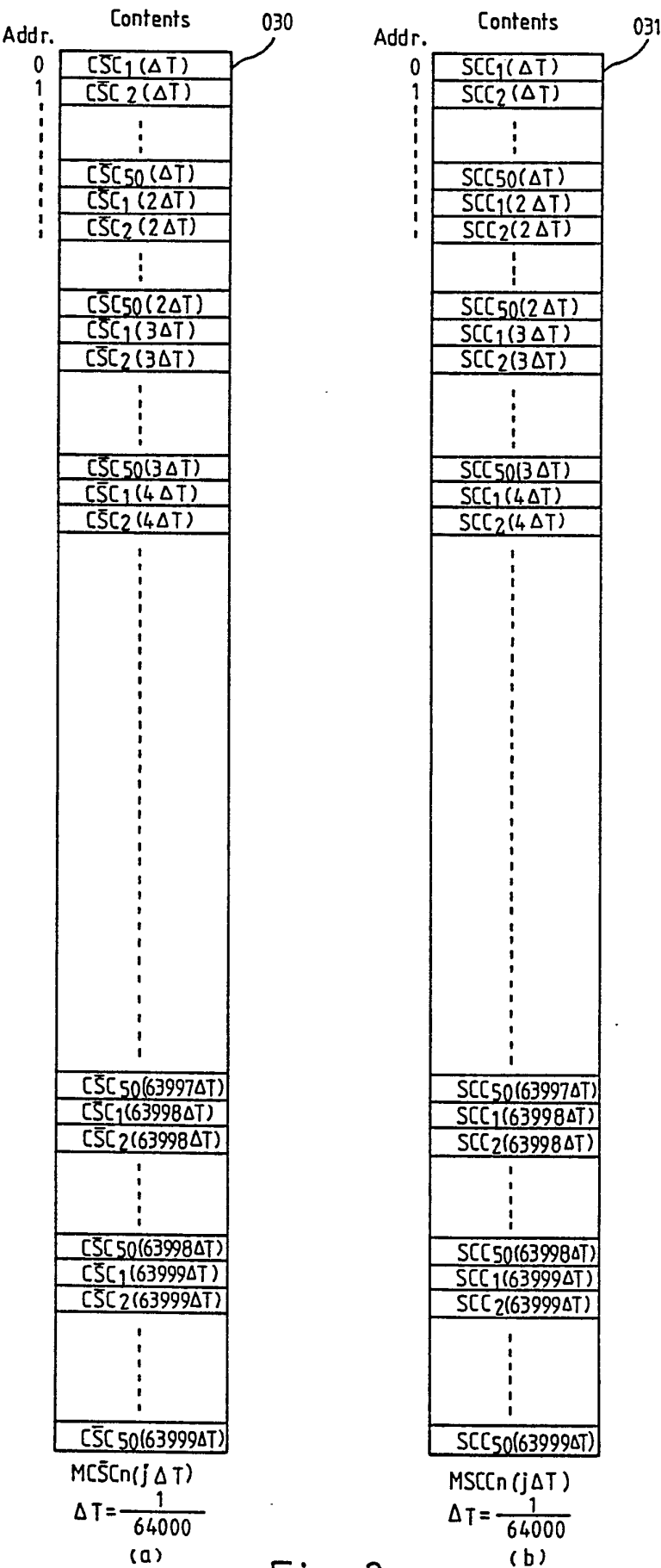


Fig.3

$$\Delta T = \frac{1}{64000}$$

Fig. 4

