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Electronic Musical Instrument

Background of the Invention

Field of the Invention

The present invention relates to electronic musical instruments, and more particularly, to electronic musical instruments capable of generating varied musical tones like those of acoustic (non-electronic) musical instruments .

Prior Art

Due to recent technological improvements, tone generators employed in electronic musical instruments have come to be capable of synthesizing a wide variety of musical tones. For example, physical-modal tone-generators which synthesize sounds of acoustic musical instruments are conventionally known. Each of the physical-modal tone-generators simulates the sound production mechanism of a target acoustic musical instrument. Examples of the physical-modal tone-generators have been disclosed in Japanese Patent Application Laid-Open Publication No. 63-40199 and US Patent No. 4,984,276.

An example of conventional physical-modal tone-generators simulating the sound production mechanism of stringed instruments is shown in the block diagram of Fig. 19. In this figure, an excitation signal generating circuit 1 includes a waveform memory which stores excitation signal waveforms made up of a large number of frequency components, such as an impulse waveform. The excitation signal from the excitation signal generating circuit 1 is supplied to a first input terminal of an adder 2. The output signal from the adder 2 is supplied to a delay circuit 3 which



simulates the delay of propagation of vibrating waves in a string of the target stringed instrument.

The delayed output signal from the delay circuit 3 is then supplied to a filter 4 which simulates acoustical losses of a vibrating string of the target stringed instrument. The output signal from the filter 4 is then supplied to a second input terminal of the adder 2. Elements 2 through 4 described above together form a closed loop. In addition to the delay circuit 3, the output signal from the adder 2 is supplied to a sound signal output terminal 5, whereby a signal circulating in the closed loop is output as a musical tone signal to be generated. With the conventional tone generator described above, when the excitation signal output from the excitation signal generating circuit 1 is supplied to the first input terminal of the adder 2, the supplied excitation signal begins to circulate in the closed loop. In this case, the signal circulates around the closed loop once in the time which is equal to the period of oscillation of the vibrating string being simulated, and the band width of the signal is limited by the filter 4 each time the signal passes through the filter 4. Then, the signal circulating in the closed loop is delivered as a musical tone signal from the musical tone output terminal 5. An example of the above-described type of tone generator has been disclosed in Japanese Patent Publication No. 58-48109.

In the above conventional electronic musical instrument comprising the above conventional tone generator, the variation of tone colors of the musical tones to be synthesized is limited and is a drawback in obtaining musical tone with a certain feeling of pitch and high quality, and in many cases where the



pitch and the spectral construction of the excitation signal supplied to the closed loop must correspond to a pitch designated by a performer.

By increasing the loop gain of the closed loop (the filter with the comb-formed frequency characteristics), the comb-formed frequency characteristics of the entire closed loop for the signal circulating become sharper, so that the feeling of the pitch is improved. However, in this case, the stability of the operation of the closed loop decreases, and in the worst case, there is drawback in that the closed loop self-oscillates. Accordingly, there is a drawback in that the reliability of the system is degraded.

Summary of the Invention

In consideration of the above, it is an objective of the present invention to provide an electronic musical instrument which is capable of generating the musical tone with a great variety of spectral constructions under no influence of the kind of the waveform of the excitation signal and with a rich variation of tone color of the musical tone, and which is capable of stable closed loop operation, and which is capable of constructing a system with high reliability.

To satisfy these objectives, the present invention provides an electronic musical instrument comprising an excitation signal generating means for generating an excitation signal in accordance with a musical tone designating information and a plurality of loop means for at least delaying an input signal in response to the musical tone designating information and



repeatedly circulating the signal, so that the excitation signal is supplied to at least one of the plurality of loop means; and coupling means for coupling the plurality of loop means in accordance with a predetermined coupling form, wherein a signal circulated in at least one of the plurality of loop means is output as a musical tone signal.

According to such a structure, the plurality of loop means, which is coupled to each other in accordance with the predetermined coupling form, at least delays the supplied excitation signal in response to the musical tone designating information to and repeatedly circulates the signal. The signal gradually changes into a signal having a desirable waveform in response to the coupling form while circulating in the plurality of loop means. Accordingly, the signal circulated in one of any plurality of loop means is delivered as a musical tone signal.

According to the present invention, a positive effect is that the musical tone can be generated with a great variety of spectral constructions under no influence of the kind of the waveform of the excitation signal and with the rich variation of tone color of the musical tone. Furthermore, there is the positive effect that a system with high reliability can be constructed so that the closed loop operates stably.

Brief Explanation of the Drawings

Fig. 1 shows a block diagram of the electrical structure of an electronic musical instrument based on the preferred embodiment of the present invention.

Fig. 2 shows a block diagram of the electrical structure of



a resonance portion 19.

Fig. 3 shows a block diagram of the electrical structure of a signal synthesis portion 21.

Fig. 4 shows a block diagram of the electrical structure of a LOOP 42.

Fig. 5 shows a block diagram of the electrical structure of a signal synthesis portion 49.

Figs. 6 through 9 show block diagrams of examples of the algorithms constructed by the LOOPS 42_1 through 42_4 .

Fig. 10 shows an example of the frequency characteristics corresponding to the block diagram of Fig. 9.

Fig. 11 shows a block diagram of other example of the algorithm constructed by the LOOPS 42_1 through 42_4 .

Fig. 12 shows an example of the frequency characteristics corresponding to each of the LOOPS 42_1 and 42_2 of Fig. 11.

Fig. 13 shows an example of the frequency characteristics corresponding to the block diagram of Fig. 11.

Fig. 14 shows a block diagram of other example of the algorithm constructed by the LOOPS 42_1 through 42_4 .

Fig. 15 shows an example of the frequency characteristics corresponding to the block diagram of Fig. 14.

Fig. 16 shows a block diagram of other example of the algorithm constructed by the LOOPS 42_1 through 42_4 .



Fig. 17 shows an example of the frequency characteristics corresponding to the block diagram of Fig. 16.

Fig. 18 shows a block diagram of another electrical structure of the resonance portion 19.

Fig. 19 shows a block diagram of a structural example of the conventional physical-modal tone-generator simulating a stringed instrument.

Detailed Description of the Preferred Embodiments

Hereinafter, an explanation of the preferred embodiment of the present invention is given with reference to the figures. Fig. 1 shows a block diagram of the structure of an electronic musical instrument in accordance with the preferred embodiment of the present invention. In this figure, manually operable performance members 6 such as a keyboard, manually operable members 7 for setting musical tone parameter designating a musical tone parameter such as a tone color, and a control portion 8 controlling all apparatuses, are provided.

Moreover, an excitation signal generating portion 9 is provided which comprises a waveform generating portion 10 which generates a signal including a rich overtone with the required waveform based on data WAVE for designating the waveform of the generated signal, a key-on signal KON for designating the generating timing of the generated signal and a pitch data PITCH for designating the pitch of the generated signal from the control portion 8. The excitation signal generating portion 9 further comprises a noise signal generating portion 11 which generates a noise signal such as a white noise signal; each of



the filters 12 and 13 append the desired characteristics to the output signal from the waveform generating portion 10 and the noise signal generating portion 11 based on coefficient data FLT_1 and FLT_2 from the control portion 8, respectively. The output signal from the filter 12 is supplied to a multiplier 14 which multiplies it by an amplitude control signal AMP_1 from the control portion 8. The output signal from the filter 13 is supplied to a multiplier 15 which multiplies it by an amplitude control signal AMP_2 from the control portion 8. Each of the output signals from the multipliers 14 and 15 are supplied to first and second terminals of an adder 16 which adds the former and the latter and delivers an excitation signal.

Furthermore, the output signal from the adder 16 of the excitation signal generating portion 9, namely the excitation signal, is supplied to a filter 17 which appends the desired characteristics to it based on the coefficient data FLT_3 from the control portion 8. The output signal from the filter 17 is supplied to a multiplier 18 which multiplies it by an amplitude control signal AMP_3 from the control portion 8. The output signal from the multiplier 18 is supplied to a resonance portion 19 which simulates the resonance phenomenon of the non-electronic musical instrument. The resonance portion 19 appends the desired characteristics to the output signal from the multiplier 18 based on data ALG for designating the combinations (the connection forms, namely algorithms) of a plurality of resonance elements (loop circuits described below) forming the resonance portion 19, data MIX for designating the synthesis coefficient for synthesizing the output signals from each of the loop circuits, data DLY_n ($n=1$ through 4, etc.) corresponding to the delay period



of each of the loop circuits, the coefficient LPF_n of low pass filters (LPF) forming each of the loop circuits, the coefficient APF_n of all pass filters (APF) forming each of the loop circuits, the coefficient HPF_n of high pass filters (HPF) forming each of the loop circuits and loop gain LG_n of each of the loop circuits, from the control portion 8. Thus, the resonance portion 19 delivers output signals as the musical tone signals of each of the channels L and R.

The coefficient data FLT_1 through FLT_3 and the amplitude control signals AMP_1 through AMP_3 may be constant or variable over time. Next, Fig. 2 shows a block diagram of the electrical structure of the resonance portion 19. In this figure, a resonance elements control portion 20 is provided which determines multiplicative coefficients m_{11} through m_{14} , m_{21} through m_{24} , m_{31} through m_{34} , and m_{41} through m_{44} of each of multipliers 22 through 37 (see Fig. 3) in a signal synthesis portion 21 based on the data ALG from the control portion 8 and delivers these to the multipliers 22 through 37. In Fig. 3, the multipliers 22, 26, 30, and 34 multiply input signals; that is, the output signal from the multiplier 18 shown in Fig. 1, by multiplicative coefficients m_{11} , m_{21} , m_{31} , and m_{41} , respectively. The multipliers 23 through 25 multiply output signals LO_2 through LO_4 from loop circuits 42₂ through 42₄ described below by multiplicative coefficients m_{12} through m_{14} , respectively. An adder 38 adds the output signals from each of the multipliers 22 through 25 and delivers an output signal LI_1 . The multipliers 27 through 29 multiply output signals LO_1 , LO_3 , and LO_4 from loop circuits 42₁, 42₃, and 42₄ described below by multiplicative coefficients m_{22} through m_{24} , respectively. An adder 39 adds the



output signals from each of the multipliers 26 through 29 and delivers an output signal LI_2 . The multipliers 31 through 33 multiply output signals LO_1 , LO_2 , and LO_4 from loop circuits 42_1 , 42_2 , and 42_4 described below by multiplicative coefficients m_{32} through m_{34} , respectively. An adder 40 adds the output signals from each of the multipliers 30 through 33 and delivers an output signal LI_3 . The multipliers 35 through 37 multiply output signals LO_1 through LO_4 from loop circuits 42_1 through 42_3 described below by multiplicative coefficients m_{42} through m_{44} , respectively. An adder 41 adds the output signals from each of the multipliers 34 through 37 and delivers an output signal LI_4 . Thus, the signal synthesis portion 21 synthesizes the output signal from the multiplier 18 and the output signals from the loop circuits 42_1 through 42_4 and delivers the synthesized signals, namely, the output signals from the adders 38 through 41 to the loop circuits 42_1 through 42_4 , respectively.

In Fig. 2, the loop circuits (hereinafter referred to as LOOP) 42_1 through 42_4 having the same electrical structure are provided. Fig. 4 shows a block diagram of the electrical structure of the LOOP 42. In this figure, a high pass filter (HPF) 43 is provided, which cuts off the low frequency component of an input signal, that is, the output signal LI from the signal synthesis portion 21 based on a coefficient HPF_n from the control portion 8 via the resonance elements control portion 20. The output signal from the HPF43 is supplied to a first input terminal of an adder 44. The output signal from the adder 44 is supplied to a low pass filter (LPF) 45 which cuts off the high frequency component of it based on a coefficient LPF_n from the control portion 8 via the resonance elements control portion 20.



The output signal from the LPF 45 is supplied to an all-pass filter (APF) 46 in which the phase difference between an input signal and an output signal changes in response with the frequency of the signals based on a coefficient APF_n from the control portion 8, via the resonance elements control portion 20. The output signal from the APF 46 is supplied to a delay circuit (DELAY) 47 which delays it for the desired delay period based on data DLY_n from the control portion 8, via the resonance elements control portion 20. The output signal from the DELAY 47 is supplied to a multiplier 48 which multiplies it by a loop gain LG_n from the control portion 8, via the resonance elements control portion 20. The resonance frequency pitches of each of the LOOPS 42₁ through 42₄ are decided by the total sum of the delay time of each of the LPF 45, the APF 46 and the DELAY 47 which is the construction element in the closed loop, that is, the total sum of the delay period of the closed loop. Accordingly, the delay period of the DELAY 47 must be designated based on the data DLY_n in consideration of the delay characteristics of the filters (i.e., the LPF45 and the APF46) in the closed loop to control the tone pitch.

Moreover, in Fig. 2, a signal synthesis portion 49 is provided which synthesizes the output signals from each of the LOOPS 42₁ through 42₄ and delivers output signals as the musical tone signals of each of the channels L and R. The resonance elements control portion 20 decides multiplicative coefficients k_{1L} through k_{4L} , and k_{1R} through k_{4R} , of each of the multipliers 50 through 57 (see Fig. 5) in a signal synthesis portion 49 based on the data MIX from the control portion 8 and delivers these to the multipliers 50 through 57. In Fig. 5, the multipliers 50 and



54 multiply input signals, namely, the output signal from the LOOP 42₁ shown in Fig. 2 by multiplicative coefficients k_{1L} and k_{1R} , respectively. The multipliers 51 and 55 multiply input signals, namely, the output signal from the LOOP 42₂ shown in Fig. 2 by multiplicative coefficients k_{2L} and k_{2R} , respectively. The multipliers 52 and 56 multiply input signals, namely, the output signal from the LOOP 42₃ shown in Fig. 2 by multiplicative coefficients k_{3L} and k_{3R} , respectively. The multipliers 53 and 57 multiply input signals, namely, the output signal from the LOOP 42₄ shown in Fig. 2 by multiplicative coefficients k_{4L} and k_{4R} , respectively. The adder 58 is provided which adds the output signal from the multipliers 50 through 53 and delivers the additional result as the musical tone signal OUTL of the channel L. The adder 59 is provided which adds the output signal from the multipliers 54 through 57 and delivers the additional result as the musical tone signal OUTR of the channel R.

When the control portion 8 delivers one data ALG to designate the combinations (the connection forms, namely algorithms) of the LOOPS 42₁ through 42₄, the resonance elements control portion 20 determines the multiplicative coefficients m_{11} through m_{14} , m_{21} through m_{24} , m_{31} through m_{34} , and m_{41} through m_{44} of each of multipliers 22 through 37 in the signal synthesis portion 21 (shown in Fig. 3) based on the data ALG and delivers these to the multipliers 22 through 37. Accordingly, the algorithm (the connection form) of the LOOPS 42₁ through 42₄ are, for example, designated as shown in Figs. 6(A) through 6(C), 7(A) through 7(C), 8(A), and 8(B). Next, when the control portion 8 delivers one data MIX to designate the synthesis coefficient of the output signal from each of the LOOPS 42₁ through 42₄, the



resonance elements control portion 20 decides the multiplicative coefficients k_{1L} through k_{4L} , and k_{1R} through k_{4R} , of each of the multipliers 50 through 57 in the signal synthesis portion 49 (shown in Fig. 5) based on the data MIX and delivers these to the multipliers 50 through 57. Accordingly, the output signals from the algorithm of the LOOPS 42_1 through 42_4 , for example, as shown in Figs. 6(A) through 6(C), 7(A) through 7(C), 8(A), and 8(B), are variously synthesized over great range.

As described above, when the control portion 8 delivers the data ALG and MIX to the resonance portion 19, the combination of the LOOPS 42_1 through 42_4 of the resonance portion 19 can be variously constructed over great range.

When synthesizing musical tones with a certain feeling of the pitch and with high quality, the control portion 8 delivers the data ALG and MIX to the resonance portion 19 to connect the LOOPS 42_1 and 42_2 in series as shown in Fig. 9. When the performer depresses, for example, the key of the keyboard of the performance manually operable member 6 corresponding to the note C, the keyboard delivers key data such as the tone pitch corresponding to the note C. The input portion of the touch (not shown) detects the initial touch and the after touch of each of the keys of the keyboard, and generates the touch data indicating the force of the touch and delivers these to the control portion 8. Then, the control portion 8 delivers the loop gain LG_1 and G_2 , the coefficient LPF_1 and LPF_2 , the coefficient APF_1 and APF_2 , and the coefficient HPF_1 and HPF_2 for the key data, the touch data, the tone color and the like corresponding to C note to the resonance portion 19 to designate the fundamental frequency pitch of each of the LOOP 42_1 and 42_2 to the frequency f_1 . In



addition, the control portion 8 delivers to the resonance portion 19 the resultant value which the above-mentioned value; such as the delay period of the LPF 45 and the APF 46; are subtracted from the phase delay period of the entire loop (see Fig. 9) corresponding to the note C as the delay period of the DELAY 47. Accordingly, the resonance elements control portion 20 in the resonance portion 19 delivers these data to the HPF43, the LPF45, the APF46, the DELAY47, and the multiplier 48 of each of the LOOPS 42_1 and 42_2 .

Next, the control portion 8 delivers the data WAVE, the key-on signal KON and the pitch data PITCH to the waveform generating portion 10 in the excitation signal generating portion 9 and delivers the coefficient data FLT_1 and FLT_2 to the filters 12 and 13, respectively and delivers the amplitude control signals AMP_1 and AMP_2 to the multipliers 14 and 15, respectively. In this case, the amplitude control signals AMP_1 and AMP_2 are designated so that the ratio of the output signal from the filter 12 to the output signal from the filter 13 becomes higher. Furthermore, the control portion 8 supplies the coefficient data FLT_3 to the filter 17 and supplies the amplitude control signals AMP_3 to the multiplier 18.

Thus, the waveform generating portion 10 generates the generated signal having the waveform designated by the data WAVE with the generating timing designated by the key-on signal KON and the pitch designated by the pitch data PITCH and supplies it to the filter 12. The filter 12 appends the desired characteristics to the generated signal based on the coefficient data FLT_1 . The multiplier 14 multiplies the output signal from the filter 12 by the amplitude control signal AMP_1 . In contrast,



the filter 13 appends the desired characteristics to the noise signal, such as white noise signal from the noise generating portion 11, based on the coefficient data FLT_2 . The multiplier 15 multiplies the output signal from the filter 13 by the amplitude control signal AMP_2 . Then, the adder 16 adds the output signals from the multipliers 14 and 15 and delivers the resultant signal as the excitation signal to the filter 17.

Next, the filter 17 appends the desired characteristics to the excitation signal based on the coefficient data FLT_3 from the control portion 8. The multiplier 18 multiplies the output signal from the filter 17 by the amplitude control signal AMP_3 from the control portion 8 and supplies its output signal to the resonance portion 19. Accordingly, in the resonance portion 19, the HPF 43 in the LOOP 42₁ cuts off the low frequency component of the input signal, that is, the output signal from the multiplier 18 based on the coefficient HPF_n from the control portion 8 via the resonance elements control portion 20. The output signal from the HPF 43 is supplied to the first input terminal of the adder 44. The output signal from the adder 44 is fed back to the second terminal of the adder 44 via the LPF 45, the APF 46, and the multiplier 48. Thus, the phase difference between each of the frequency components of the output signal from the HPF 43 varies and the level of the output signal from the HPF 43 gradually decreases as the output signal of the HPF 43 repeatedly circulates in the closed loop formed by the adder 44, the LPF 45, the APF 46, the DELAY 47 and the multiplier 48. Next, in the LOOP 422, the output signal from the APF 46 of the LOOP 42₁, namely, the output signal LO_1 from the LOOP 42₁ is supplied to the LOOP 42₂ and is treated in the same way as in the



LOOP 42_1 . Accordingly, the output signal from the APF 46 of the LOOP 42_2 , in other words, the output signal LO_2 from the LOOP 42_2 is supplied to the signal synthesis portion 49. The signal synthesis portion 49, that is, the resonance portion 19 delivers the output signals as the musical tone signals OUTL and OUTR of each of the channels L and R.

As described above, since the resonance portion 19 comprises the LOOPS 42_1 and 42_2 connected in series and the fundamental frequency pitch of each of the LOOPS 42_1 and 42_2 is designated to the frequency f_1 , the frequency characteristic of the whole resonance portion 19 becomes the frequency characteristic of the curve a shown in Fig. 10. In Fig. 10, curve b shows the frequency characteristic of each of the LOOPS 42_1 or 42_2 and the frequency interval f_I is one which the human ear recognizes as the pitch. As shown by Fig. 10, in the case where the LOOPS 42_1 and 42_2 having approximately the same frequency characteristics and are connected in series, the comb-formed frequency characteristic as a whole becomes sharper than one of each of the LOOPS 42_1 or 42_2 , and a musical tone with a certain feeling of the pitch and with high quality can be synthesized.

The musical tone made using a non-electronic musical instrument not only has a simple line spectrum, but also has a spectrum in which the noisy components lie near the original overtone, and furthermore contains irregularities. For example, in the case where the electronic musical instrument of the above-mentioned embodiment synthesizes similar musical tones to the musical tone having irregularities made using the non-electronic musical instrument, the control portion 8 may designate the amplitude control signals AMP_1 and AMP_2 so that the



ratio of the output signal from the filter 13 to the output signal from the filter 12 becomes higher.