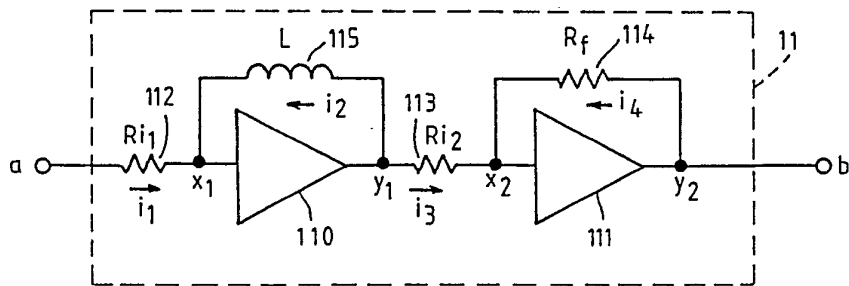


Fig. 5

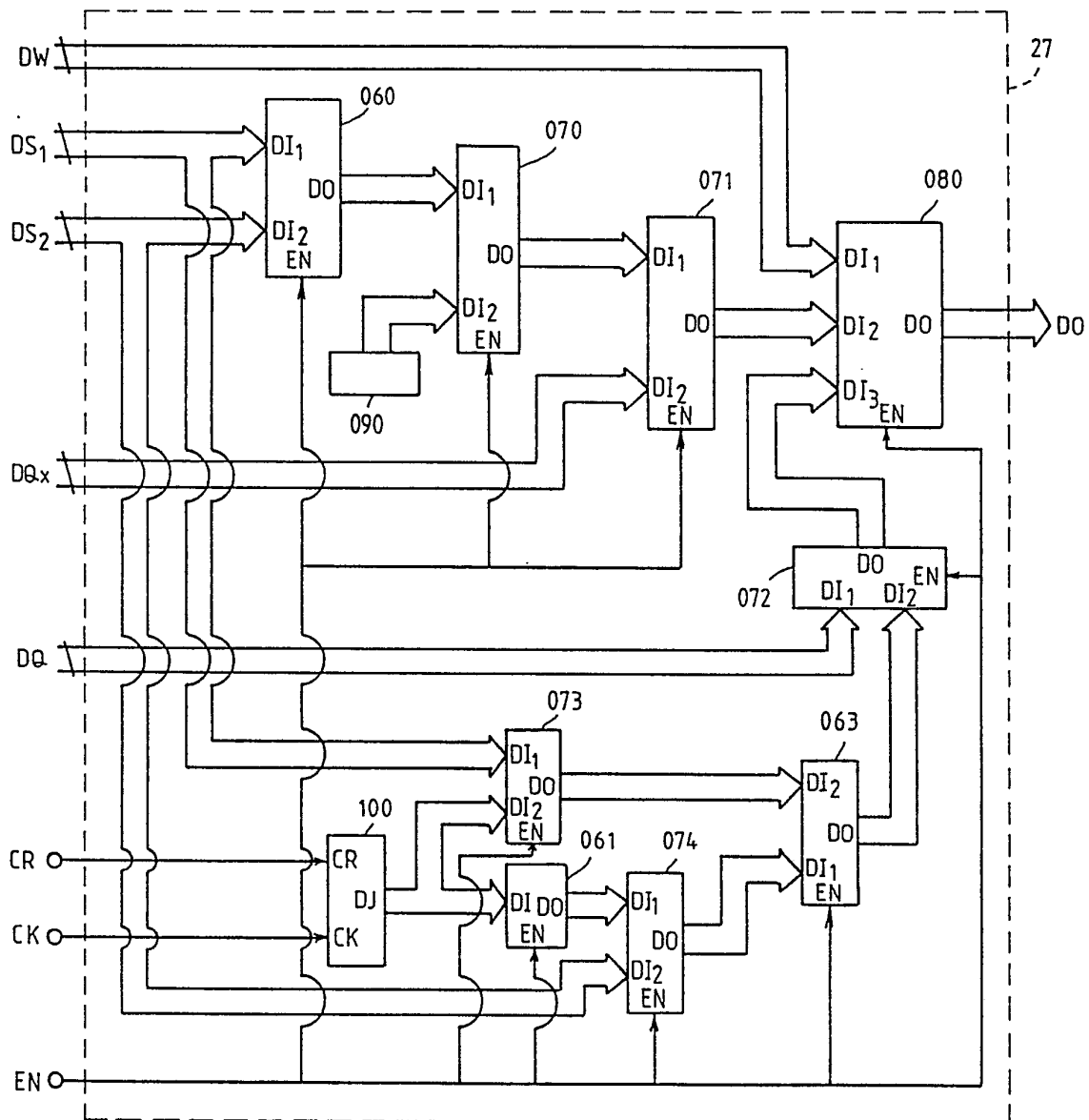


Fig. 6

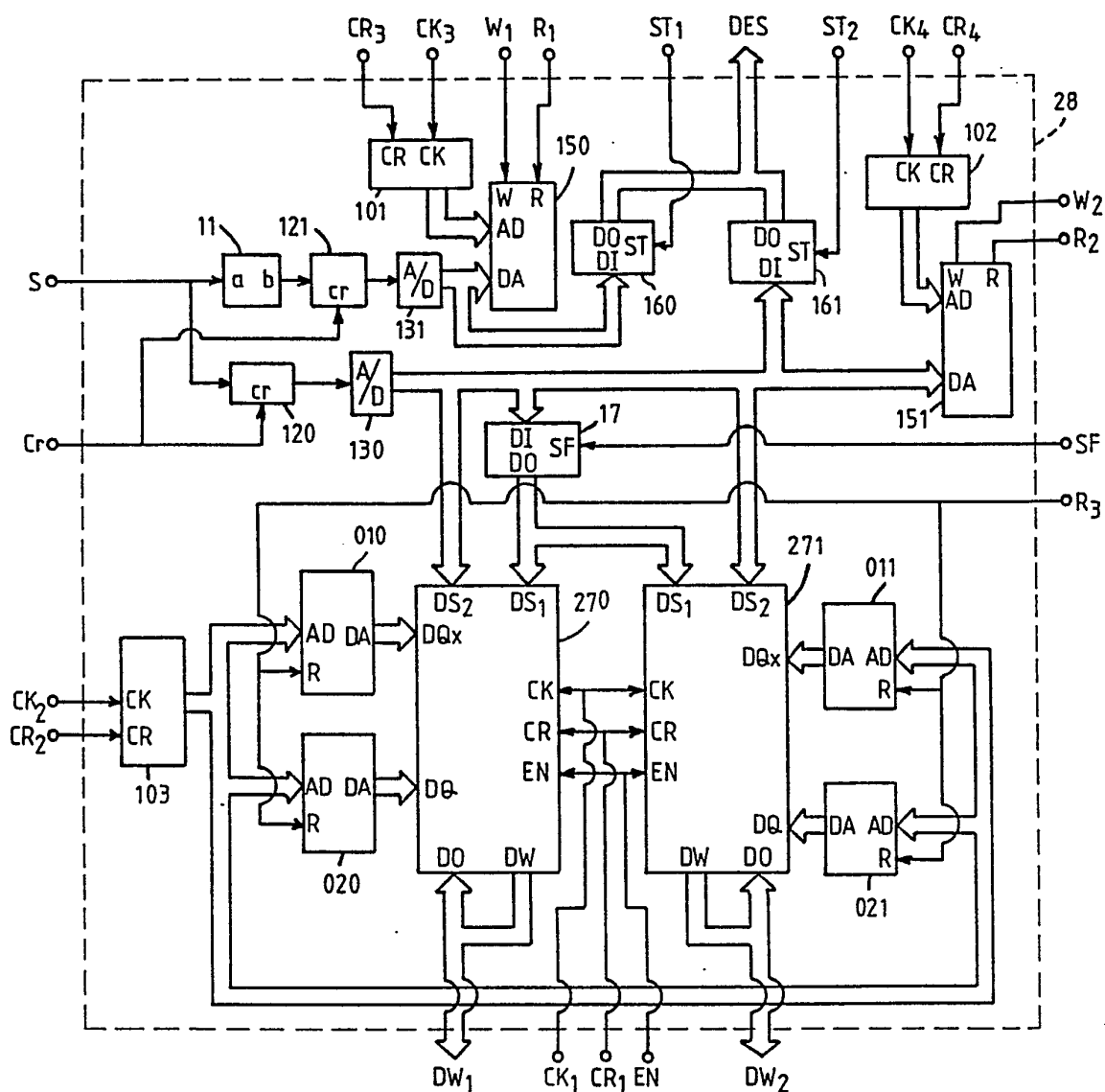


Fig. 7

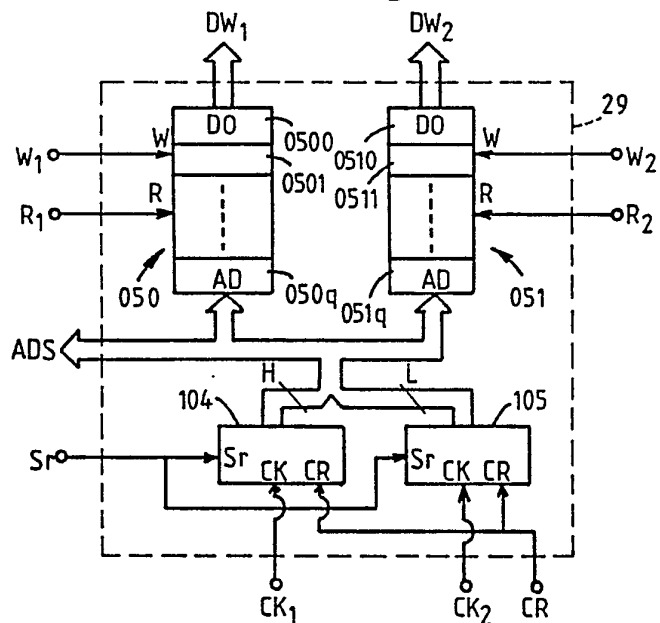


Fig. 8