When the resonance portion 19 comprises a similar connection to the one shown in Fig. 9, the fundamental frequency pitch of the LOOP 42₁ is designated as the frequency f_1 (see curve a in Fig. 12), the fundamental frequency pitch of the LOOP 42₂ is designated to the frequency $3f_1$ (see curve b in Fig. 12) as shown in Fig. 11, and the frequency characteristic of the whole resonance portion 19 becomes the frequency characteristic as shown in Fig. 13.

When the resonance portion 19 comprises further the LOOPS 42₁ and 42₂ connected in parallel and an adder 60 adding the output signals from each of the LOOPS 42₁ and 42₂ as shown in Fig. 14, the fundamental frequency pitch of the LOOP 42₁, which corresponds to the delay period of the LOOP 42, is designated to the frequency f_1 , and the fundamental frequency pitch of the LOOP 42₂ is designated to the frequency which shifts by the frequency Δf against the frequency f_1 . The frequency characteristic of the whole resonance portion 19 becomes somewhat similar to the frequency characteristic which both of the fundamental frequency pitch and the overtone frequency shift, as shown by the curve b in Fig. 15. Accordingly, the electronic musical instrument of the above-mentioned embodiment can synthesize the musical tone with a detuning effect in which the musical interval is finely shifted and with the sound effects of a chorus. In Fig. 15, the frequency component of curve a is practically removed by the HPF 43 (see Fig. 4) in the LOOP 42.

Moreover, the resonance portion 19 is constructed as a construction in which the LOOPS 42₁ and 42₂ are connected in



parallel, a multiplier 61 multiplies the output signal from the LOOP 42₁ by a multiplicative coefficient k_{L1} , a multiplier 62 multiplies the output signal from the LOOP 42₂ by a multiplicative coefficient k_{L2} and an adder 60 adds the output signals from each of the multipliers 61 and 62 as shown in Fig. 16. The multipliers 61 and 62 correspond to the multiplier 48 and 50 through 57 in the signal synthesis portion 49 shown in Figs. 2 and 5. When the fundamental frequency pitch f_1 and f_2 of each of the LOOPS 42₁ and 42₂, which corresponds to each of the data DLY₁ and DLY₂, and the loop gain LG₁ and LG₂ are adjusted and the output levels of each of the LOOPS 42₁ and 42₂ is adjusted by modifying the multiplicative coefficients k_{L1} and k_{L2} , the specific row of the overtone component appearing in every pitch difference between the fundamental frequency pitches f_1 and f_2 can be independently controlled in every row. For example, when the loop gain LG₂ of the LOOP 42₂ and the multiplicative coefficient k_{L2} of the multiplier 62 are adjusted, the gain can be independently controlled every row of each of the overtone components as shown by the arrow in Fig. 17; thus, the musical tone having the desired overtone construction can be obtained.

As described above, since the resonance portion 19 is constructed so that the LOOPS 42₁ through 42₄ can be combined at random, the rich variation of tone color of the musical tone can be ensured. Since each of the LOOPS 42₁ through 42₄ can be usable in the range of stable operation, the reliability of the system becomes high. In particular, when the serial connection and the parallel connection of the LOOP 42 are included as shown in Fig. 6(B), Fig. 6(C), Figs. 7(A) through 7(C), and Fig. 8(B), the tone color and the variation of the tone color of the



generated musical tone can be more varied.

As the above-mentioned embodiment of the present invention, the overtone construction of the generated musical tone is more easily anticipated than in the tone generating form using modulation such as the frequency modulated tone generating circuit, and the number of calculations is far less than in the tone generating form using the harmonic synthesizing form (Fourier synthesizing form).

Moreover, in the above-mentioned embodiment of the present invention, the sampling of the musical tone data with high quality and the waveform memory with large volume are not particularly necessary such as in an electronic musical instrument using the tone-generating circuit which reads the waveform data from the waveform memory.

In the above-mentioned embodiment of the present invention, it is described that the resonance portion 19 is simply constructed by a combination of the LOOPS 42_1 through 42_4 ; however, for example, the resonance portion 19 may be constructed in which an interstage process circuit 63 is inserted between the LOOP 42_1 and the LOOP 42_2 as shown in Fig. 18. In this case, as the interstage process, for example, the following processes can be employed.

The processes are ones in which the output signal from the LOOP 42_1 is nonlinearly processed using a nonlinear table, in which the amplitude of the output signal from the LOOP 42_1 is controlled using such as a compressor or a limiter, or in which the sound effects of every kind such as reverberation, delay, and chorus is given for the output signal from the LOOP 42_1 .

In the above-mentioned embodiment of the present invention,



it is described that the LOOPS 42_1 and 42_4 are combined so that the resonance elements control portion 20 determines the multiplicative coefficients m_{11} through m_{14} , m_{21} through m_{24} , m_{31} through m_{34} , and m_{41} through m_{44} , of each of the multipliers 22 through 37 of the signal synthesis portion 21 based on the data ALG from the control portion 8 and supplied to these; however, the present invention is not limited by the above-mentioned embodiment. For example, the LOOPS 42_1 and 42_4 may be combined so that an internal memory in which is pre-stored a plurality of the algorithms of the LOOPS 42_1 and 42_4 is provided in the control portion 8 and a performer selects one of these algorithms using the selection switch (not shown); thereby, the control portion 8 supplies the selected algorithm to the resonance elements control portion 20.

In the above-mentioned embodiment of the present invention, circuits corresponding to an excitation signal generating means, a plurality of loop means and coupling means in claims preferably consist of digital signal processors, respectively.

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What is claimed is:



1. An electronic musical instrument comprising:

an excitation signal generating means for generating an excitation signal in accordance with musical tone designating information;

a plurality of loop means for at least delaying an input signal in response to said musical tone designating information and repeatedly circulating said signal, said excitation signal is supplied to at least one of said plurality of loop means; and

coupling means for coupling said plurality of loop means in accordance with a predetermined coupling form, wherein a signal circulated in at least one of said plurality of loop means is output as a musical tone signal.

2. An electronic musical instrument comprising:

an excitation signal generating means for generating an excitation signal in accordance with a musical tone designating information;

a plurality of loop means for at least delaying an input signal in response to said musical tone designating information and repeatedly circulating said signal, said excitation signal is supplied to at least one of said plurality of loop means; and

coupling means for coupling said plurality of loop means in series, wherein a signal circulated in at least one of said plurality of loop means is output as a musical tone signal.

3. An electronic musical instrument comprising:

an excitation signal generating means for generating an





excitation signal in accordance with a musical tone designating information;

a plurality of loop means for at least delaying an input signal in response to said musical tone designating information and repeatedly circulating said signal, said excitation signal is supplied to at least one of said plurality of loop means; and

coupling means for coupling said plurality of loop means in parallel, wherein a signal circulated in at least one of said plurality of loop means is output as a musical tone signal.

4. An electronic musical instrument comprising:

an excitation signal generating means for generating an excitation signal in accordance with a musical tone designating information;

a plurality of loop means for at least delaying an input signal in response to said musical tone designating information and repeatedly circulating said signal, said excitation signal is supplied to at least one of said plurality of loop means; and

coupling means for coupling said plurality of loop means in series and in parallel, wherein a signal circulated in at least one of said plurality of loop means is output as a musical tone signal.

5. An electronic musical instrument according to claim 1 further comprising coupling form data output means for providing coupling form data indicating how to couple input and output terminals of said plurality of loop means, wherein said input and output terminals of said plurality of loop means are coupled each other based on said coupling form data output by said coupling



form data output means.



6. An electronic musical instrument according to claim 1 further comprising a memory means for storing a plurality of coupling forms indicating how to couple input and output terminals of said plurality of loop means, wherein said coupling means couples said input and output terminals of said plurality of loop means are coupled each other based on a coupling form read from said memory means.

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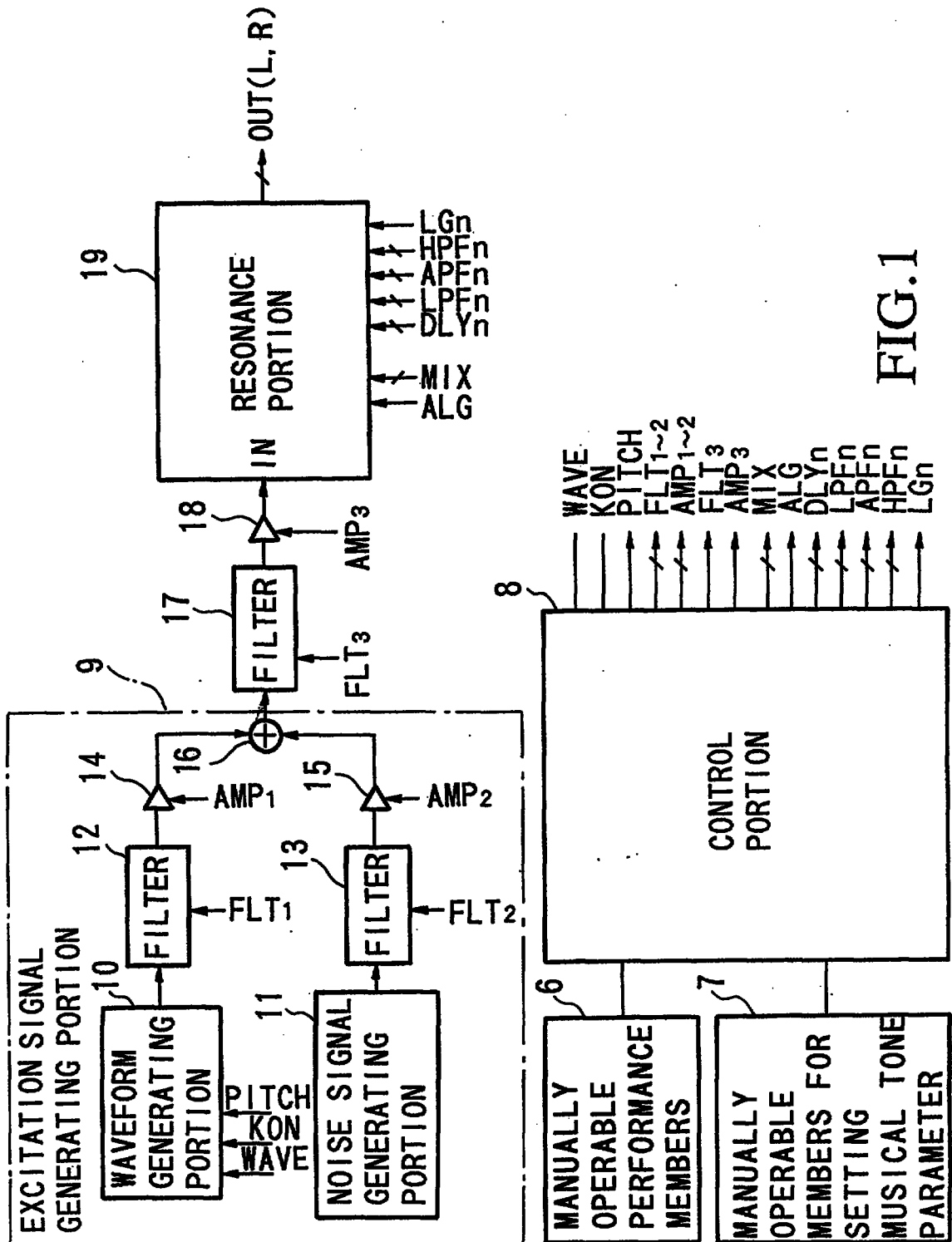


ABSTRACT OF THE DISCLOSURE

An electronic musical instrument includes an excitation signal generating device, a plurality of loop circuits and a coupling circuit. The excitation signal generating device generates an excitation signal in accordance with musical tone designating information. Each of the plurality of loop circuits at least delays an input signal in response to the musical tone designating information and repeatedly circulates the input signal therein. The excitation signal generated by the excitation signal generating device is supplied to at least one of the plurality of loop circuits as an input signal. The coupling circuit couples the plurality of loop circuits in accordance with a predetermined coupling form. At least one signal circulated in at least one of the plurality of loop circuits is output as a musical tone signal to be generated. The electronic musical instrument further includes a memory circuit which stores a plurality of coupling forms. The coupling forms respectively indicate how to couple input and output terminals of the plurality of loop circuits. The input and output terminals are coupled to each other in accordance with one of the plurality of coupling forms.

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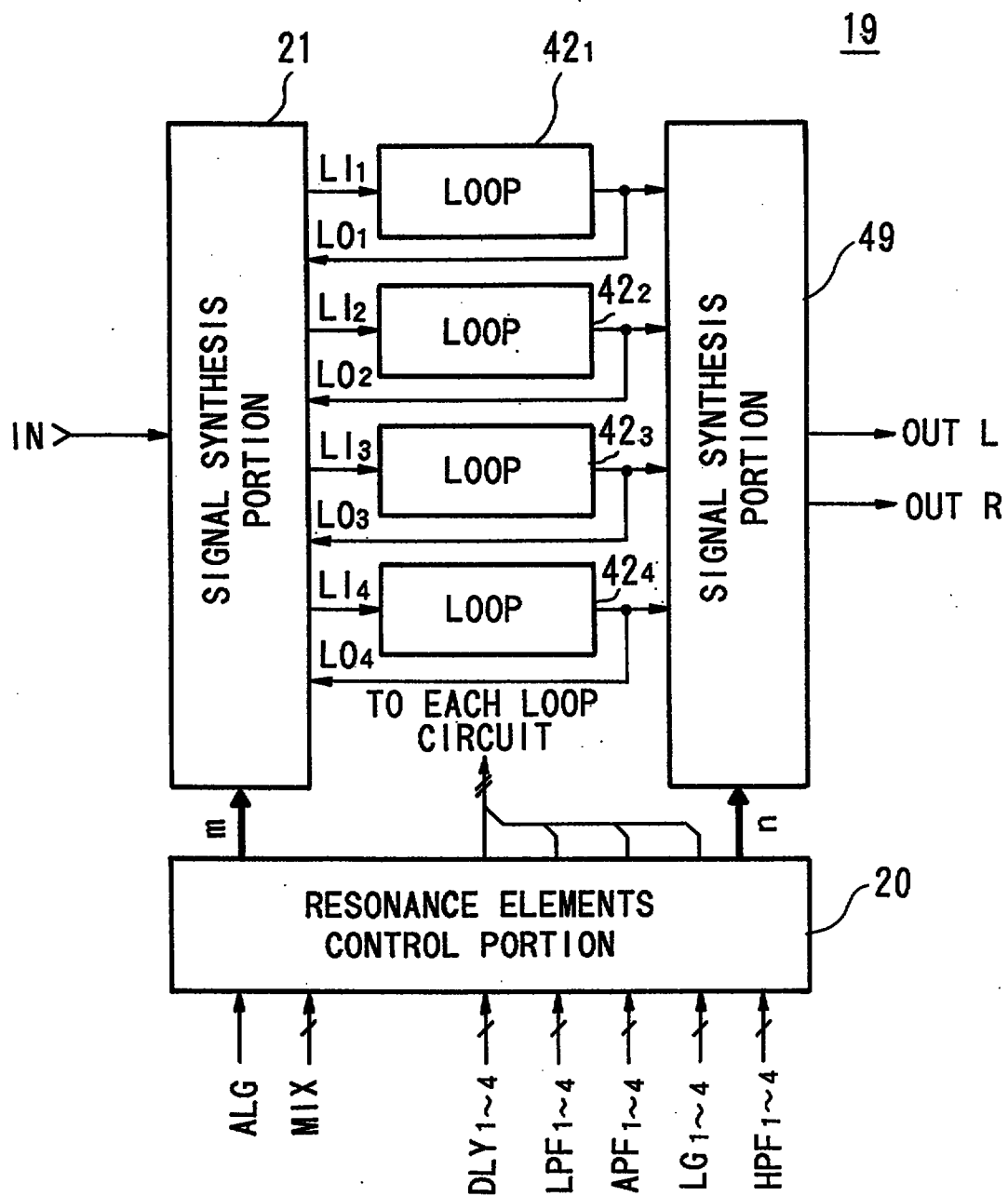


FIG.2

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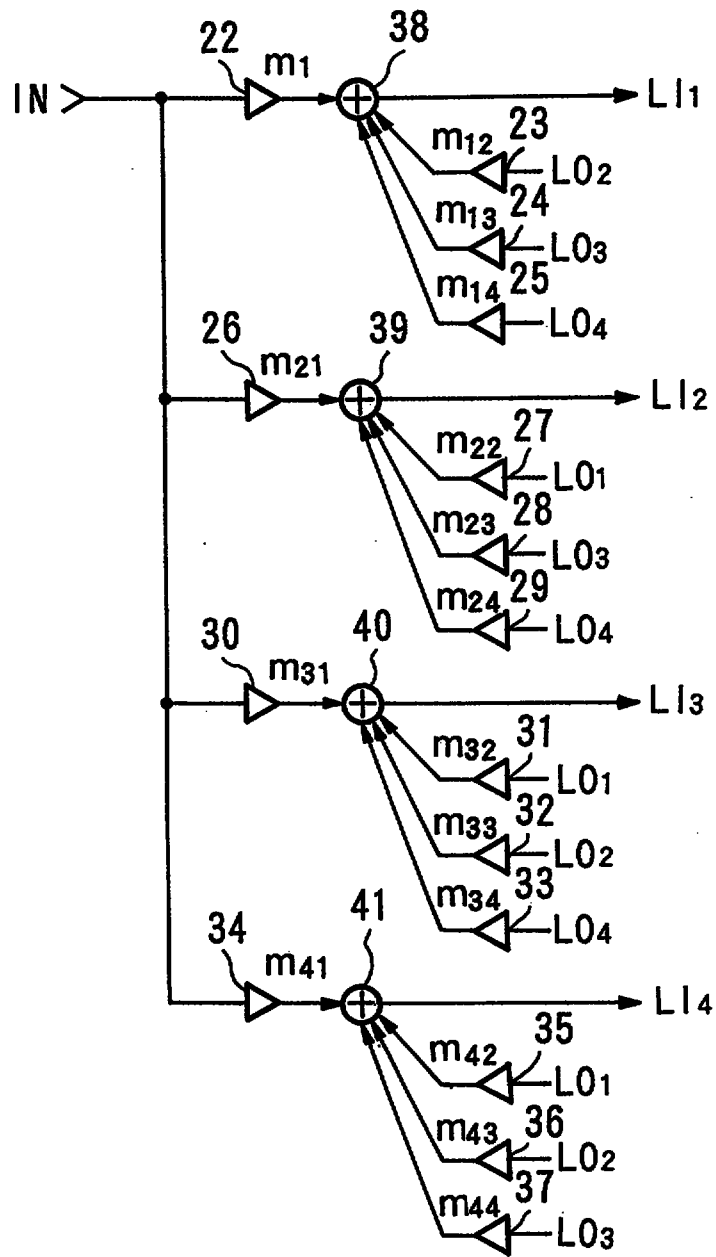


FIG.3

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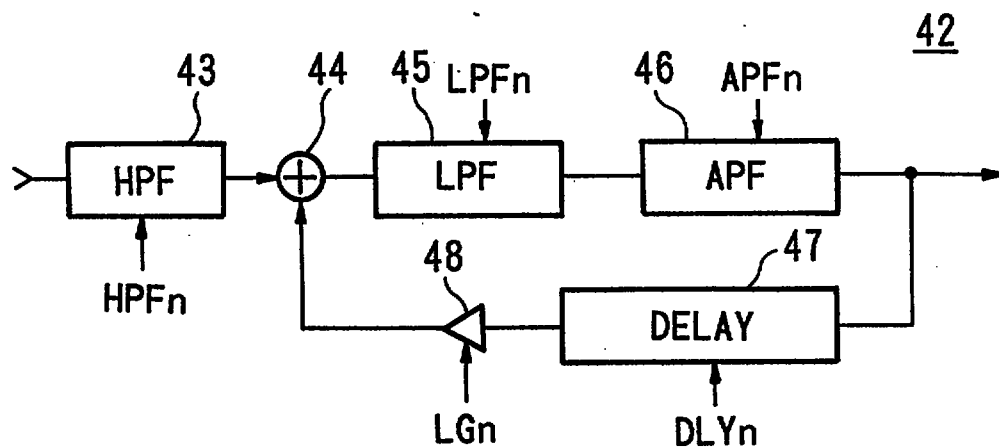


FIG.4

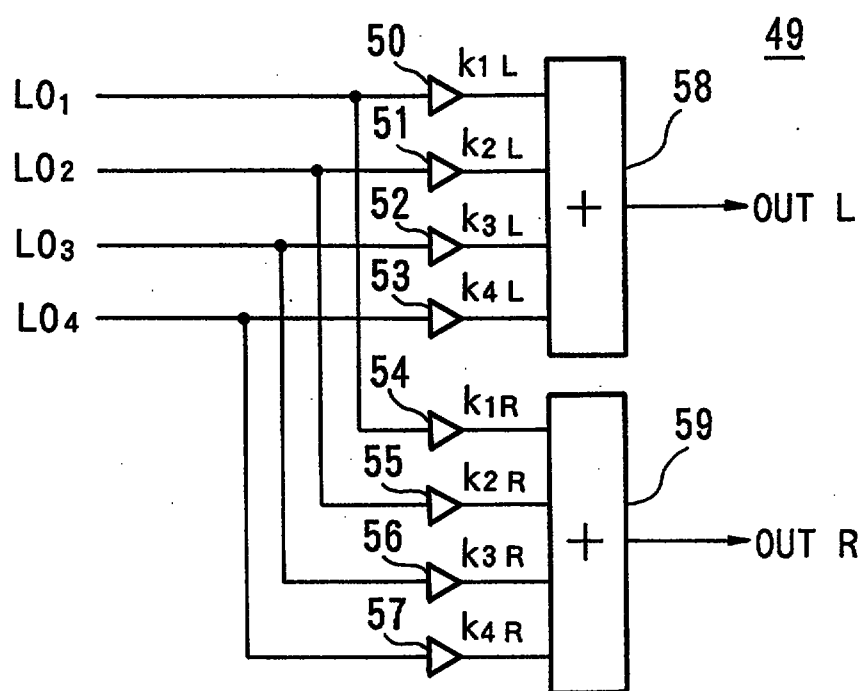


FIG.5

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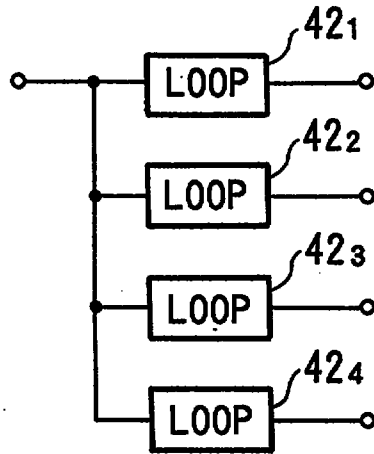


FIG. 6(A)

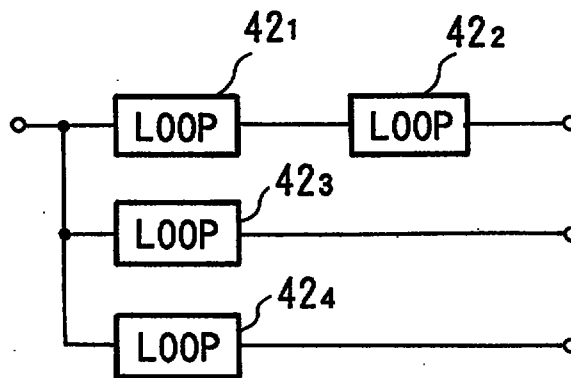


FIG. 6(B)

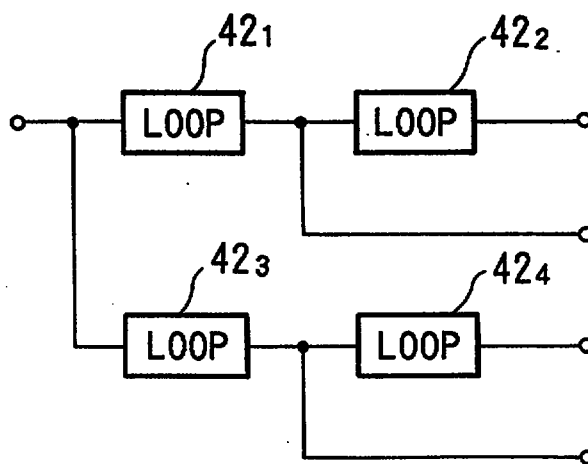


FIG. 6(C)

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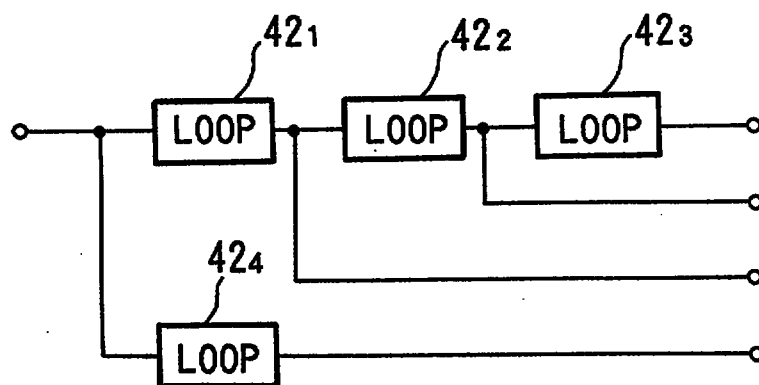


FIG. 7(A)

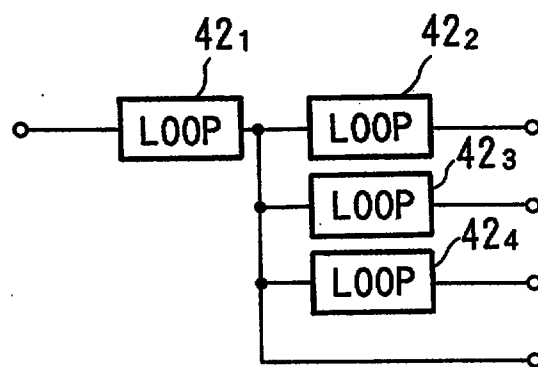


FIG. 7(B)

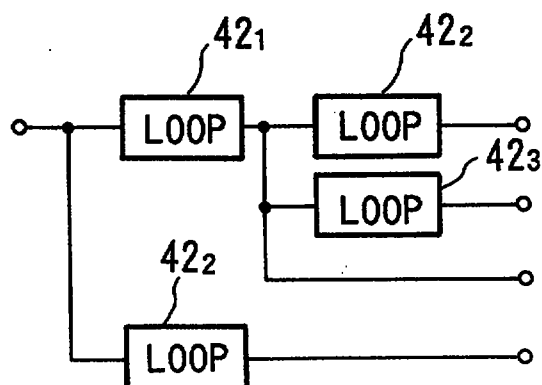


FIG. 7(C)



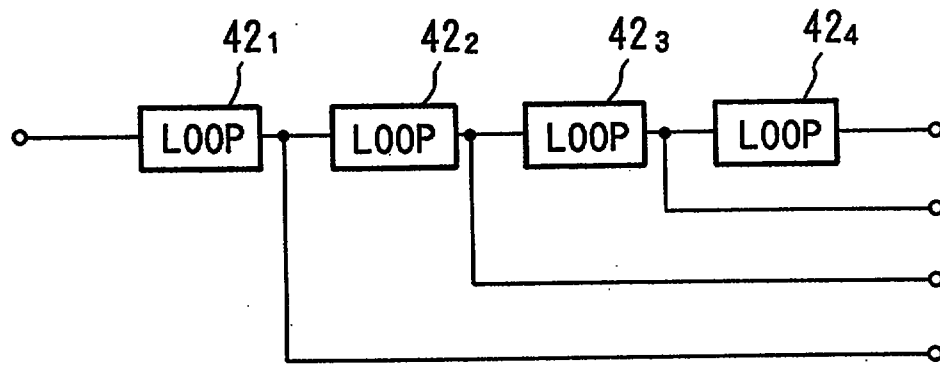


FIG. 8(A)

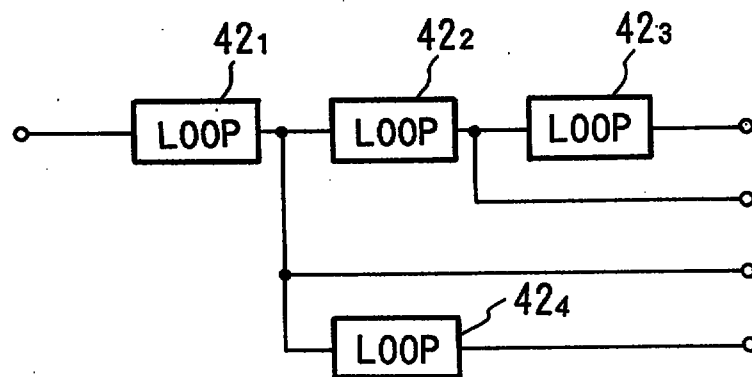


FIG. 8(B)

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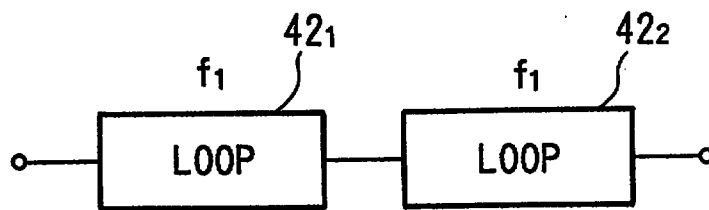


FIG.9

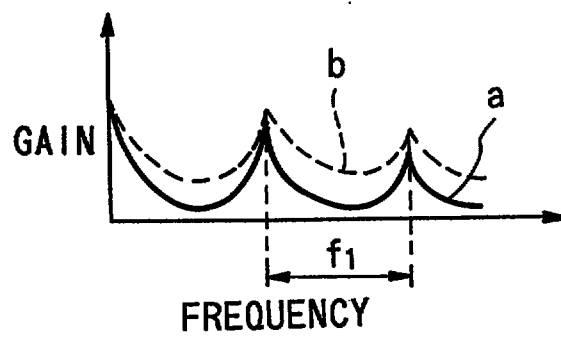


FIG.10

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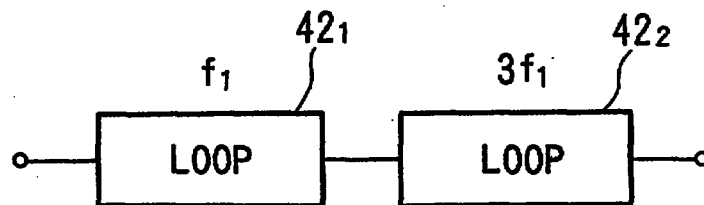


FIG.11

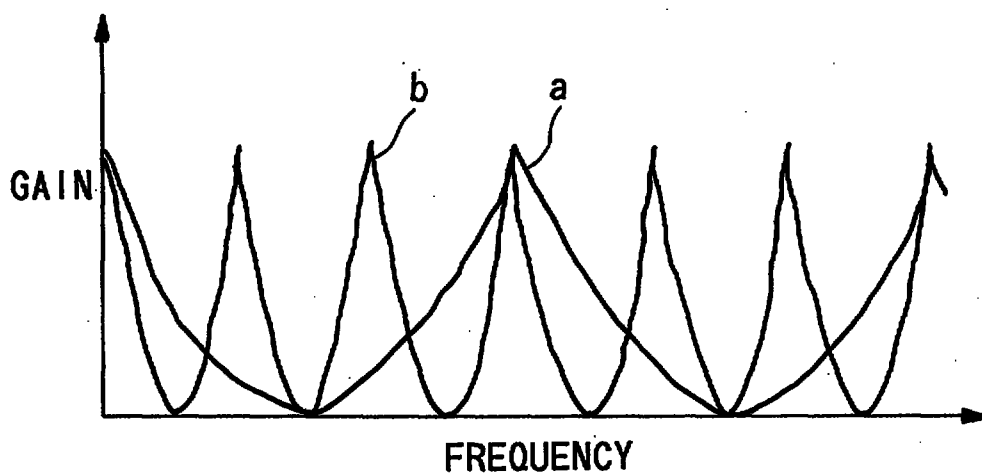


FIG.12

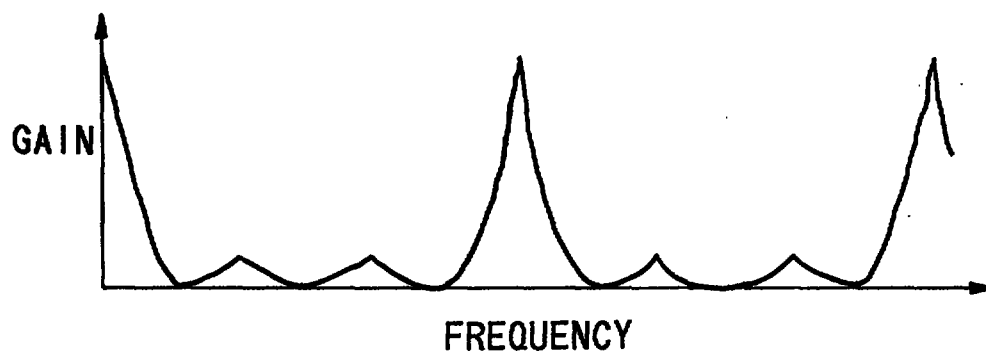


FIG.13

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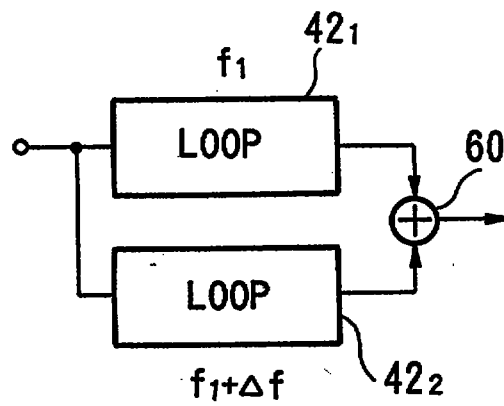


FIG.14

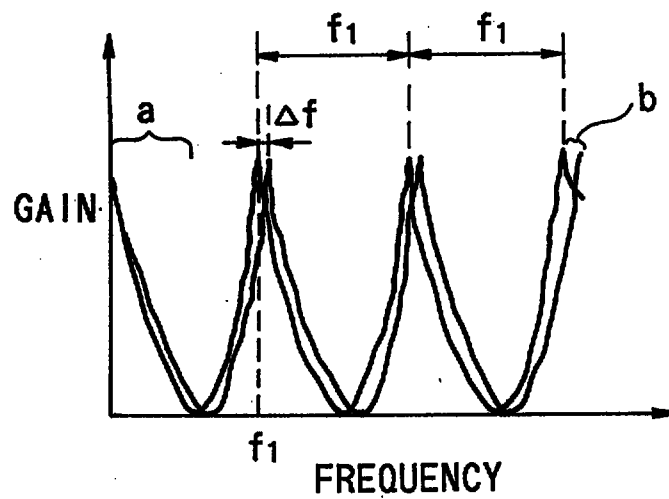


FIG.15

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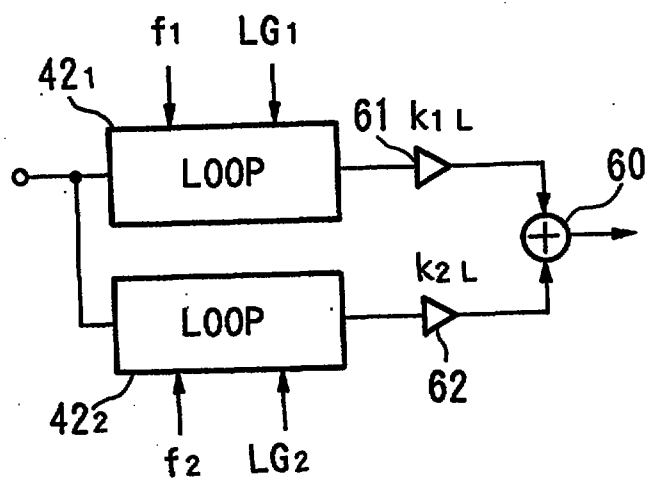


FIG.16

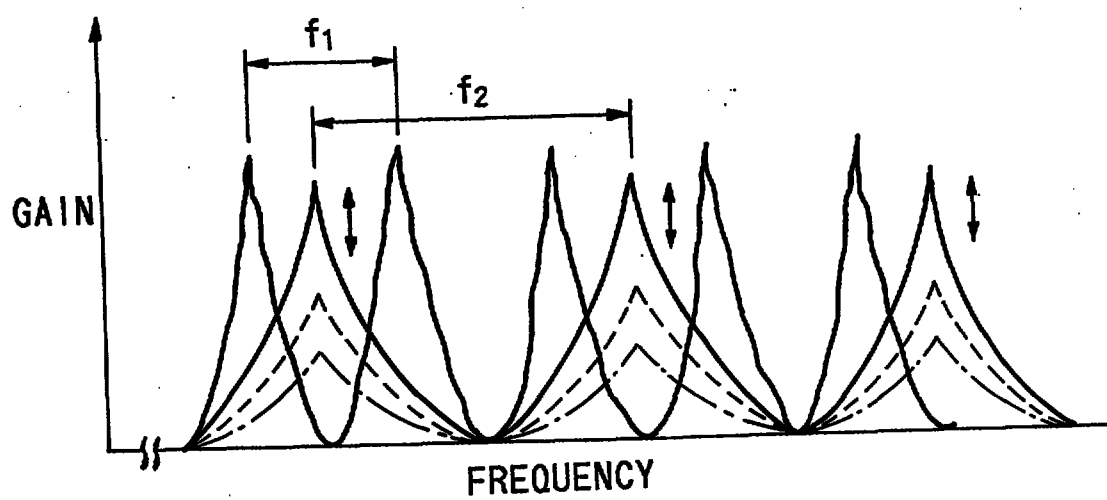


FIG.17

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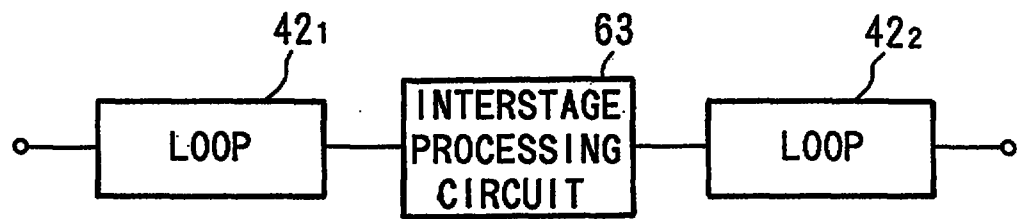


FIG.18

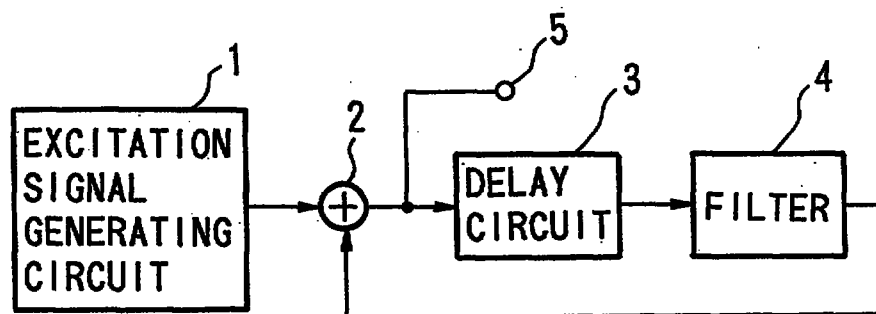
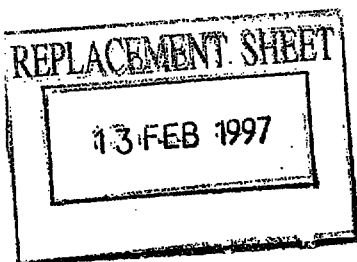


FIG.19(PRIOR ART)

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ELECTRONIC MUSICAL INSTRUMENT.

ABSTRACT OF THE DISCLOSURE

An electronic musical instrument includes an excitation signal generating device, a plurality of loop circuits and a coupling circuit. The excitation signal generating device generates an excitation signal in accordance with musical tone designating information. Each of the plurality of loop circuits at least delays an input signal in response to the musical tone designating information and repeatedly circulates the input signal therein. The excitation signal generated by the excitation signal generating device is supplied to at least one of the plurality of loop circuits as an input signal. The coupling circuits couples the plurality of loop circuits in accordance with a predetermined coupling form. At least one signal circulated in at least one of the plurality of loop circuits is output as a musical tone signal to be generated. The electronic musical instrument further includes a memory circuit which stores a plurality of coupling forms. The coupling forms respectively indicates how to couple input and output terminals of the plurality of loop circuits. The input and output terminals are coupled to each other in accordance with one of the plurality of coupling forms.