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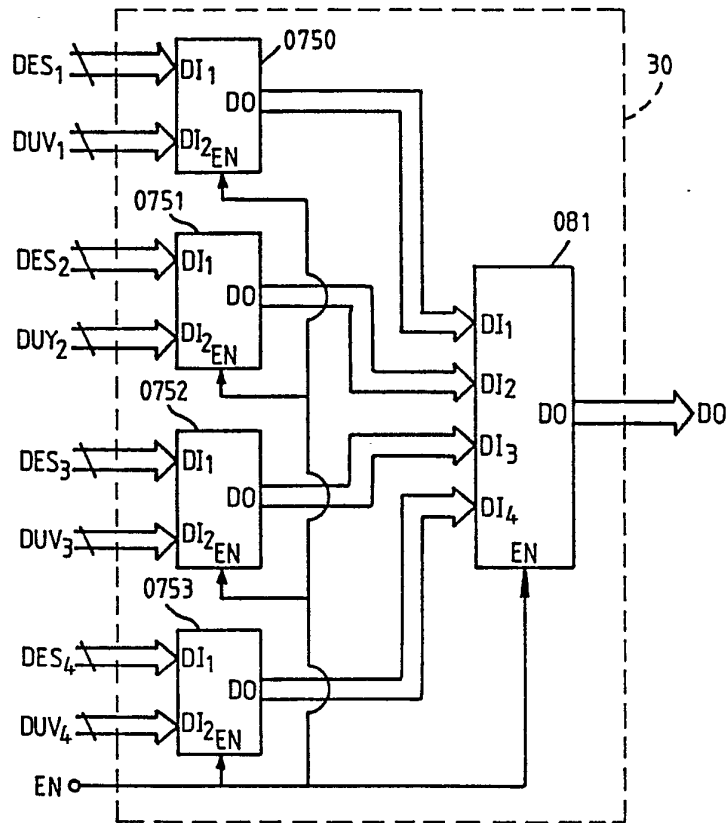