FIGURE 1

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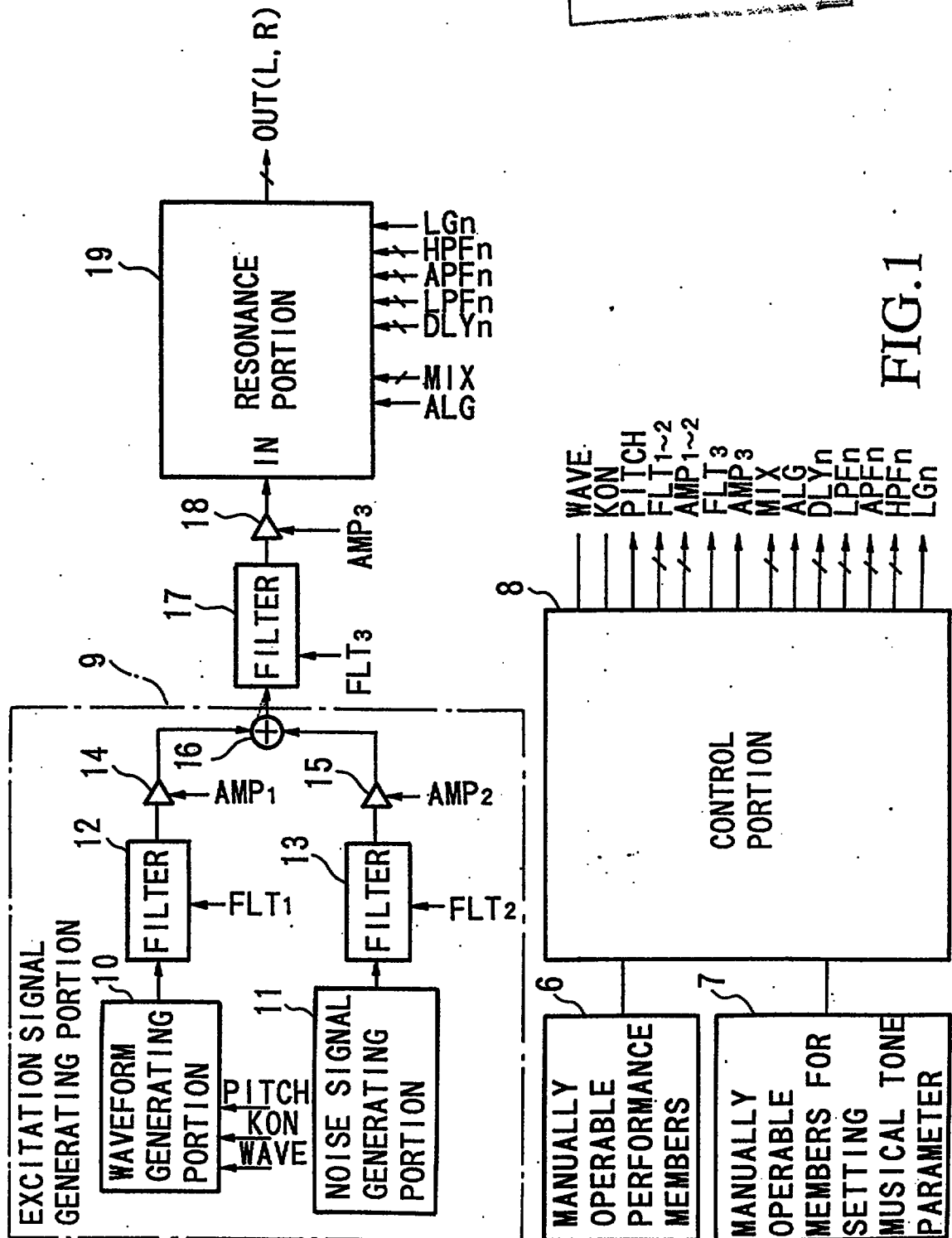
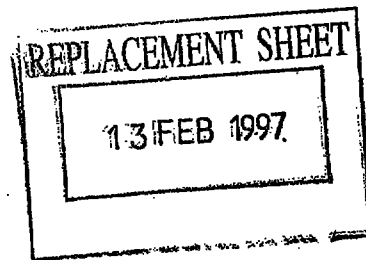


FIG. 1

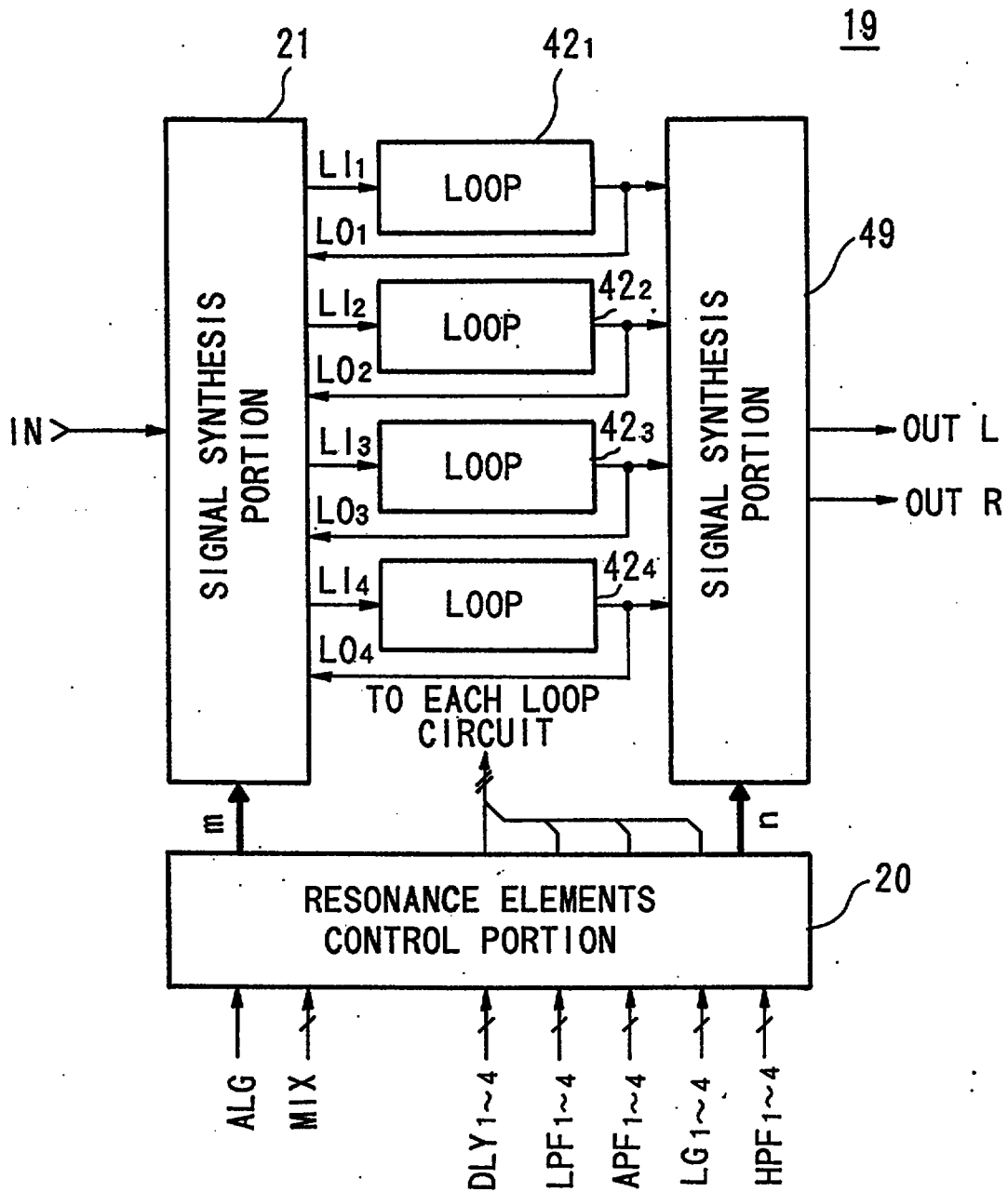
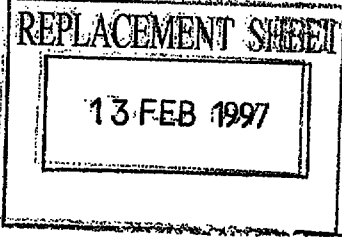
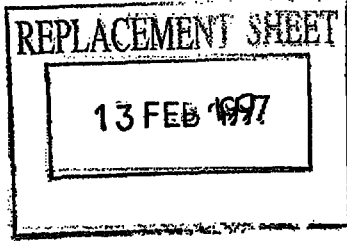


FIG.2



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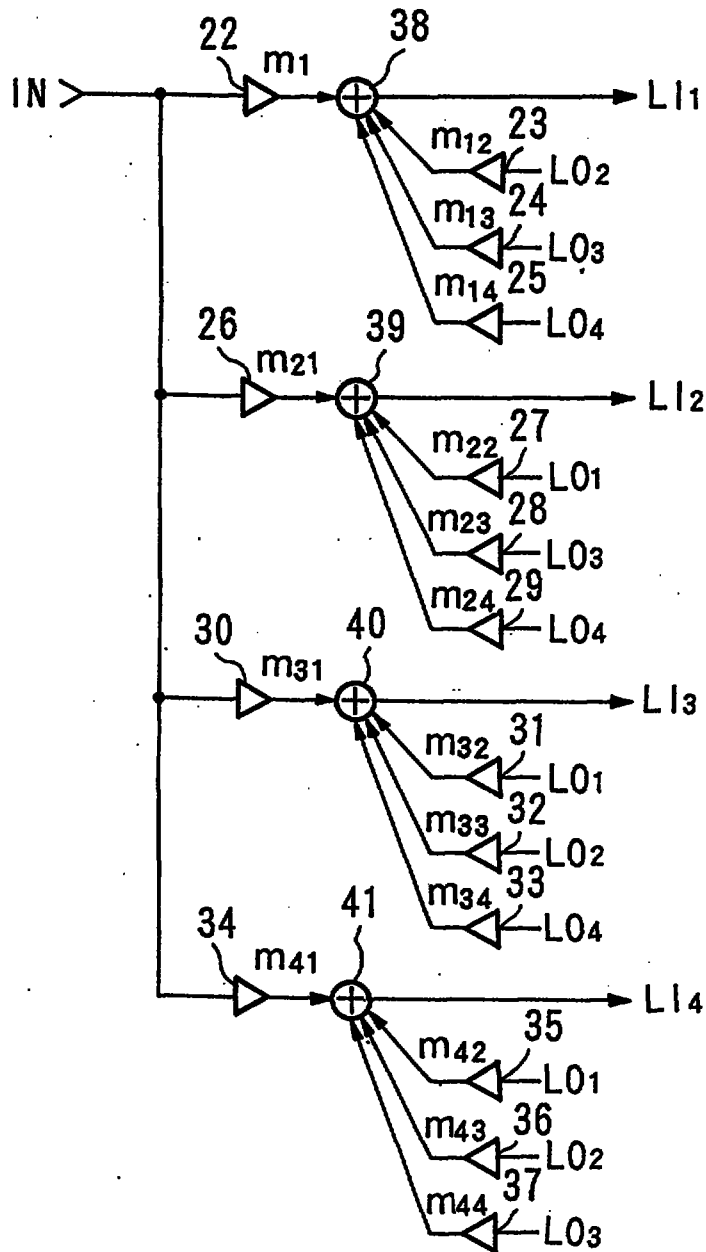


FIG.3

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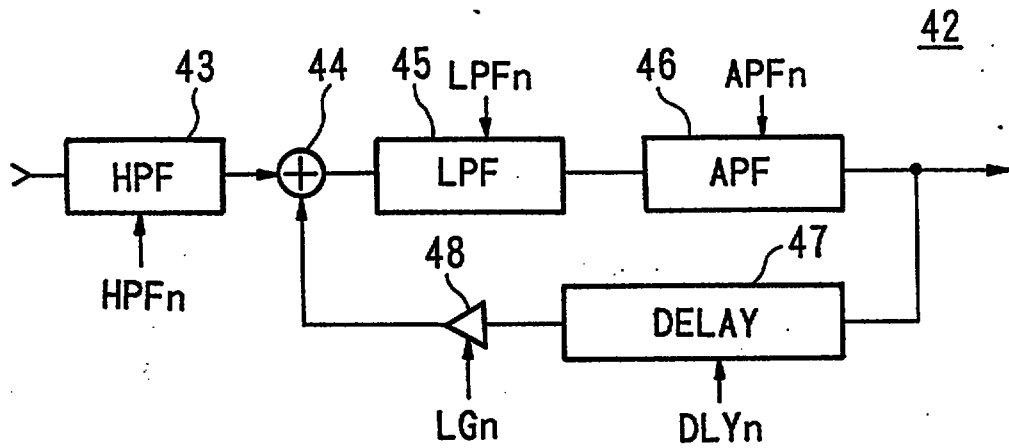
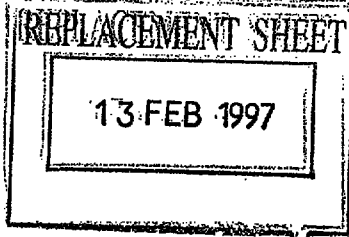


FIG. 4

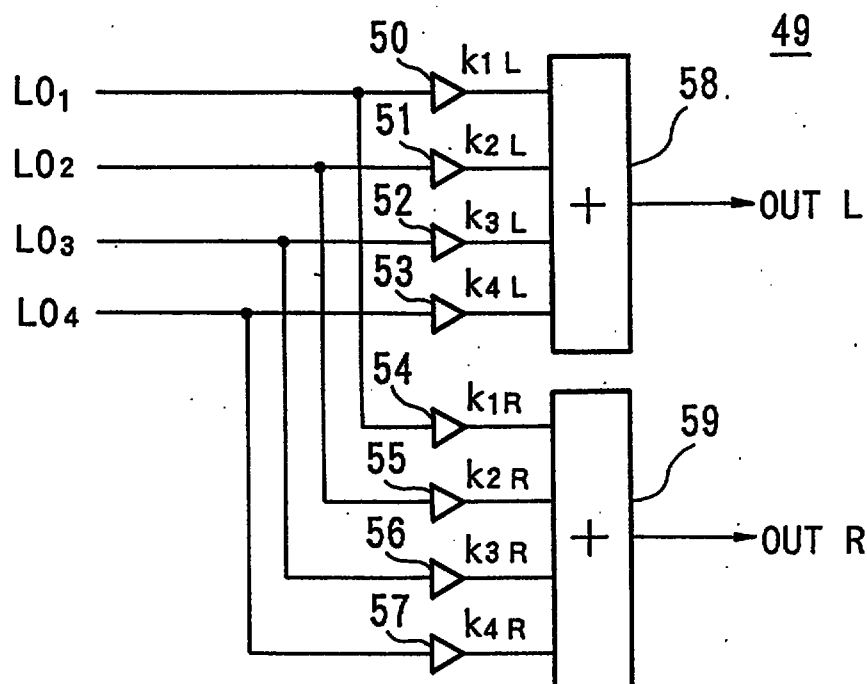


FIG. 5



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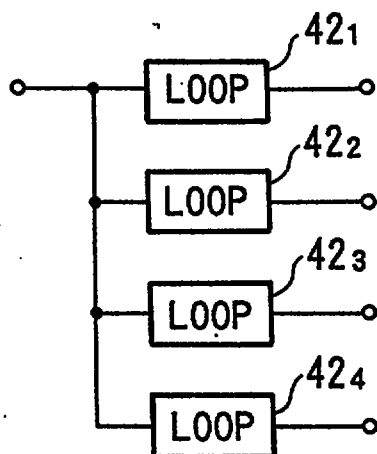


FIG. 6 A

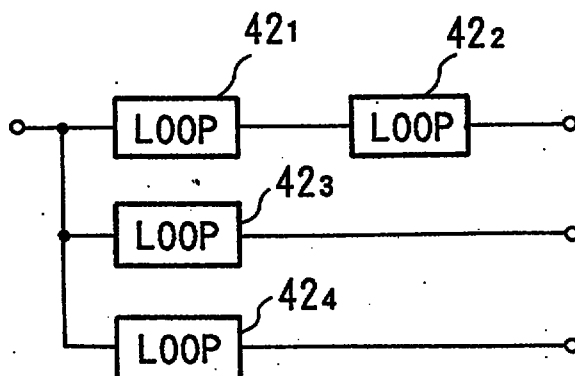


FIG. 6 B

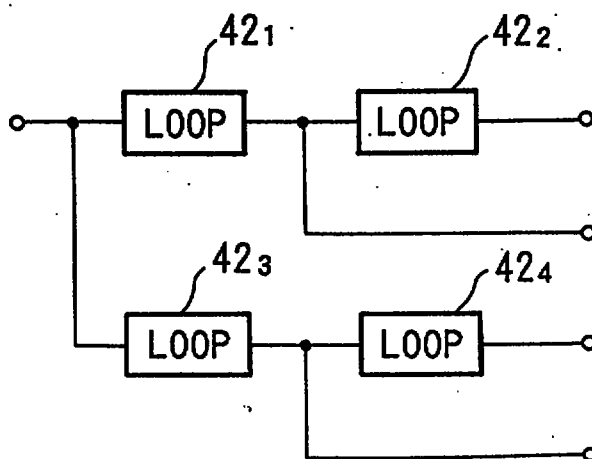


FIG. 6 C

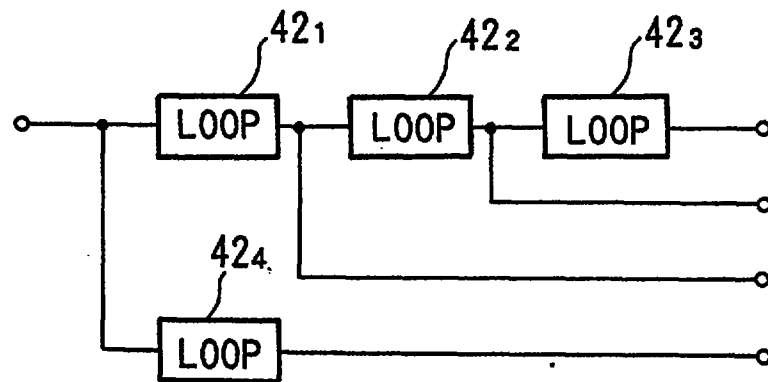
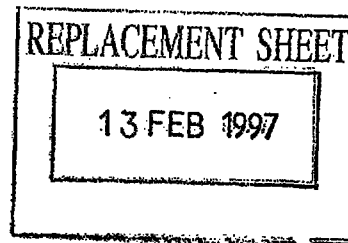


FIG. 7 A

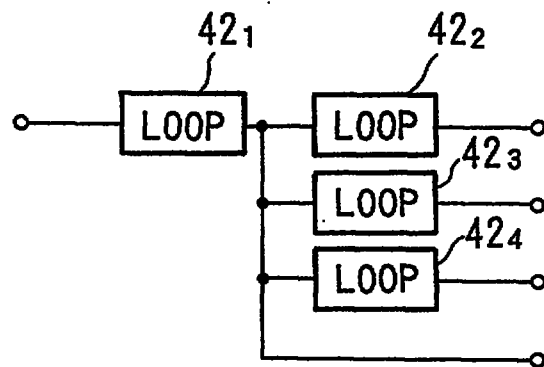


FIG. 7 B

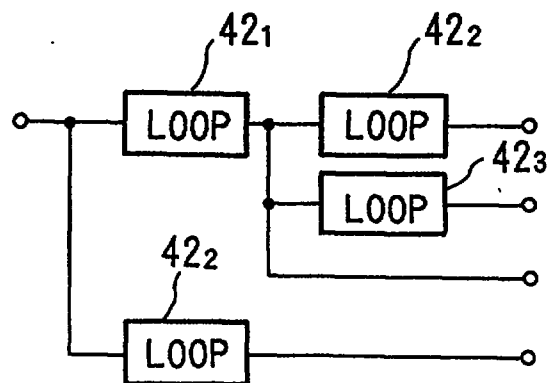


FIG. 7 C

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- 7 -

REPLACEMENT SHEET

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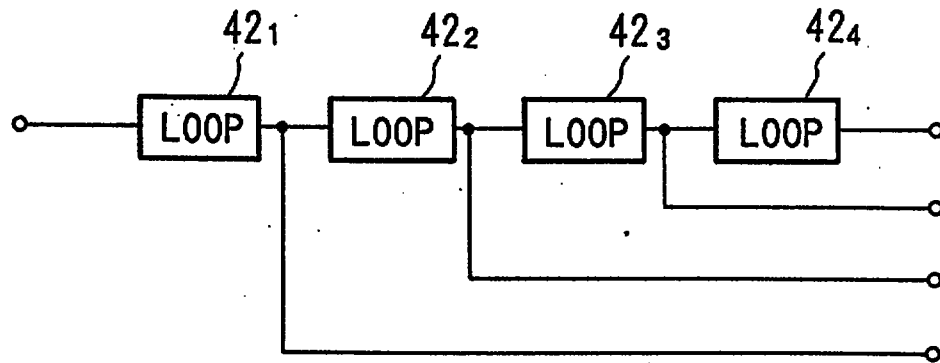


FIG.8 A

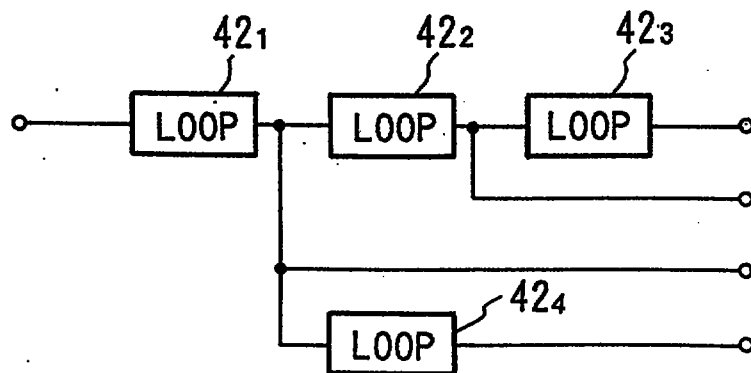


FIG.8 B

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- 8 -

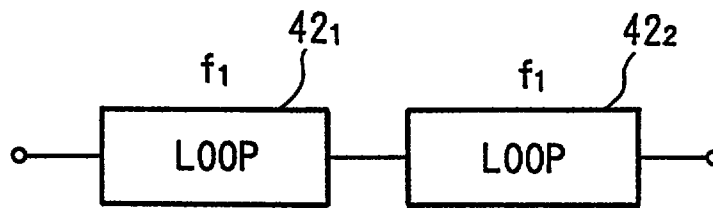
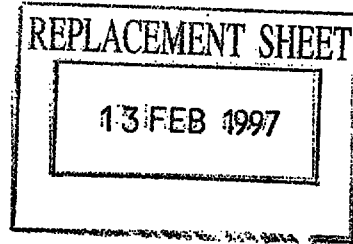