Fig. 9

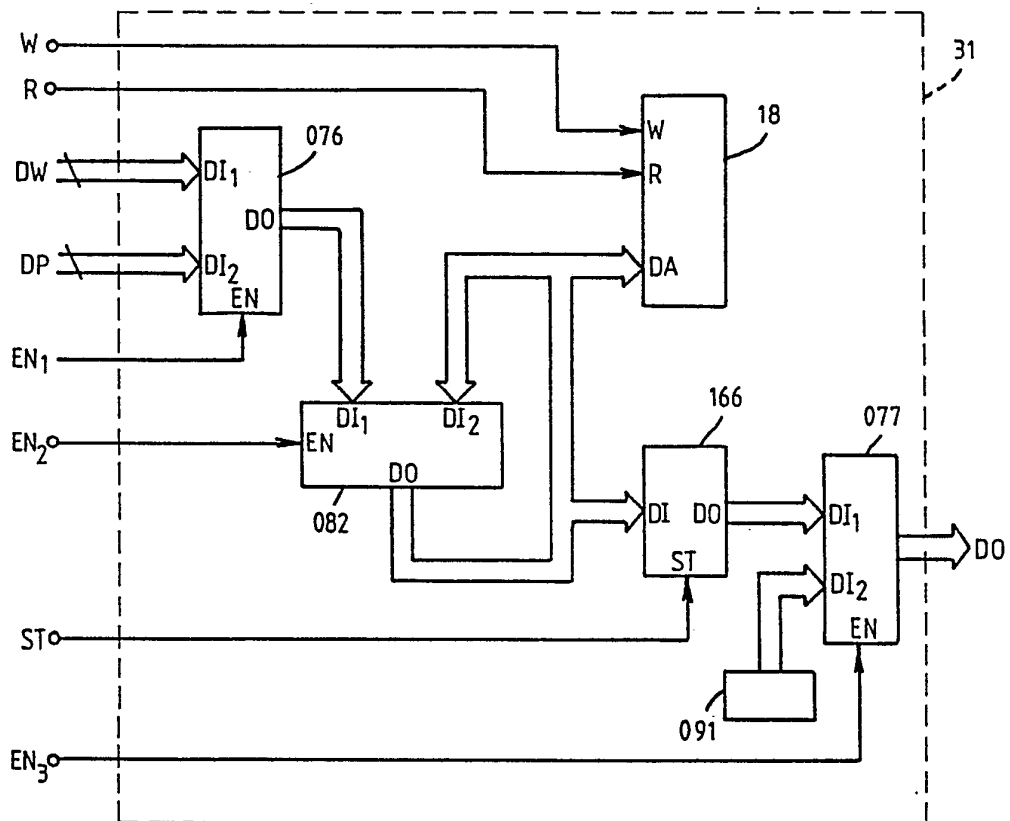


Fig. 10

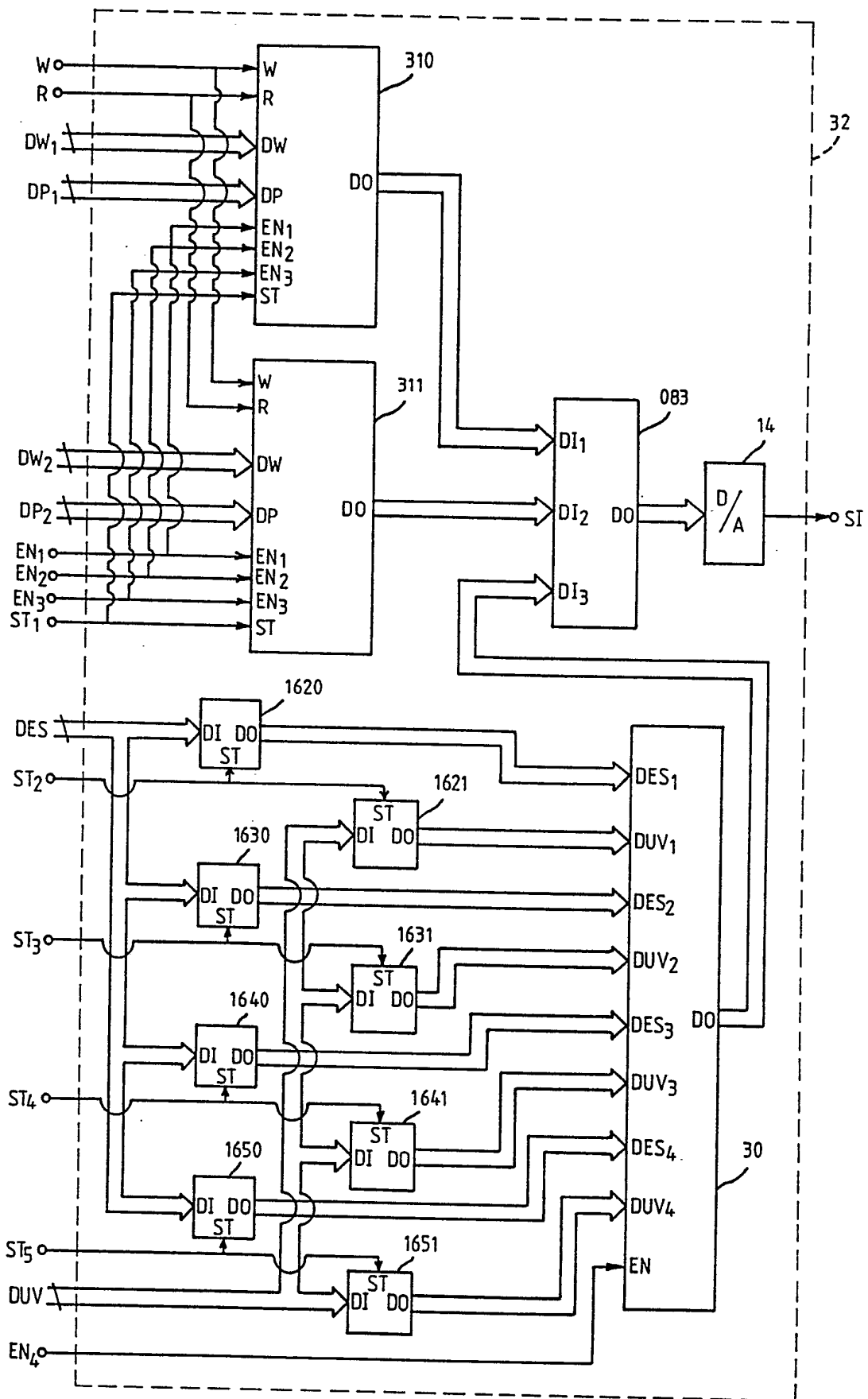


Fig. 11

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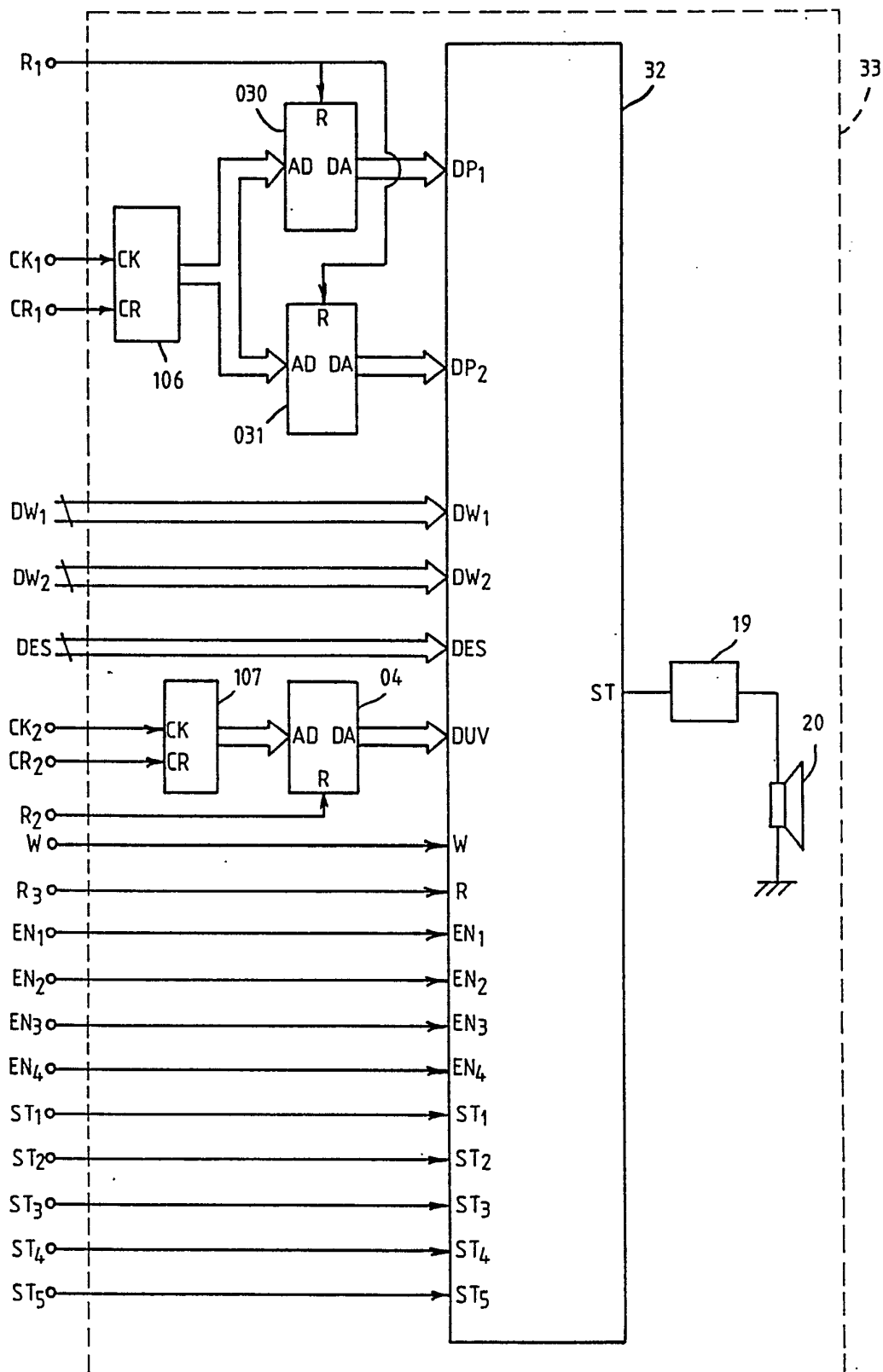