FIG.9

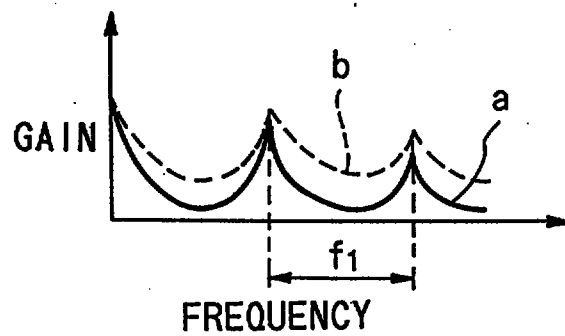


FIG.10



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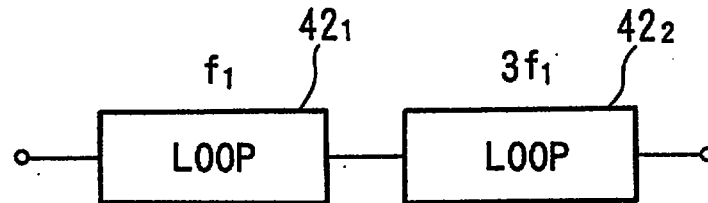


FIG.11

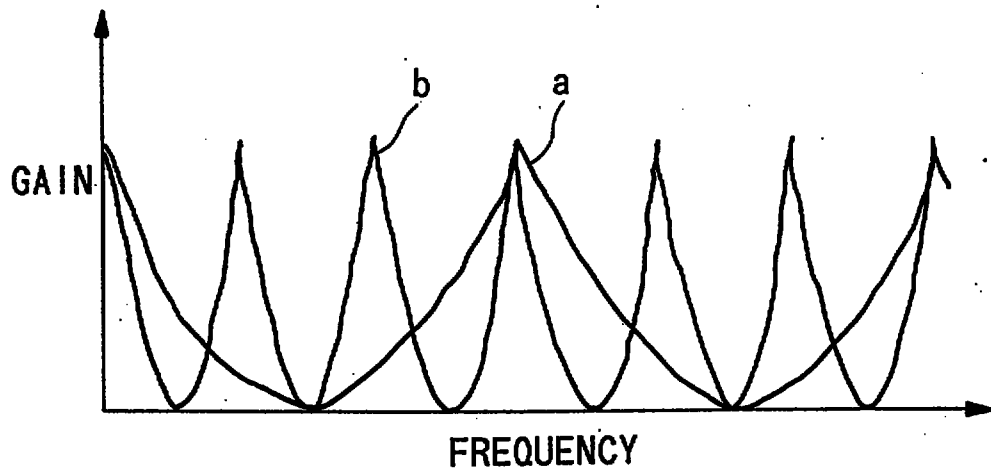


FIG.12

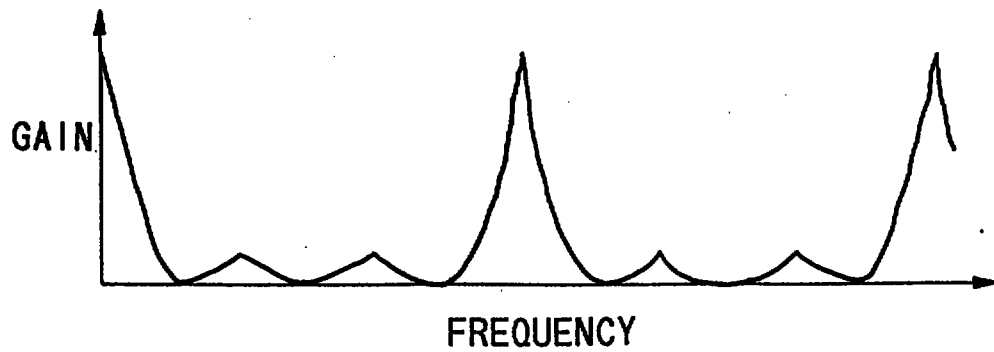


FIG.13

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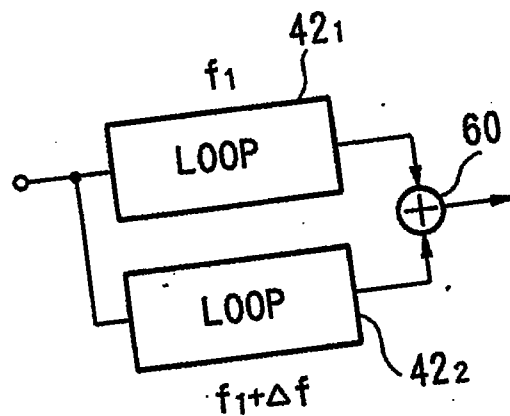


FIG.14

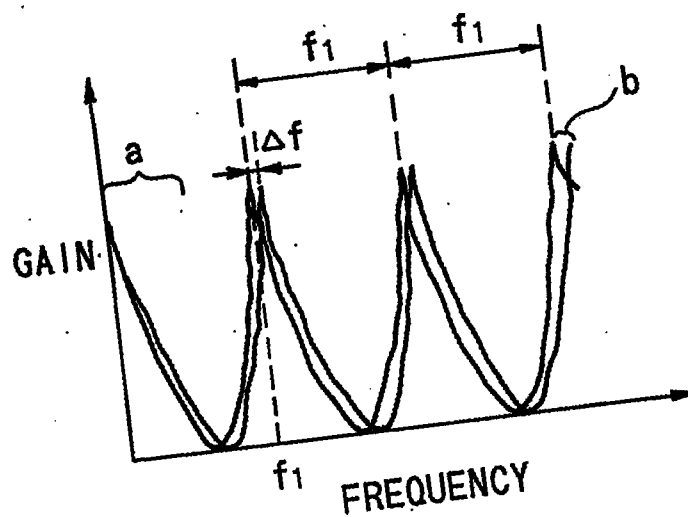


FIG.15

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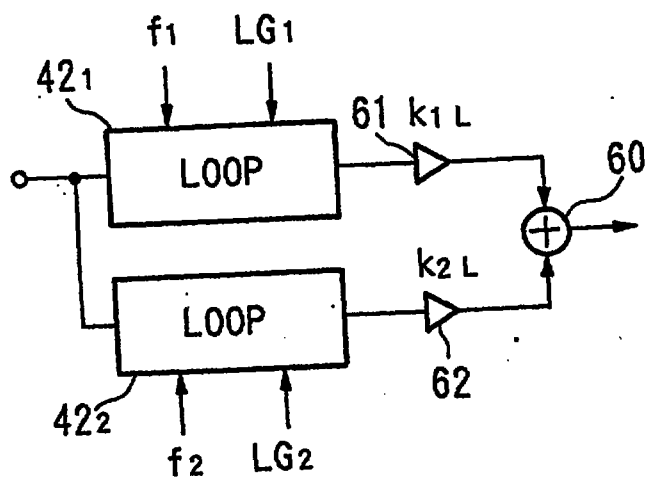
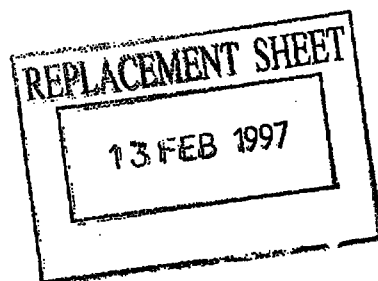


FIG.16

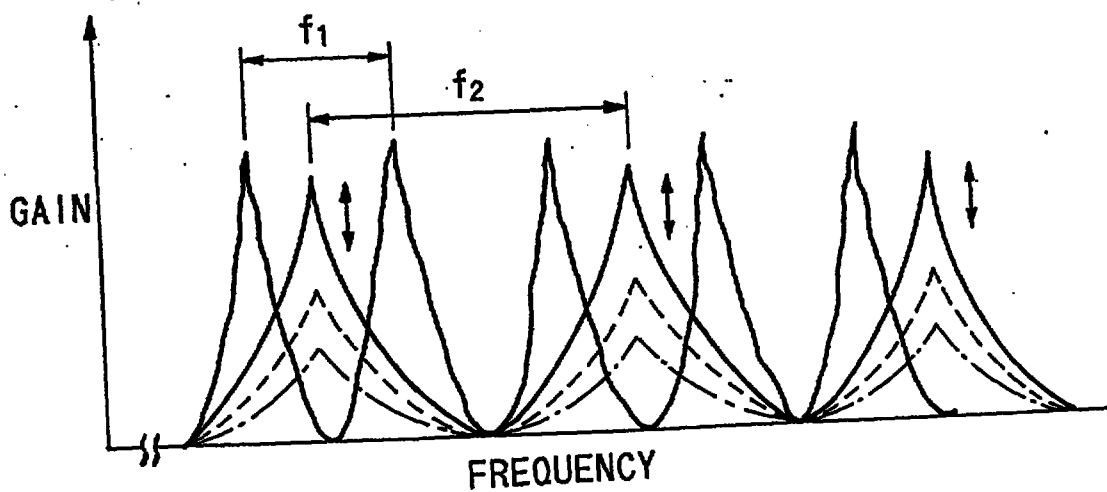


FIG.17

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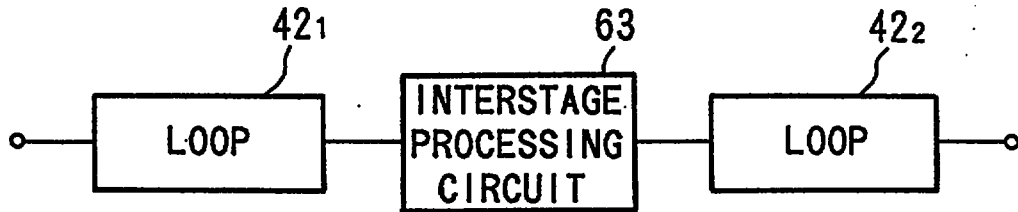


FIG.18

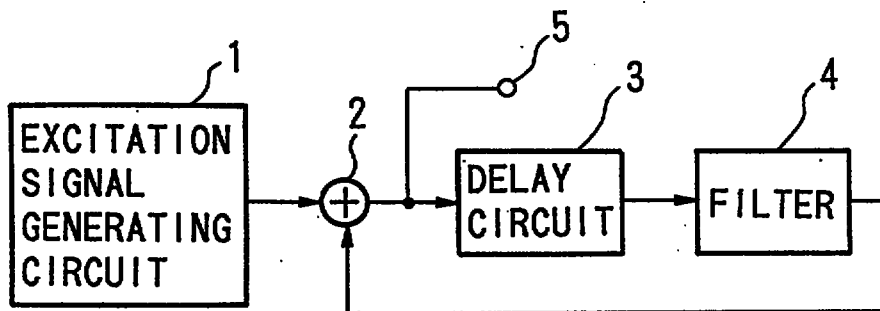


FIG.19(PRIOR ART)



ABSTRACT / ZUSAMMENFASSUNG / ABREGE

92120691.8

An electronic musical instrument includes an excitation signal generating device (9), a plurality of loop circuits (42) and a coupling circuit. The excitation signal generating device (9) generates an excitation signal in accordance with musical tone designating information. Each of the plurality of loop circuits (42) at least delays an input signal in response to the musical tone designating information and repeatedly circulates the input signal therein. The excitation signal generated by the excitation signal generating device (9) is supplied to at least one of the plurality of loop circuits (42) as an input signal. The coupling circuit couples the plurality of loop circuits in accordance with a predetermined coupling form. At least one signal circulated in at least one of the plurality of loop circuits (42) is output as a musical tone signal to be generated. The electronic musical instrument further includes a memory circuit which stores a plurality of coupling forms. The coupling forms respectively indicate how to couple input and output terminals of the plurality of loop circuits (42). The input and output terminals are coupled to each other in accordance with one of the plurality of coupling forms.

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pitch and the spectral construction of the excitation signal supplied to the closed loop must correspond to a pitch designated by a performer.

By increasing the loop gain of the closed loop (the filter with the comb-formed frequency characteristics), the comb-formed frequency characteristics of the entire closed loop for the signal circulating become sharper, so that the feeling of the pitch is improved. However, in this case, the stability of the operation of the closed loop decreases, and in the worst case there is drawback in that the closed loop self-oscillates. Accordingly, there is a drawback in that the reliability of the system is degraded.

EP-A-0 393 701 discloses a musical tone synthesizing apparatus including a reverberation effect applying apparatus. The reverberation effect applying apparatus comprises several loops connected in parallel. Each loop simulates a certain sound transmission path and consists of shift registers, phase inverters and adders.

Summary of the Invention

In consideration of the above, it is an objective of the present invention to provide an electronic musical instrument which is capable of generating the musical tone with a great variety of spectral constructions under no influence of the kind of the waveform of the excitation signal and with a rich variation of tone color of the musical tone, and which is capable of stable closed loop operation, and which is capable of constructing a system with high reliability.

To satisfy these objectives, the present invention provides an electronic musical instrument comprising: an excitation signal generating means for generating an excitation signal in accordance with musical tone designating information; a plurality of loop means for at least delaying an input signal in response to said musical tone designating information and repeatedly circulating said signal, said excitation signal being supplied to at least one of said plurality of loop means; characterized by coupling designation means for generating coupling designation data in accordance with a tone color of the musical tone to be generated; and coupling means for coupling said plurality of loop means in accordance with said coupling designation data, wherein a signal circulated in at least one of said plurality of loop means is output as a musical tone signal.

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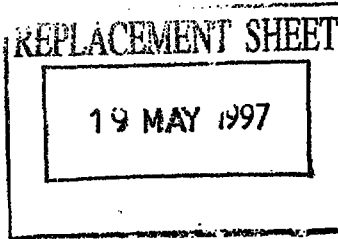
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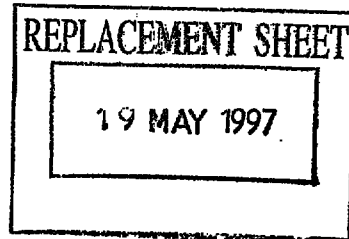
According to such a structure, the plurality of loop means, which is coupled to each other in accordance with the predetermined coupling form, at least delays the supplied excitation signal in response to the musical tone designating information to and repeatedly circulates the signal. The signal gradually changes into a signal having a desirable waveform in response to the coupling form while circulating in the plurality of loop means. Accordingly, the signal circulated in one of any plurality of loop means is delivered as a musical tone signal.

According to the present invention, a positive effect is that the musical tone can be generated with a great variety of spectral constructions under no influence of the kind of the waveform of the excitation signal and with the rich variation of tone color of the musical tone. Furthermore, there is the positive effect that a system with high reliability can be constructed so that the closed loop operates stably.

Brief Explanation of the Drawings

Fig. 1 shows a block diagram of the electrical structure of an electronic musical instrument based on the preferred embodiment of the present invention.

Fig. 2 shows a block diagram of the electrical structure of

**CLAIMS**

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1. An electronic musical instrument comprising:
an excitation signal generating means (9) for generating an excitation signal in accordance with musical tone designating information;
a plurality of loop means (42) for at least delaying an input signal in response to said musical tone designating information and repeatedly circulating said signal, said excitation signal being supplied to at least one of said plurality of loop means (42);
characterized by coupling designation means (20) for generating coupling designation data in accordance with a tone color of the musical tone to be generated; and
coupling means (21) for coupling said plurality of loop means in accordance with said coupling designation data, wherein a signal circulated in at least one of said plurality of loop means (42) is output as a musical tone signal.
2. An electronic musical instrument according to claim 1, wherein said plurality of loop means is coupled in series.
3. An electronic musical instrument according to claim 1, wherein said plurality of loop means is coupled in parallel.
4. An electronic musical instrument according to claim 1, wherein said plurality of loop means is coupled in series and in parallel.
5. An electronic musical instrument according to claim 1 further comprising a memory means for storing a plurality of coupling forms indicating how to couple input and output terminals of said plurality of loop means, wherein said coupling means



couples said input and output terminals of said plurality of loop means are coupled each other based on a coupling form read from said memory means.

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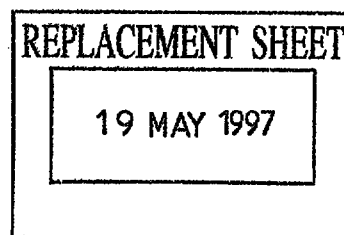
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ELECTRONIC MUSICAL INSTRUMENT

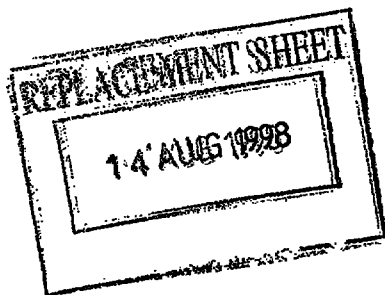
ABSTRACT OF THE DISCLOSURE

An electronic musical instrument includes an excitation signal generating device, a plurality of loop circuits and a coupling circuit. The excitation signal generating device generates an excitation signal in accordance with musical tone designating information. Each of the plurality of loop circuits at least delays an input signal in response to the musical tone designating information and repeatedly circulates the input signal therein. The excitation signal generated by the excitation signal generating device is supplied to at least one of the plurality of loop circuits as an input signal. The coupling circuits couples the plurality of loop circuits in accordance with a predetermined coupling form. At least one signal circulated in at least one of the plurality of loop circuits is output as a musical tone signal to be generated. The electronic musical instrument further includes a memory circuit which stores a plurality of coupling forms. The coupling forms respectively indicates how to couple input and output terminals of the plurality of loop circuits. The input and output terminals are coupled to each other in accordance with one of the plurality of coupling forms.

FIGURE 1

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-1-

ELECTRONIC MUSICAL INSTRUMENT

Description**Background of the Invention****Field of the Invention**

The present invention relates to electronic musical instruments, and more particularly, to electronic musical instruments capable of generating varied musical tones like those of acoustic (non-electronic) musical instruments.

Prior Art

Due to recent technological improvements, tone generators employed in electronic musical instruments have come to be capable of synthesizing a wide variety of musical tones. For example, physical-modal tone-generators which synthesize sounds of acoustic musical instruments are conventionally known. Each of the physical-modal tone-generators simulates the sound production mechanism of a target acoustic musical instrument. Examples of the physical-modal tone-generators have been disclosed in Japanese Patent Application Laid-Open Publication No. 63-40199 and US Patent No. 4,984,276.

An example of conventional physical-modal tone-generators simulating the sound production mechanism of stringed instruments is shown in the block diagram of Fig. 19. In this figure, an excitation signal generating circuit 1 includes a waveform memory which stores excitation signal waveforms made up of a large number of frequency components, such as an impulse waveform.

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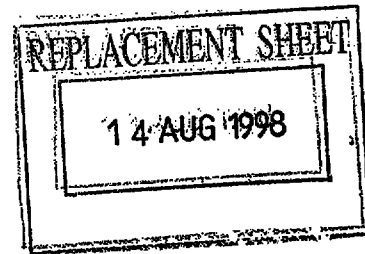


- 2 -

The excitation signal from the excitation signal generating circuit 1 is supplied to a first input terminal of an adder 2. The output signal from the adder 2 is supplied to a delay circuit 3 which simulates the delay of propagation of vibrating waves in a string of the target stringed instrument.

The delayed output signal from the delay circuit 3 is then supplied to a filter 4 which simulates acoustical losses of a vibrating string of the target stringed instrument. The output signal from the filter 4 is then supplied to a second input terminal of the adder 2. Elements 2 through 4 described above together form a closed loop. In addition to the delay circuit 3, the output signal from the adder 2 is supplied to a sound signal output terminal 5, whereby a signal circulating in the closed loop is output as a musical tone signal to be generated. With the conventional tone generator described above, when the excitation signal output from the excitation signal generating circuit 1 is supplied to the first input terminal of the adder 2, the supplied excitation signal begins to circulate in the closed loop. In this case, the signal circulates around the closed loop once in the time which is equal to the period of oscillation of the vibrating string being simulated, and the band width of the signal is limited by the filter 4 each time the signal passes through the filter 4. Then, the signal circulating in the closed loop is delivered as a musical tone signal from the musical tone output terminal 5. An example of the above-described type of tone generator has been disclosed in Japanese Patent Publication No. 58-48109.

In the above conventional electronic musical instrument comprising the above conventional tone generator, the variation of tone colors of the musical tones to be synthesized is limited and is a drawback in obtaining musical tone with a certain feeling of pitch and high quality, and in many cases where the pitch and the spectral



construction of the excitation signal supplied to the closed loop must correspond to a pitch designated by a performer.

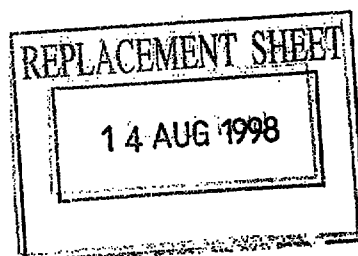
By increasing the loop gain of the closed loop (the filter with the comb-formed frequency characteristics), the comb-formed frequency characteristics of the entire closed loop for the signal circulating become sharper, so that the feeling of the pitch is improved. However, in this case, the stability of the operation of the closed loop decreases, and in the worst case there is drawback in that the closed loop self-oscillates. Accordingly, there is a drawback in that the reliability of the system is degraded.

EP-A-0 393 701 discloses a musical tone synthesizing apparatus including a reverberation effect applying apparatus. The reverberation effect applying apparatus comprises several loops connected in parallel. Each loop simulates a certain sound transmission path and consists of shift registers, phase inverters and adders.

Summary of the Invention

In consideration of the above, it is an objective of the present invention to provide an electronic musical instrument which is capable of generating the musical tone with a great variety of spectral constructions under no influence of the kind of the waveform of the excitation signal and with a rich variation of tone color of the musical tone, and which is capable of stable closed loop operation, and which is capable of constructing a system with high reliability.

To satisfy these objectives, the present invention provides an electronic musical instrument comprising: an excitation signal generating means for generating an excitation signal in accordance with musical tone designating information; a plurality of loop means for at least



delaying an input signal in response to said musical tone designating information and repeatedly circulating said signal, said excitation signal being supplied to at least one of said plurality of loop means; characterized by coupling designation means for generating coupling designation data in accordance with a tone color of the musical tone to be generated; and coupling means for coupling said plurality of loop means in accordance with said coupling designation data, wherein a signal circulated in at least one of said plurality of loop means is output as a musical tone signal.

According to such a structure, the plurality of loop means, which is coupled to each other in accordance with the predetermined coupling form, at least delays the supplied excitation signal in response to the musical tone designating information to and repeatedly circulates the signal. The signal gradually changes into a signal having a desirable waveform in response to the coupling form while circulating in the plurality of loop means. Accordingly, the signal circulated in one of any plurality of loop means is delivered as a musical tone signal.

According to the present invention, a positive effect is that the musical tone can be generated with a great variety of spectral constructions under no influence of the kind of the waveform of the excitation signal and with the rich variation of tone color of the musical tone. Furthermore, there is the positive effect that a system with high reliability can be constructed so that the closed loop operates stably.

Brief Explanation of the Drawings

Fig. 1 shows a block diagram of the electrical structure of an electronic musical instrument based on the preferred embodiment of the present invention.

Fig. 2 shows a block diagram of the electrical structure of a resonance portion 19.

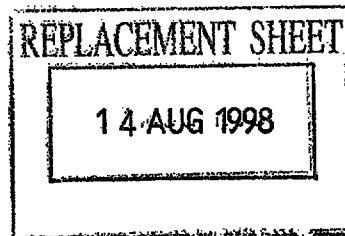


Fig. 3 shows a block diagram of the electrical structure of a signal synthesis portion 21.

Fig. 4 shows a block diagram of the electrical structure of a LOOP 42.

Fig. 5 shows a block diagram of the electrical structure of a signal synthesis portion 49.

Figs. 6 through 9 show block diagrams of examples of the algorithms constructed by the LOOPS 42₁ through 42₄.

Fig. 10 shows an example of the frequency characteristics corresponding to the block diagram of Fig. 9.

Fig. 11 shows a block diagram of other example of the algorithm constructed by the LOOPS 42₁ through 42₄.

Fig. 12 shows an example of the frequency characteristics corresponding to each of the LOOPS 42₁ and 42₂ of Fig. 11.

Fig. 13 shows an example of the frequency characteristics corresponding to the block diagram of Fig. 11.

Fig. 14 shows a block diagram of other example of the algorithm constructed by the LOOPS 42₁ through 42₄.

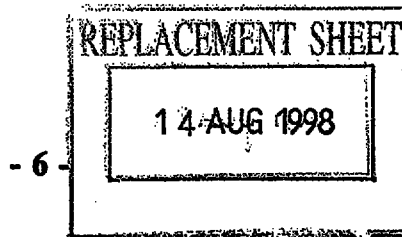
Fig. 15 shows an example of the frequency characteristics corresponding to the block diagram of Fig. 14.

Fig. 16 shows a block diagram of other example of the algorithm constructed by the LOOPS 42₁ through 42₄.

Fig. 17 shows an example of the frequency characteristics corresponding to the block diagram of Fig. 16.

Fig. 18 shows a block diagram of another electrical structure of the resonance portion 19.

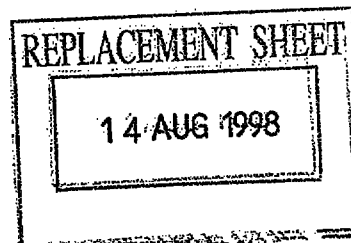
Fig. 19 shows a block diagram of a structural example of the conventional physical-modal tone-generator simulating a stringed instrument.



Detailed Description of the Preferred Embodiments

Hereinafter, an explanation of the preferred embodiment of the present invention is given with reference to the figures. Fig. 1 shows a block diagram of the structure of an electronic musical instrument in accordance with the preferred embodiment of the present invention. In this figure, manually operable performance members 6 such as a keyboard, manually operable members 7 for setting musical tone parameter designating a musical tone parameter such as a tone color, and a control portion 8 controlling all apparatuses, are provided.

Moreover, an excitation signal generating portion 9 is provided which comprises a waveform generating portion 10 which generates a signal including a rich overtone with the required waveform based on data WAVE for designating the waveform of the generated signal, a key-on signal KON for designating the generating timing of the generated signal and a pitch data PITCH for designating the pitch of the generated signal from the control portion 8. The excitation signal generating portion 9 further comprises a noise signal generating portion 11 which generates a noise signal such as a white noise signal; each of the filters 12 and 13 append the desired characteristics to the output signal from the waveform generating portion 10 and the noise signal generating portion 11 based on coefficient data FLT_1 and FLT_2 from the control portion 8, respectively. The output signal from the filter 12 is supplied to a multiplier 14 which multiplies it by an amplitude control signal AMP_1 from the control portion 8. The output signal from the filter 13 is supplied to a multiplier 15 which multiplies it by an amplitude control signal AMP_2 from the control portion 8. Each of the output signals from the multipliers 14 and 15 are supplied to first and second terminals of an adder 16 which adds the former and the later and delivers an excitation signal.

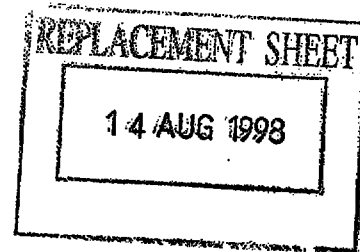


Furthermore, the output signal from the adder 16 of the excitation signal generating portion 9, namely the excitation signal, is supplied to a filter 17 which appends the desired characteristics to it based on the coefficient data FLT_3 from the control portion 8. The output signal from the filter 17 is supplied to a multiplier 18 which multiplies it by an amplitude control signal AMP_3 from the control portion 8. The output signal from the multiplier 18 is supplied to a resonance portion 19 which simulates the resonance phenomenon of the non-electronic musical instrument. The resonance portion 19 appends the desired characteristics to the output signal from the multiplier 18 based on data ALG for designating the combinations (the connection forms, namely algorithms) of a plurality of resonance elements (loop circuits described below) forming the resonance portion 19, data MIX for designating the synthesis coefficient for synthesizing the output signals from each of the loop circuits, data DLY_n ($n=1$ through 4, etc.) corresponding to the delay period of each of the loop circuits, the coefficient LPF_n of low pass filters (LPF) forming each of the loop circuits, the coefficient APF_n of all pass filters (APF) forming each of the loop circuits, the coefficient HPF_n of high pass filters (HPF) forming each of the loop circuits and loop gain LG_n of each of the loop circuits, from the control portion 8. Thus, the resonance portion 19 delivers output signals as the musical tone signals of each of the channels L and R.

The coefficient data FLT_1 through FLT_3 and the amplitude control signals AMP_1 through AMP_3 may be constant or variable over time. Next, Fig. 2 shows a block diagram of the electrical structure of the resonance portion 19. In this figure, a resonance elements control portion 20 is provided which determines multiplicative coefficients m_{11} through m_{14} , m_{21} through m_{24} , m_{31} through m_{34} , and m_{41} through m_{44} of each of multipliers

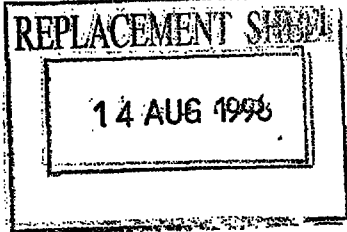
22 through 37 (see Fig. 3) in a signal synthesis portion 21 based on the data ALG from the control portion 8 and delivers these to the multipliers 22 through 37. In Fig. 3, the multipliers 22, 26, 30, and 34 multiply input signals; that is, the output signal from the multiplier 18 shown in Fig. 1, by multiplicative coefficients m_{11} , m_{21} , m_{31} , and m_{41} , respectively. The multipliers 23 through 25 multiply output signals LO_2 through LO_4 from loop circuits 42₂ through 42₄ described below by multiplicative coefficients m_{12} through m_{14} , respectively. An adder 38 adds the output signals from each of the multipliers 22 through 25 and delivers an output signal LI_1 . The multipliers 27 through 29 multiply output signals LO_1 , LO_3 , and LO_4 from loop circuits 42₁, 42₃, and 42₄ described below by multiplicative coefficients m_{22} through m_{24} , respectively. An adder 39 adds the output signals from each of the multipliers 26 through 29 and delivers an output signal LI_2 . The multipliers 31 through 33 multiply output signals LO_1 , LO_2 , and LO_4 from loop circuits 42₁, 42₂, and 42₄ described below by multiplicative coefficients m_{32} through m_{34} , respectively. An adder 40 adds the output signals from each of the multipliers 30 through 33 and delivers an output signal LI_3 . The multipliers 35 through 37 multiply output signals LO_1 through LO_4 from loop circuits 42₁ through 42₃ described below by multiplicative coefficients m_{42} through m_{44} , respectively. An adder 41 adds the output signals from each of the multipliers 34 through 37 and delivers an output signal LI_4 . Thus, the signal synthesis portion 21 synthesizes the output signal from the multiplier 18 and the output signals from the loop circuits 42₁ through 42₄ and delivers the synthesized signals, namely, the output signals from the adders 38 through 41 to the loop circuits 42₁ through 42₄, respectively.

In Fig. 2, the loop circuits (hereinafter referred to as LOOP) 42₁ through 42₄ having the same electrical structure are provided. Fig. 4 shows a block diagram of the electrical structure of the LOOP 42. In this figure, a high



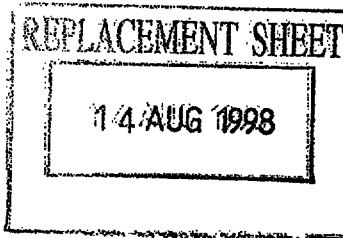
pass filter (HPF) 43 is provided, which cuts off the low frequency component of an input signal, that is, the output signal LI from the signal synthesis portion 21 based on a coefficient HPF_n from the control portion 8 via the resonance elements control portion 20. The output signal from the HPF43 is supplied to a first input terminal of an adder 44. The output signal from the adder 44 is supplied to a low pass filter (LPF) 45 which cuts off the high frequency component of it based on a coefficient LPF_n from the control portion 8 via the resonance elements control portion 20. The output signal from the LPF 45 is supplied to an all-pass filter (APF) 46 in which the phase difference between an input signal and an output signal changes in response with the frequency of the signals based on a coefficient APF_n from the control portion 8, via the resonance elements control portion 20. The output signal from the APF 46 is supplied to a delay circuit (DELAY) 47 which delays it for the desired delay period based on data DLY_n from the control portion 8, via the resonance elements control portion 20. The output signal from the DELAY 47 is supplied to a multiplier 48 which multiplies it by a loop gain LG_n from the control portion 8, via the resonance elements control portion 20. The resonance frequency pitches of each of the LOOPS 42₁ through 42₄ are decided by the total sum of the delay time of each of the LPF 45, the APF 46 and the DELAY 47 which is the construction element in the closed loop, that is, the total sum of the delay period of the closed loop. Accordingly, the delay period of the DELAY 47 must be designated based on the data DLY_n in consideration of the delay characteristics of the filters (i.e., the LPF45 and the APF46) in the closed loop to control the tone pitch.

Moreover, in Fig. 2, a signal synthesis portion 49 is provided which synthesizes the output signals from each of the LOOPS 42₁ through 42₄ and delivers output



signals as the musical tone signals of each of the channels L and R. The resonance elements control portion 20 decides multiplicative coefficients k_{1L} through k_{4L} , and k_{1R} through k_{4R} , of each of the multipliers 50 through 57 (see Fig. 5) in a signal synthesis portion 49 based on the data MIX from the control portion 8 and delivers these to the multipliers 50 through 57. In Fig. 5, the multipliers 50 and 54 multiply input signals, namely, the output signal from the LOOP 42₁ shown in Fig. 2 by multiplicative coefficients k_{1L} and k_{1R} , respectively. The multipliers 51 and 55 multiply input signals, namely, the output signal from the LOOP 42₂ shown in Fig. 2 by multiplicative coefficients k_{2L} and k_{2R} , respectively. The multipliers 52 and 56 multiply input signals, namely, the output signal from the LOOP 42₃ shown in Fig. 2 by multiplicative coefficients k_{3L} and k_{3R} , respectively. The multipliers 53 and 57 multiply input signals, namely, the output signal from the LOOP 42₄ shown in Fig. 2 by multiplicative coefficients k_{4L} and k_{4R} , respectively. The adder 58 is provided which adds the output signal from the multipliers 50 through 53 and delivers the additional result as the musical tone signal OUTL of the channel L. The adder 59 is provided which adds the output signal from the multipliers 54 through 57 and delivers the additional result as the musical tone signal OUTR of the channel R.

When the control portion 8 delivers one data ALG to designate the combinations (the connection forms, namely algorithms) of the LOOPS 42₁ through 42₄, the resonance elements control portion 20 determines the multiplicative coefficients m_{11} through m_{14} , m_{21} through m_{24} , m_{31} through m_{34} , and m_{41} through m_{44} of each of multipliers 22 through 37 in the signal synthesis portion 21 (shown in Fig. 3) based on the data ALG and delivers these to the multipliers 22 through 37. Accordingly, the



algorithm (the connection form) of the LOOPS 42_1 through 42_4 are, for example, designated as shown in Figs. 6(A) through 6(C), 7(A) through 7(C), 8(A), and 8 (B). Next, when the control portion 8 delivers one data MIX to designate the synthesis coefficient of the output signal from each of the LOOPS 42_1 through 42_4 , the resonance elements control portion 20 decides the multiplicative coefficients k_{1L} through k_{4L} , and k_{1R} through k_{4R} , of each of the multipliers 50 through 57 in the signal synthesis portion 49 (shown in Fig. 5) based on the data MIX and delivers these to the multipliers 50 through 57. Accordingly, the output signals from the algorithm of the LOOPS 42_1 through 42_4 , for example, as shown in Figs. 6(A) through 6(C), 7(A) through 7(C), 8(A), and 8(B), are variously synthesized over great range.

As described above, when the control portion 8 delivers the data ALG and MIX to the resonance portion 19, the combination of the LOOPS 42_1 through 42_4 of the resonance portion 19 can be variously constructed over great range.

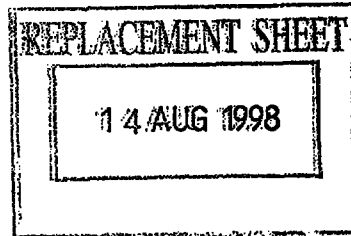
When synthesizing musical tones with a certain feeling of the pitch and with high quality, the control portion 8 delivers the data ALG and MIX to the resonance portion 19 to connect the LOOPS 42_1 and 42_2 in series as shown in Fig. 9. When the performer depresses, for example, the key of the keyboard of the performance manually operable member 6 corresponding to the note C, the keyboard delivers key data such as the tone pitch corresponding to the note C. The input portion of the touch (not shown) detects the initial touch and the after touch of each of the keys of the keyboard, and generates the touch data indicating the force of the touch and delivers these to the control portion 8. Then, the control portion 8 delivers the loop gain LG_1 and G_2 , the coefficient LPF_1 and LPF_2 , the coefficient APF_1 and APF_2 , and the coefficient HPF_1 and HPF_2 for the key data, the

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touch data, the tone color and the like corresponding to C note to the resonance portion 19 to designate the fundamental frequency pitch of each of the LOOP 42₁ and 42₂ to the frequency f1. In addition, the control portion 8 delivers to the resonance portion 19 the resultant value which the above-mentioned value; such as the delay period of the LPF 45 and the APF 46; are subtracted from the phase delay period of the entire loop (see Fig. 9) corresponding to the note C as the delay period of the DELAY 47. Accordingly, the resonance elements control portion 20 in the resonance portion 19 delivers these data to the HPF43, the LPF45, the APF46, the DELAY47, and the multiplier 48 of each of the LOOPS 42₁ and 42₂.

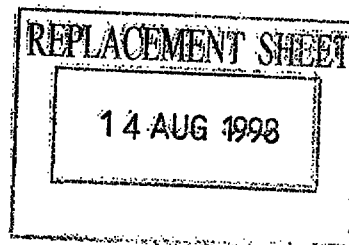
Next, the control portion 8 delivers the data WAVE, the key-on signal KON and the pitch data PITCH to the waveform generating portion 10 in the excitation signal generating portion 9 and delivers the coefficient data FLT₁ and FLT₂ to the filters 12 and 13, respectively and delivers the amplitude control signals AMP₁ and AMP₂ to the multipliers 14 and 15, respectively. In this case, the amplitude control signals AMP₁ and AMP₂ are designated so that the ratio of the output signal from the filter 12 to the output signal from the filter 13 becomes higher. Furthermore, the control portion 8 supplies the coefficient data FLT₃ to the filter 17 and supplies the amplitude control signals AMP₃ to the multiplier 18.

Thus, the waveform generating portion 10 generates the generated signal having the waveform designated by the data WAVE with the generating timing designated by the key-on signal KON and the pitch designated by the pitch data PITCH and supplies it to the filter 12. The filter 12 appends the desired characteristics to the generated signal based on the coefficient data FLT₁. The multiplier 14 multiplies the output signal from the



filter 12 by the amplitude control signal AMP_1 . In contrast, the filter 13 appends the desired characteristics to the noise signal, such as white noise signal from the noise generating portion 11, based on the coefficient data FLT_2 . The multiplier 15 multiplies the output signal from the filter 13 by the amplitude control signal AMP_2 . Then, the adder 16 adds the output signals from the multipliers 14 and 15 and delivers the resultant signal as the excitation signal to the filter 17.

Next, the filter 17 appends the desired characteristics to the excitation signal based on the coefficient data FLT_3 from the control portion 8. The multiplier 18 multiplies the output signal from the filter 17 by the amplitude control signal AMP_3 from the control portion 8 and supplies its output signal to the resonance portion 19. Accordingly, in the resonance portion 19, the HPF 43 in the LOOP 42₁ cuts off the low frequency component of the input signal, that is, the output signal from the multiplier 18 based on the coefficient HPF_n from the control portion 8 via the resonance elements control portion 20. The output signal from the HPF 43 is supplied to the first input terminal of the adder 44. The output signal from the adder 44 is fed back to the second terminal of the adder 44 via the LPF 45, the APF 46, and the multiplier 48. Thus, the phase difference between each of the frequency components of the output signal from the HPF 43 varies and the level of the output signal from the HPF 43 gradually decreases as the output signal of the HPF 43 repeatedly circulates in the closed loop formed by the adder 44, the LPF 45, the APF 46, the DELAY 47 and the multiplier 48. Next, in the LOOP 42₂, the output signal from the APF 46 of the LOOP 42₁, namely, the output signal LO_1 from the LOOP 42₁ is supplied to the

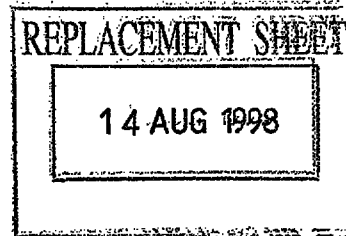


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LOOP 42_2 and is treated in the same way as in the LOOP 42_1 . Accordingly, the output signal from the APF 46 of the LOOP 42_2 , in other words, the output signal LO_2 from the LOOP 42_2 is supplied to the signal synthesis portion 49. The signal synthesis portion 49, that is, the resonance portion 19 delivers the output signals as the musical tone signals OUTL and OUTR of each of the channels L and R.