Fig. 12

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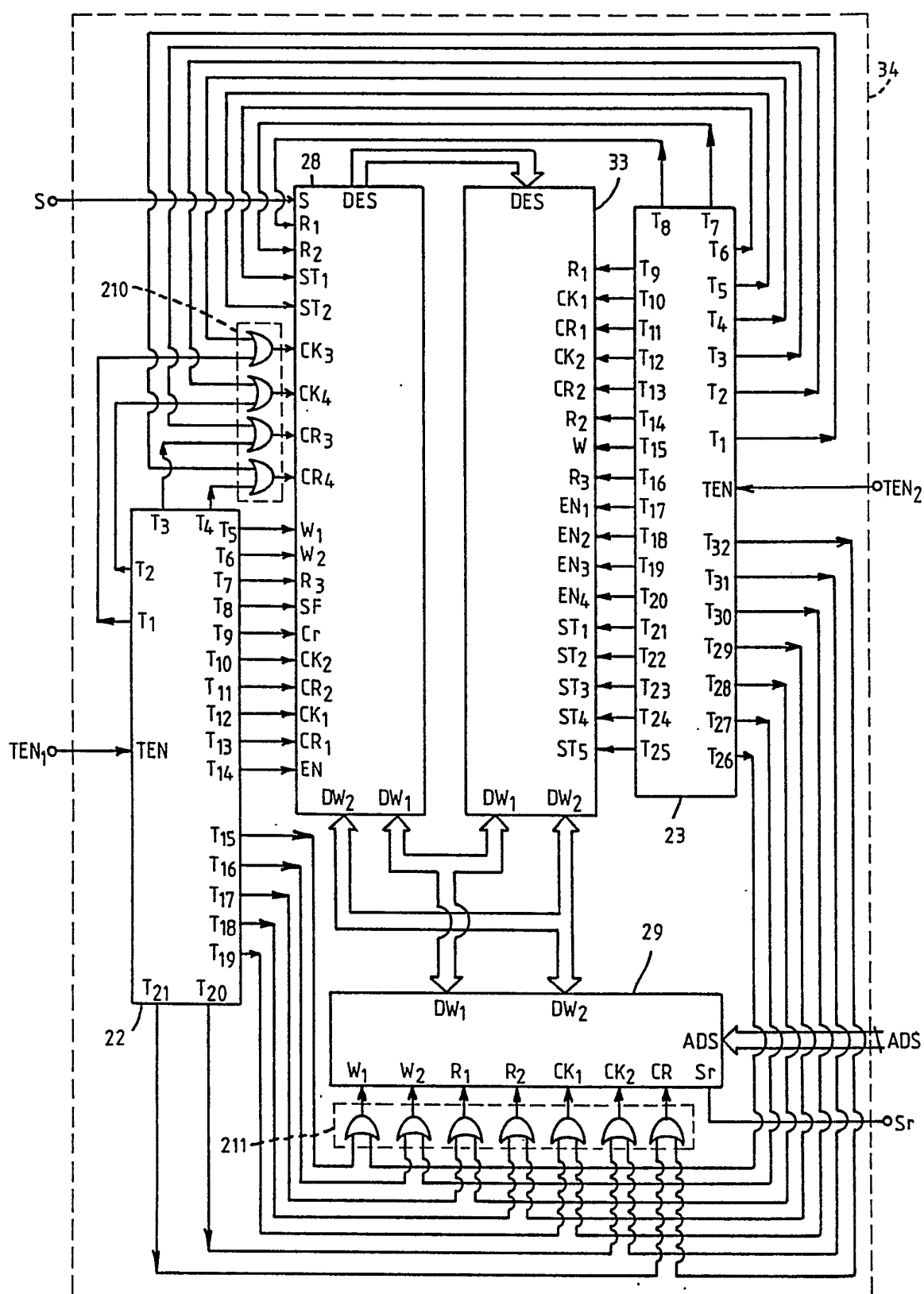