As described above, since the resonance portion 19 comprises the LOOPS 42_1 and 42_2 connected in series and the fundamental frequency pitch of each of the LOOPS 42_1 and 42_2 is designated to the frequency f_1 , the frequency characteristic of the whole resonance portion 19 becomes the frequency characteristic of the curve a shown in Fig. 10. In Fig. 10, curve b shows the frequency characteristic of each of the LOOPS 42_1 or 42_2 and the frequency interval f_1 is one which the human ear recognizes as the pitch. As shown by Fig. 10, in the case where the LOOPS 42_1 and 42_2 having approximately the same frequency characteristics and are connected in series, the comb-formed frequency characteristic as a whole becomes sharper than one of each of the LOOPS 42_1 or 42_2 , and a musical tone with a certain feeling of the pitch and with high quality can be synthesized.

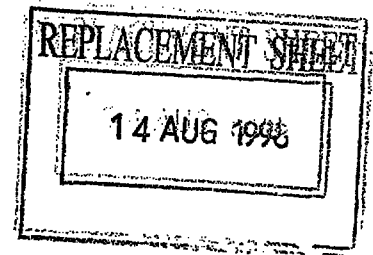
The musical tone made using a non-electronic musical instrument not only has a simple line spectrum, but also has a spectrum in which the noisy components lie near the original overtone, and furthermore contains irregularities. For example, in the case where the electronic musical instrument of the above-mentioned embodiment synthesizes similar musical tones to the musical tone having irregularities made using the non-electronic musical instrument, the control portion 8 may designate the amplitude control signals AMP_1 and AMP_2 so that the ratio of the output signal from the filter 13 to the output signal from the filter 12 becomes higher.



When the resonance portion 19 comprises a similar connection to the one shown in Fig. 9, the fundamental frequency pitch of the LOOP 42₁ is designated as the frequency f_1 (see curve a in Fig. 12), the fundamental frequency pitch of the LOOP 42₂ is designated to the frequency $3f_1$ (see curve b in Fig. 12) as shown in Fig. 11, and the frequency characteristic of the whole resonance portion 19 becomes the frequency characteristic as shown in Fig. 13.

When the resonance portion 19 comprises further the LOOPS 42₁ and 42₂ connected in parallel and an adder 60 adding the output signals from each of the LOOPS 42₁ and 42₂ as shown in Fig. 14, the fundamental frequency pitch of the LOOP 42₁, which corresponds to the delay period of the LOOP 42, is designated to the frequency f_1 , and the fundamental frequency pitch of the LOOP 42₂ is designated to the frequency which shifts by the frequency Δf against the frequency f_1 . The frequency characteristic of the whole resonance portion 19 becomes somewhat similar to the frequency characteristic which both of the fundamental frequency pitch and the overtone frequency shift, as shown by the curve b in Fig. 15. Accordingly, the electronic musical instrument of the above-mentioned embodiment can synthesize the musical tone with a detuning effect in which the musical interval is finely shifted and with the sound effects of a chorus. In Fig. 15, the frequency component of curve a is practically removed by the HPF 43 (see Fig. 4) in the LOOP 42.

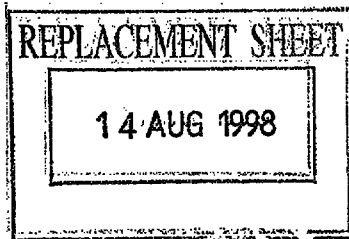
Moreover, the resonance portion 19 is constructed as a construction in which the LOOPS 42₁ and 42₂ are connected in parallel, a multiplier 61 multiplies the output signal from the LOOP 42₁ by a multiplicative coefficient k_{L1} , a multiplier 62 multiplies the output signal from the LOOP 42₂ by a multiplicative coefficient k_{L2} and an



adder 60 adds the output signals from each of the multipliers 61 and 62 as shown in Fig. 16. The multipliers 61 and 62 correspond to the multiplier 48 and 50 through 57 in the signal synthesis portion 49 shown in Figs. 2 and 5. When the fundamental frequency pitch f_1 and f_2 of each of the LOOPS 42₁ and 42₂, which corresponds to each of the data DLY₁ and DLY₂, and the loop gain LG₁ and LG₂ are adjusted and the output levels of each of the LOOPS 42₁ and 42₂ is adjusted by modifying the multiplicative coefficients k_{L1} and k_{L2} , the specific row of the overtone component appearing in every pitch difference between the fundamental frequency pitches f_1 and f_2 can be independently controlled in every row. For example, when the loop gain LG₂ of the LOOP 42₂ and the multiplicative coefficient k_{L2} of the multiplier 62 are adjusted, the gain can be independently controlled every row of each of the overtone components as shown by the arrow in Fig. 17; thus, the musical tone having the desired overtone construction can be obtained.

As described above, since the resonance portion 19 is constructed so that the LOOPS 42₁ through 42₄ can be combined at random, the rich variation of tone color of the musical tone can be ensured. Since each of the LOOPS 42₁ through 42₄ can be usable in the range of stable operation, the reliability of the system becomes high. In particular, when the serial connection and the parallel connection of the LOOP 42 are included as shown in Fig. 6(B), Fig. 6(C), Figs. 7(A) through 7(C), and Fig. 8(B), the tone color and the variation of the tone color of the generated musical tone can be more varied.

As the above-mentioned embodiment of the present invention, the overtone construction of the generated musical tone is more easily anticipated than in the tone generating form using modulation such as the frequency modulated tone generating circuit, and the



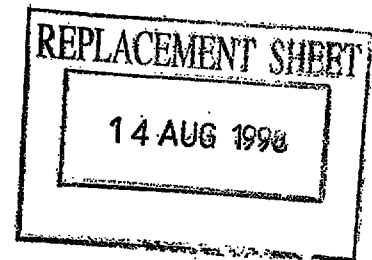
number of calculations is far less than in the tone generating form using the harmonic synthesizing form (Fourier synthesizing form).

Moreover, in the above-mentioned embodiment of the present invention, the sampling of the musical tone data with high quality and the waveform memory with large volume are not particularly necessary such as in an electronic musical instrument using the tone-generating circuit which reads the waveform data from the waveform memory.

In the above-mentioned embodiment of the present invention, it is described that the resonance portion 19 is simply constructed by a combination of the LOOPS 42₁ through 42₄; however, for example, the resonance portion 19 may be constructed in which an interstage process circuit 63 is inserted between the LOOP 42₁ and the LOOP 42₂ as shown in Fig. 18. In this case, as the interstage process, for example, the following processes can be employed.

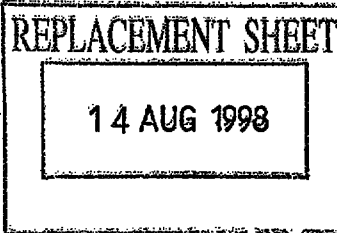
The processes are ones in which the output signal from the LOOP 42₁ is nonlinearly processed using a nonlinear table, in which the amplitude of the output signal from the LOOP 42₁ is controlled using such as a compressor or a limiter, or in which the sound effects of every kind such as reverberation, delay, and chorus is given for the output signal from the LOOP 42₁.

In the above-mentioned embodiment of the present invention, it is described that the LOOPS 42₁ and 42₄ are combined so that the resonance elements control portion 20 determines the multiplicative coefficients m_{11} through m_{14} , m_{21} through m_{24} , m_{31} through m_{34} , and m_{41} through m_{44} , of each of the multipliers 22 through 37 of the signal synthesis portion 21 based on the data ALG from the control portion 8 and supplied to these; however, the present invention is not limited by the above-mentioned embodiment. For example, the



LOOPS 42₁ and 42₄ may be combined so that an internal memory in which is pre-stored a plurality of the algorithms of the LOOPS 42₁ and 42₄ is provided in the control portion 8 and a performer selects one of these algorithms using the selection switch (not shown); thereby, the control portion 8 supplies the selected algorithm to the resonance elements control portion 20.

In the above-mentioned embodiment of the present invention, circuits corresponding to an excitation signal generating means, a plurality of loop means and coupling means in claims preferably consist of digital signal processors, respectively.



Claims

1. An electronic musical instrument comprising:

an excitation signal generating means (9) for generating an excitation signal in accordance with musical tone designating information;
a plurality of loop means (42) for at least delaying an input signal in response to said musical tone designating information and repeatedly circulating said signal, said excitation signal being supplied to at least one of said plurality of loop means (42);

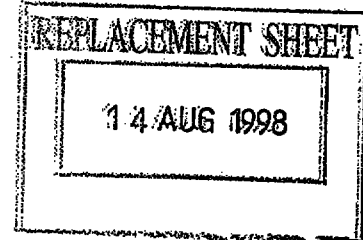
characterized by coupling designation means (20) for generating coupling designation data in accordance with a tone color of the musical tone to be generated; and

coupling means (21) for coupling said plurality of loop means in accordance with said coupling designation data, wherein a signal circulated in at least one of said plurality of loop means (42) is output as a musical tone signal.

- 2. An electronic musical instrument according to claim 1, wherein said plurality of loop means is coupled in series.**
- 3. An electronic musical instrument according to claim 1, wherein said plurality of loop means is coupled in parallel.**
- 4. An electronic musical instrument according to claim 1, wherein said plurality of loop means is coupled in series and in parallel.**

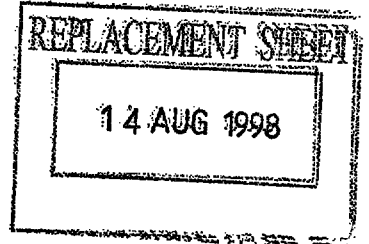


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5. An electronic musical instrument according to claim 1 further comprising a memory means for storing a plurality of coupling forms indicating how to couple input and output terminals of said plurality of loop means, wherein said coupling means couples said input and output terminals of said plurality of loop means are coupled each other based on a coupling form read from said memory means.

ELECTRONIC MUSICAL INSTRUMENT
ABSTRACT OF THE DISCLOSURE



An electronic musical instrument includes an excitation signal generating device, a plurality of loop circuits and a coupling circuit. The excitation signal generating device generates an excitation signal in accordance with musical tone designating information. Each of the plurality of loop circuits at least delays an input signal in response to the musical tone designating information and repeatedly circulates the input signal therein. The excitation signal generated by the excitation signal generating device is supplied to at least one of the plurality of loop circuits as an input signal. The coupling circuit couples the plurality of loop circuits in accordance with a predetermined coupling form. At least one signal circulated in at least one of the plurality of loop circuits is output as a musical tone signal to be generated. The electronic musical instrument further includes a memory circuit which stores a plurality of coupling forms. The coupling forms respectively indicate how to couple input and output terminals of the plurality of loop circuits. The input and output terminals are coupled to each other in accordance with one of the plurality of coupling forms.