Fig. 13

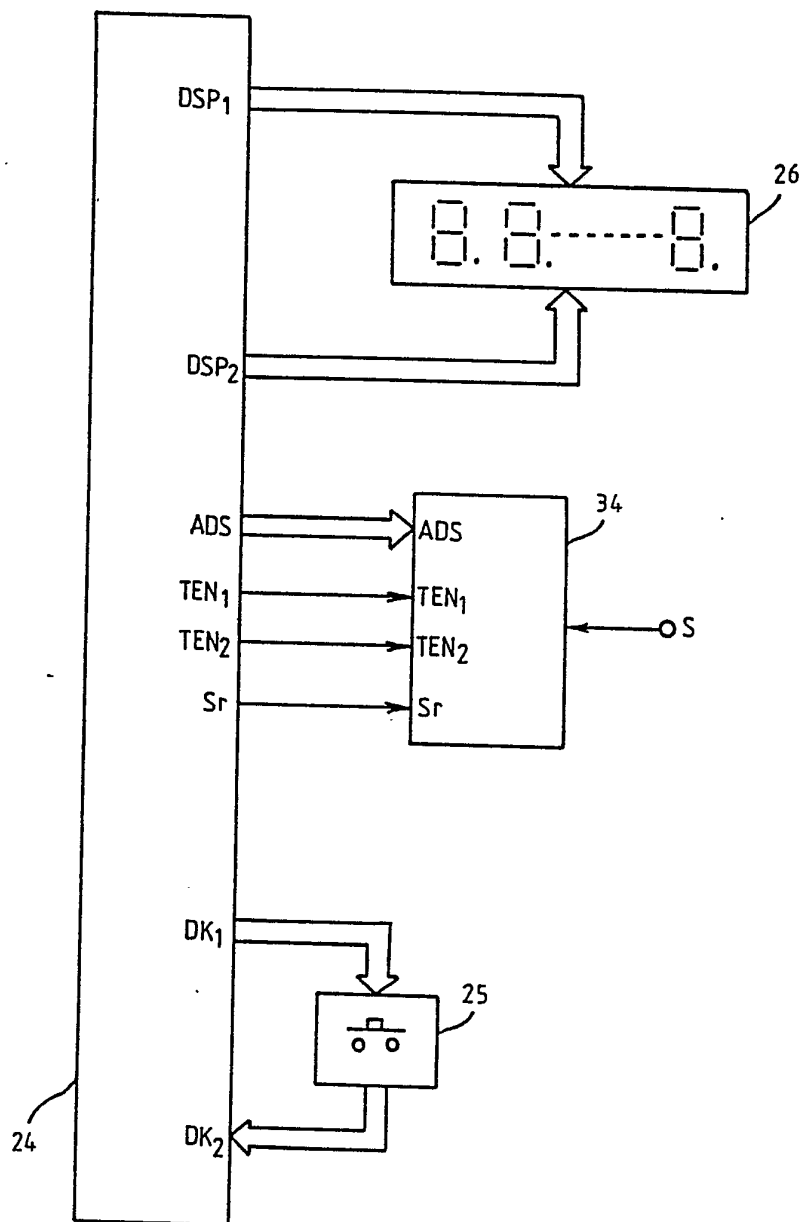
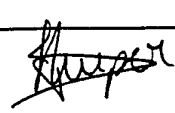


Fig.14

INTERNATIONAL SEARCH REPORT

International Application No PCT/JP 90/00323

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ⁶		
According to International Patent Classification (IPC) or to both National Classification and IPC		
IPC ⁵ : G 01 L 7/06, H 03 M 7/00		
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁷		
Classification System	Classification Symbols	
IPC ⁵ G 10 L 7/06		
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁸		
III. DOCUMENTS CONSIDERED TO BE RELEVANT ⁹		
Category ⁹	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
A	WO, A, 88/01811 (BRANDENBURG) 10 March 1988 see page 2, line 6; page 6, line 13 ---	1-27
A	WO, A, 89/03574 (FRAUNHOFER GmbH) 20 April 1989 see page 3, line 9; page 7, line 15 ---	1-27
A	WO, A, 87/01851 (COMPUSONICS) 26 March 1987 see page 6, line 10; page 7, line 2 ---	1-27
[*] Special categories of cited documents: ¹⁰ "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. "&" document member of the same patent family		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
14th September 1990	11. 10. 90	
International Searching Authority	Signature of Authorized Officer	
EUROPEAN PATENT OFFICE	Mme N. KUIPER 	

**ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO.**

JP 900323

SA 35094

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on 05/10/90
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO-A- 8801811	10-03-88	DE-A- 3629434	03-03-88
		EP-A- 0287578	26-10-88
		JP-T- 1500695	09-03-89
WO-A- 8903574	20-04-89	DE-A- 3733772	27-04-89
		DE-A, C 3733786	27-04-89
		EP-A- 0340301	08-11-89
WO-A- 8701851	26-03-87	US-A- 4682248	21-07-87
		AU-A- 6400786	07-04-87
		EP-A- 0237561	23-09-87
		JP-T- 63501532	09-06-88
		US-A- 4755889	05-07-88