FIGURE 1

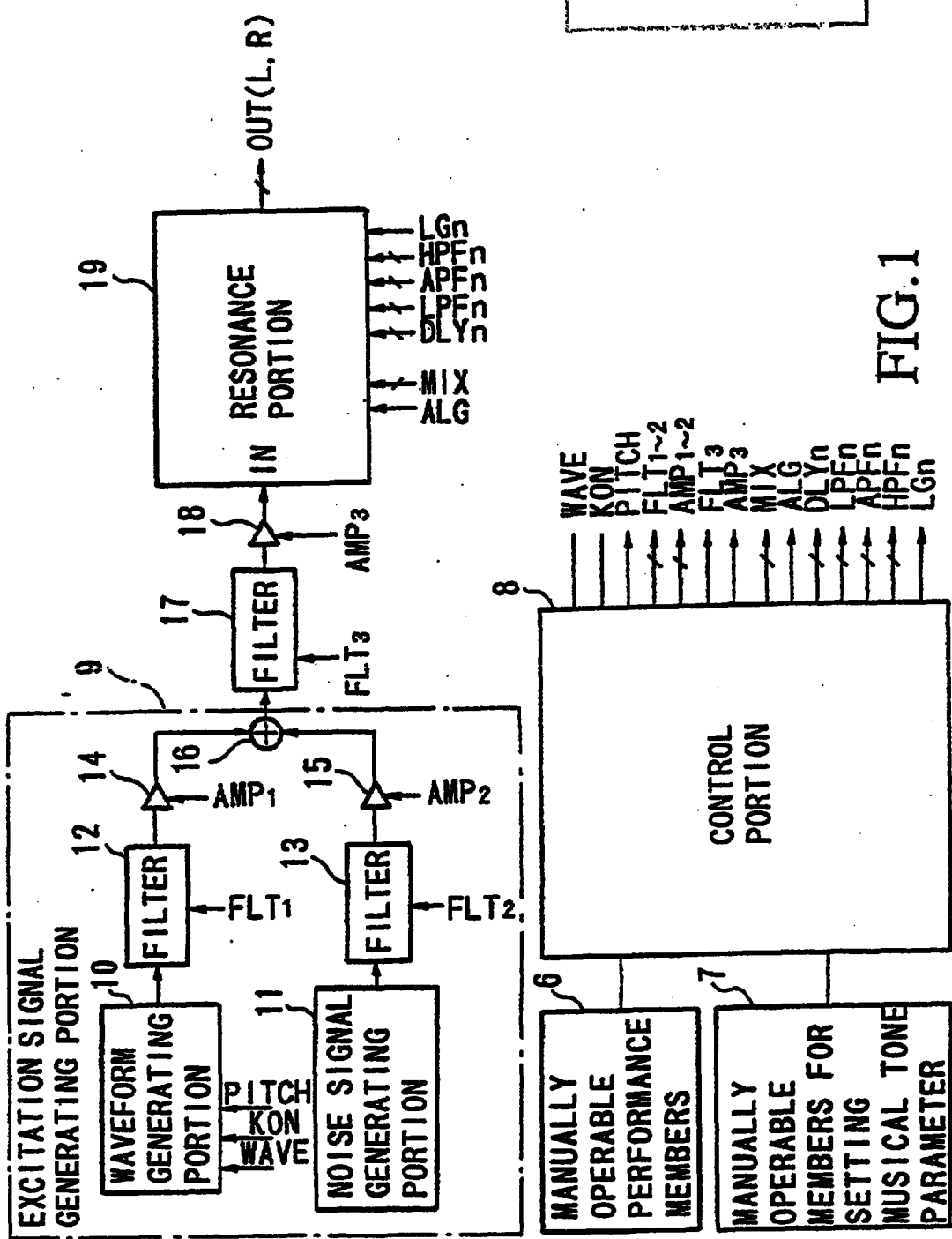


FIG.1

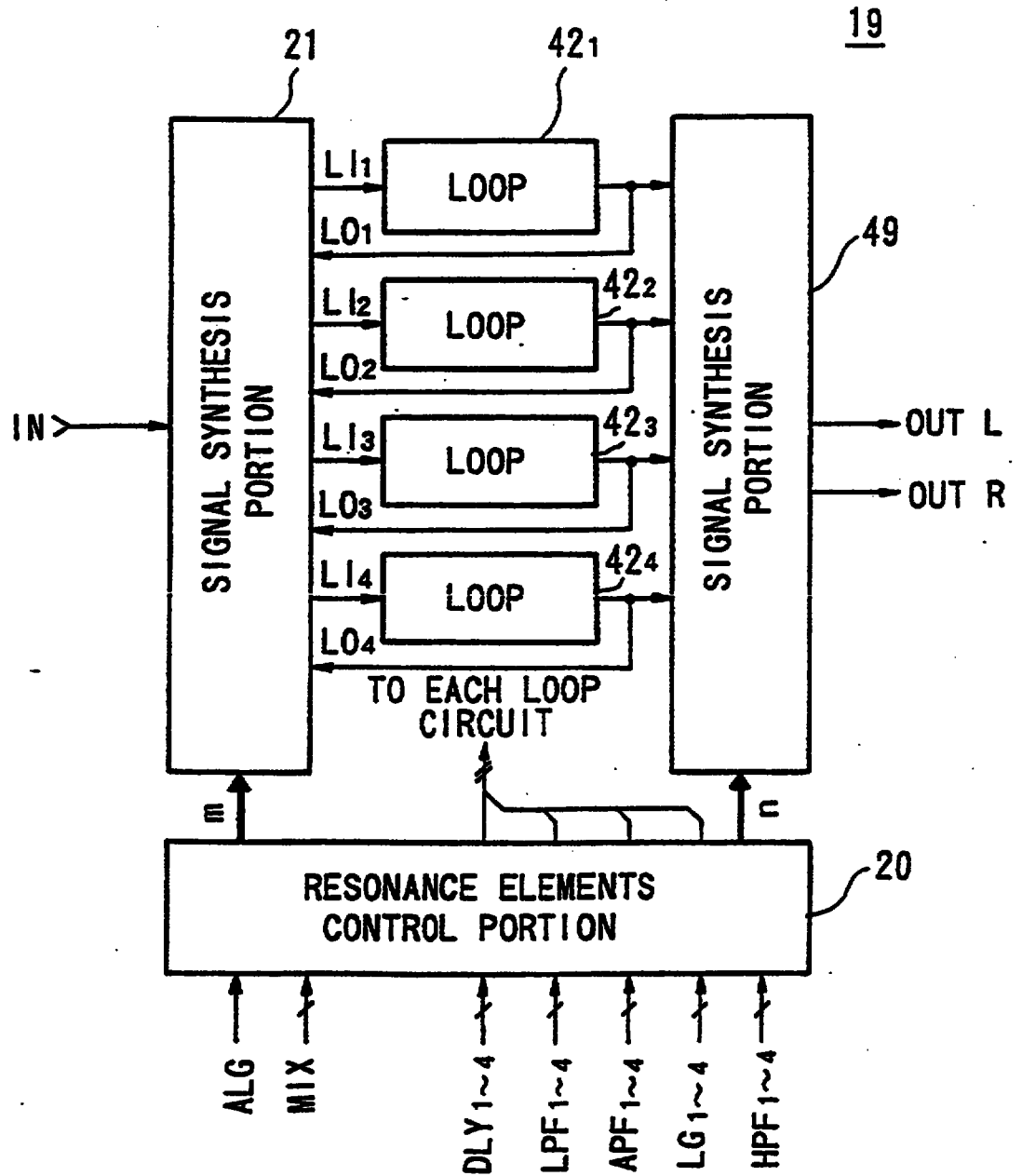


FIG.2

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- 3 -

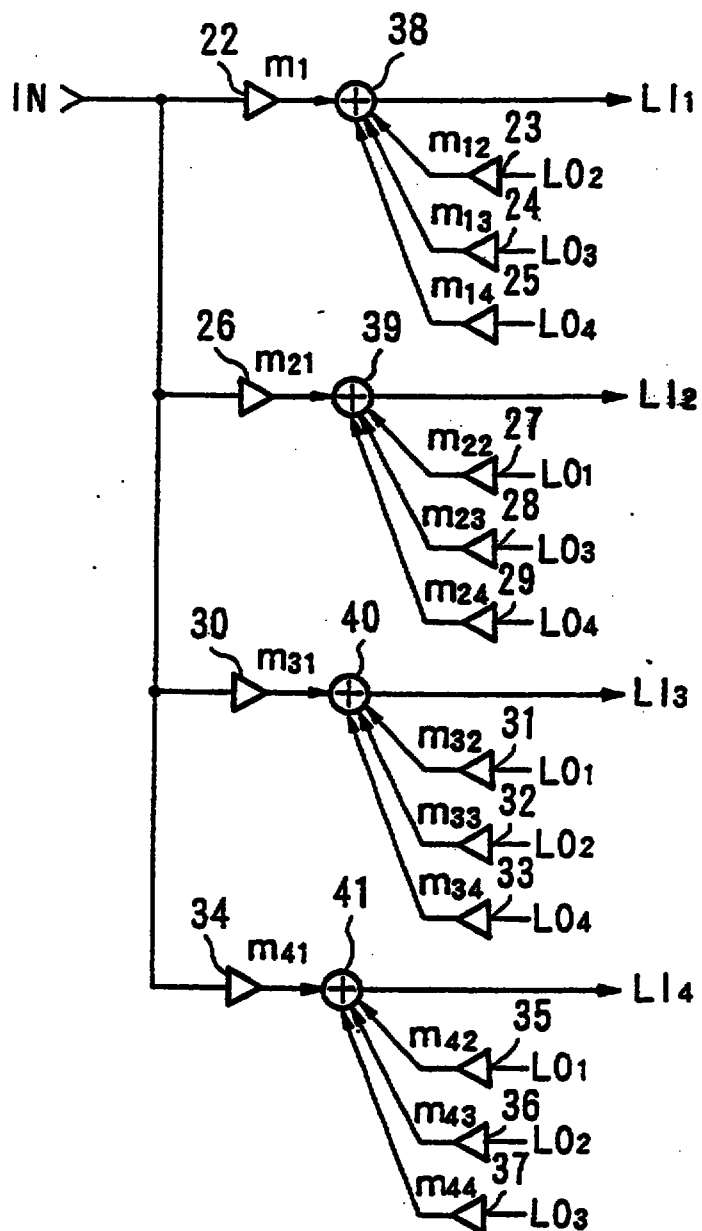
21

FIG.3

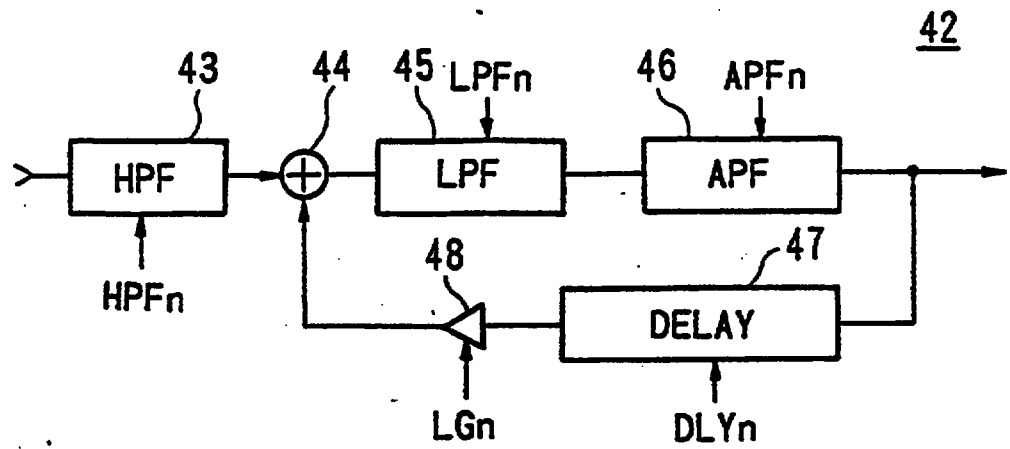


FIG.4

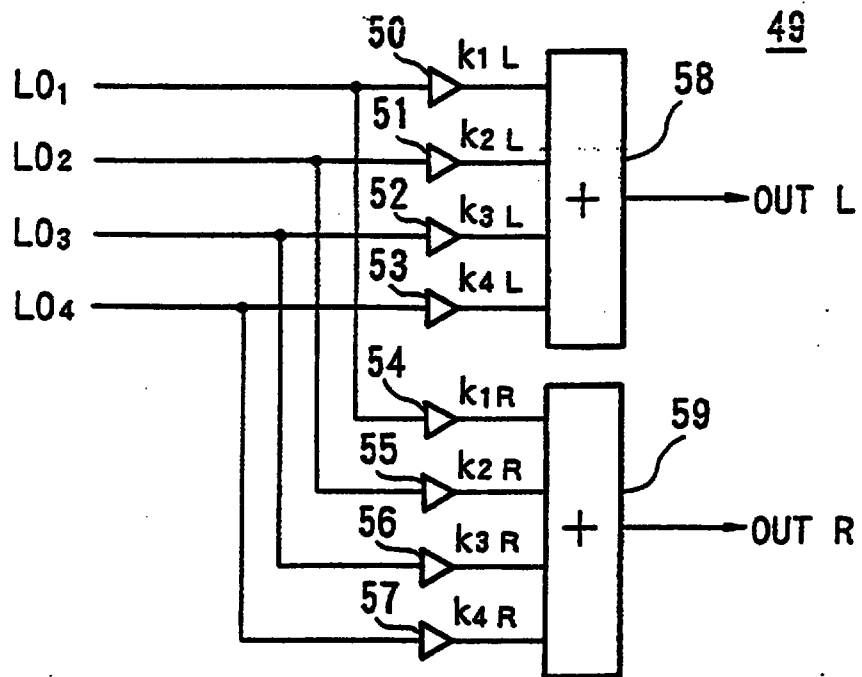
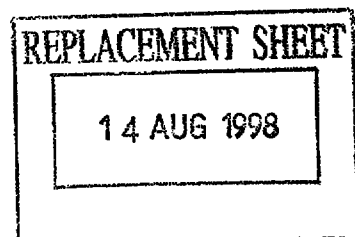


FIG.5



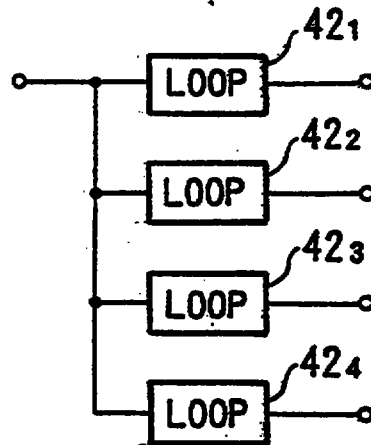


FIG. 6(A)

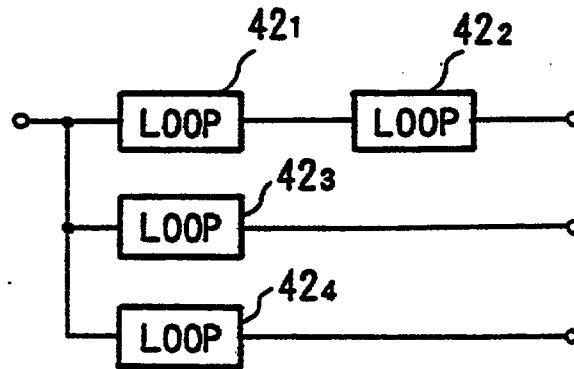


FIG. 6(B)

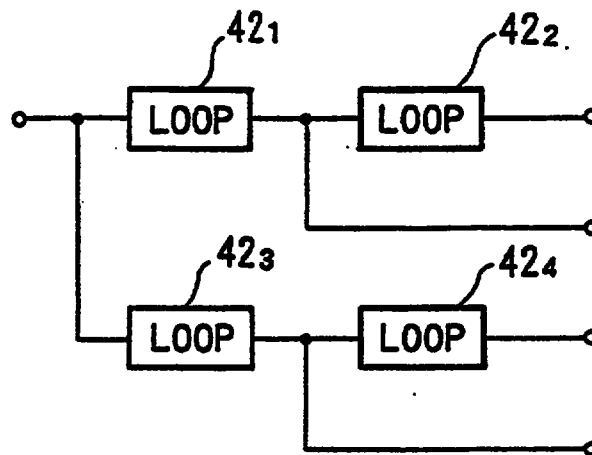


FIG. 6(C)

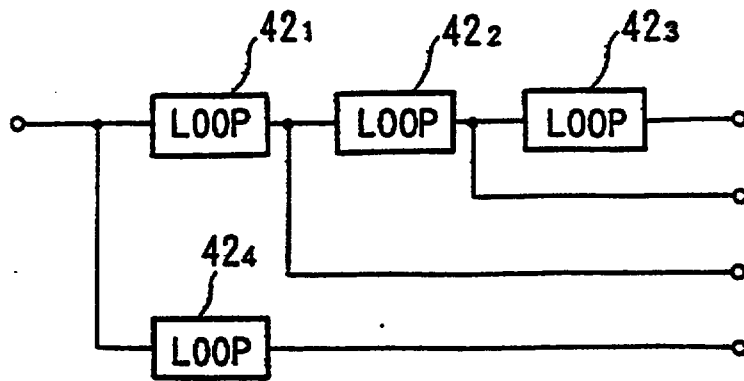


FIG. 7(A)

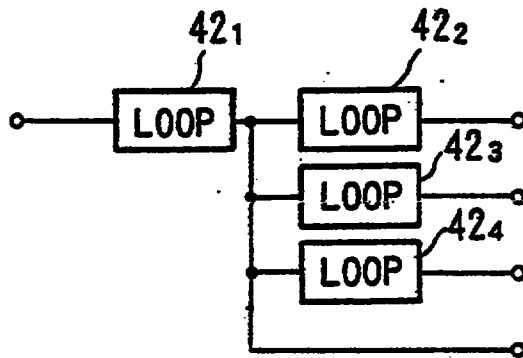


FIG. 7(B)

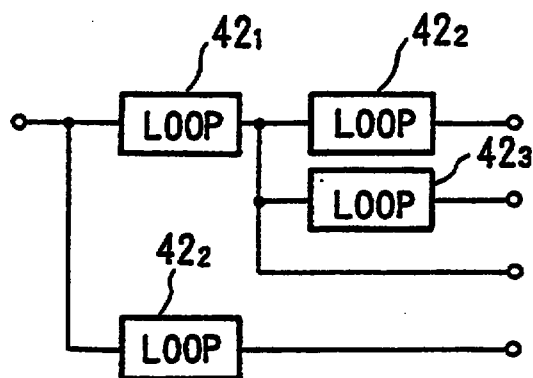
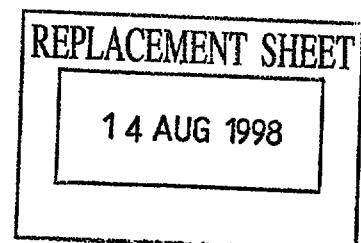


FIG. 7(C)



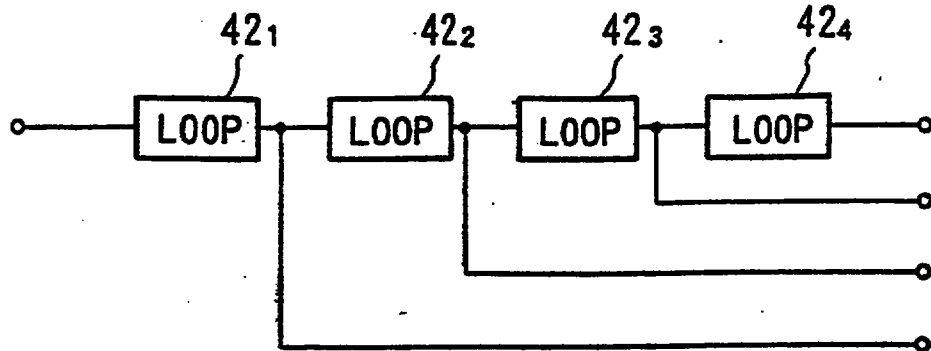


FIG.8(A)

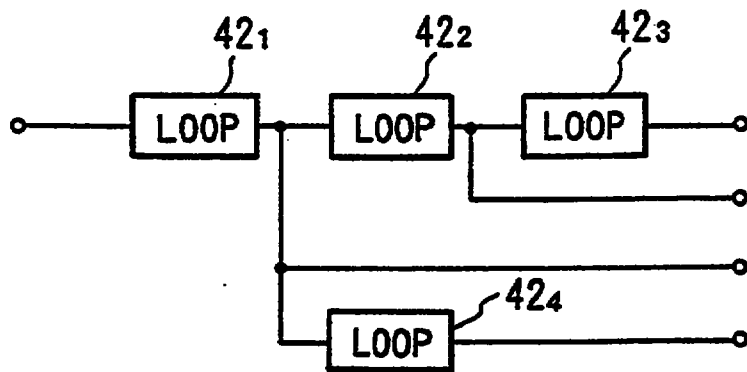
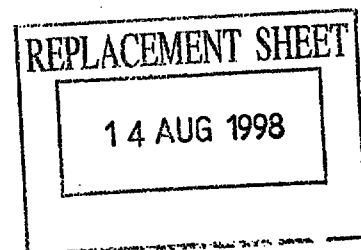


FIG.8(B)



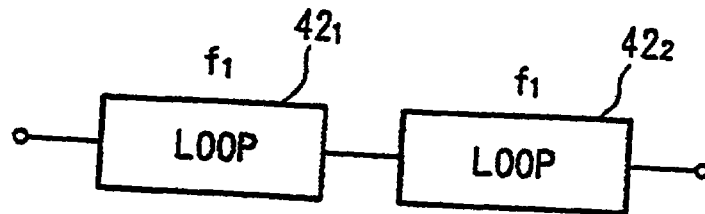


FIG.9

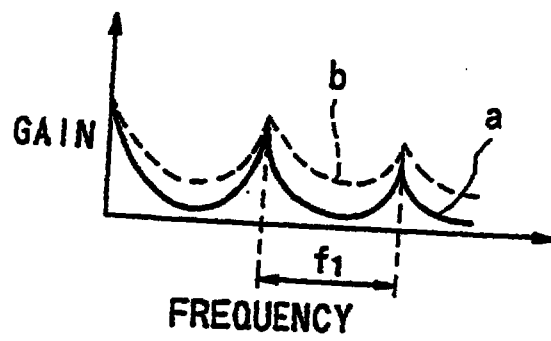


FIG.10

REPLACEMENT SHEET
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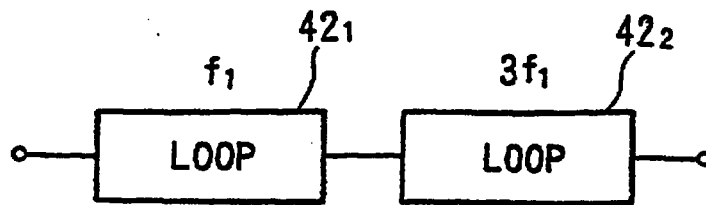


FIG.11

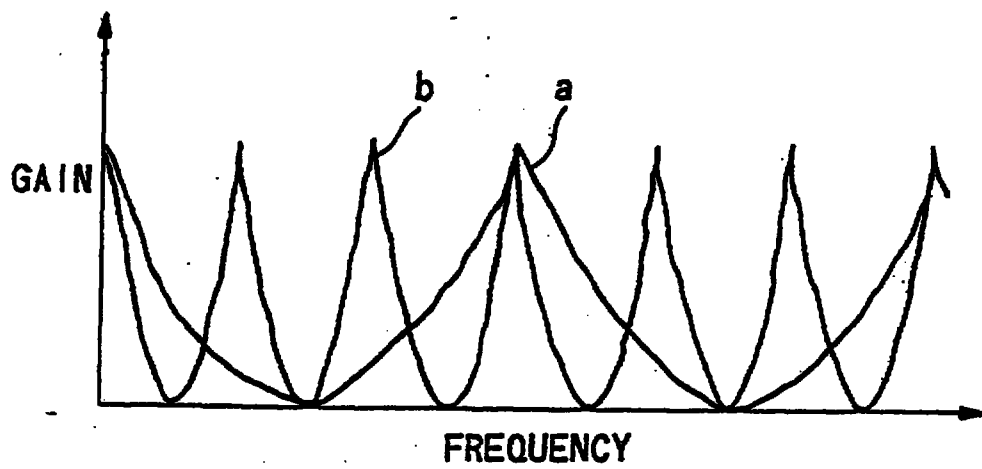


FIG.12

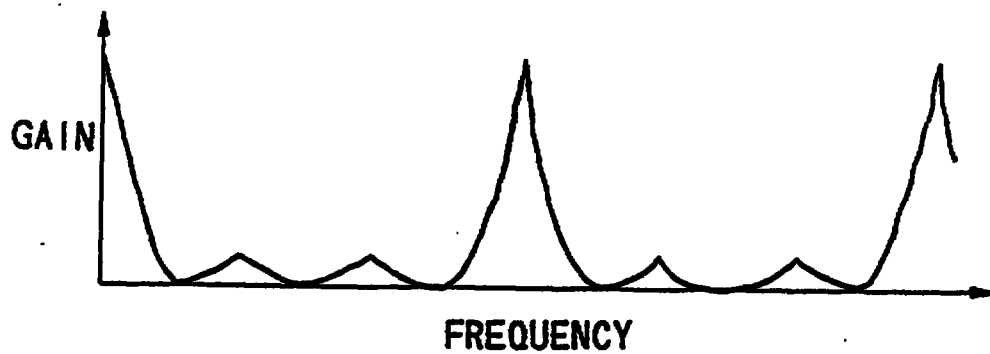


FIG.13

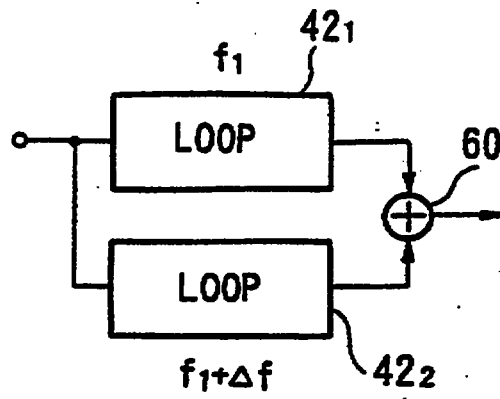


FIG.14

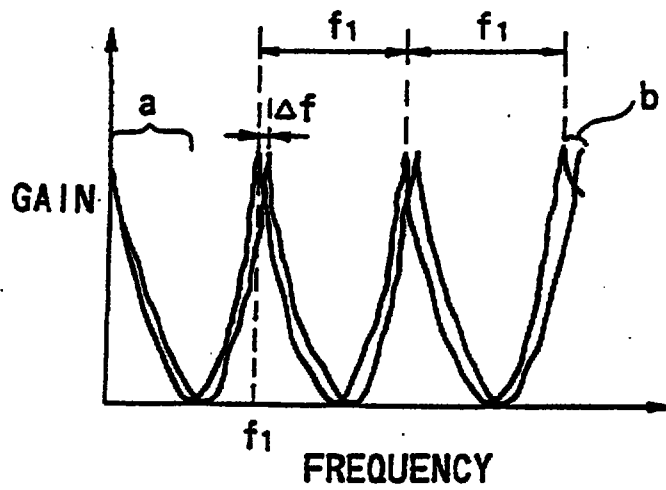
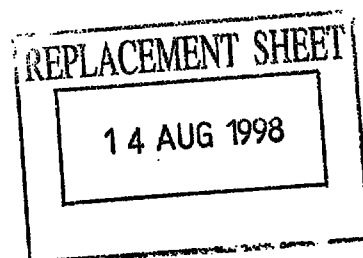


FIG.15



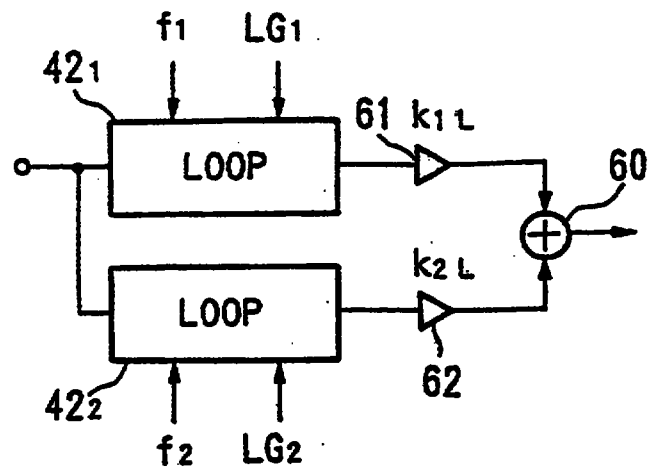


FIG.16

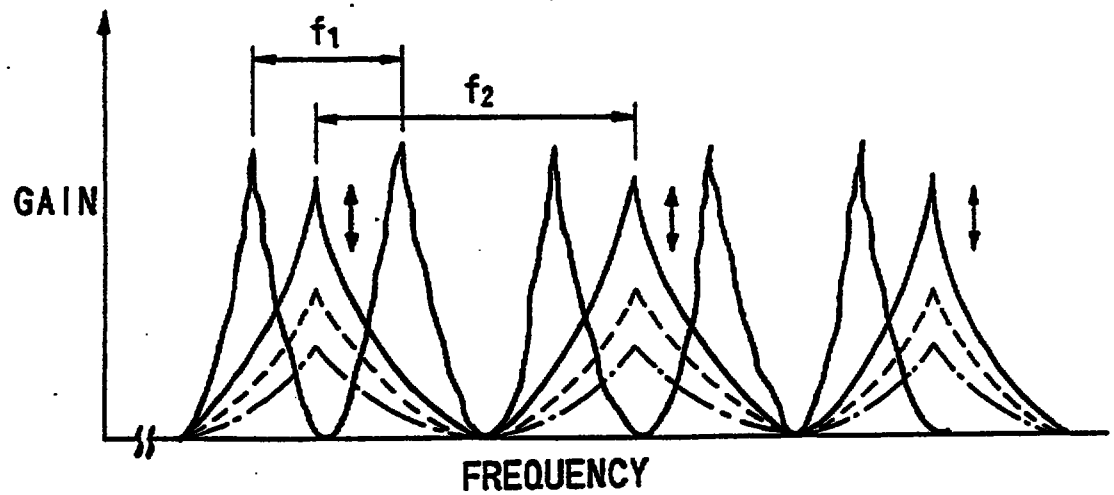
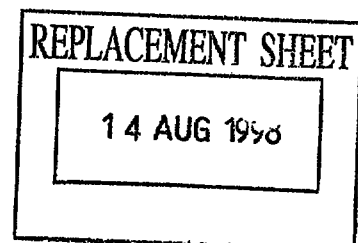


FIG.17



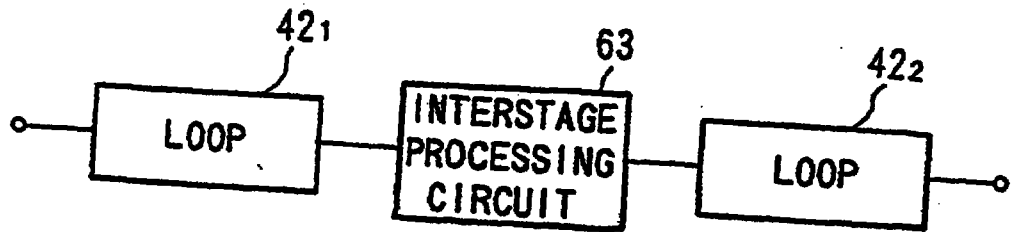


FIG.18

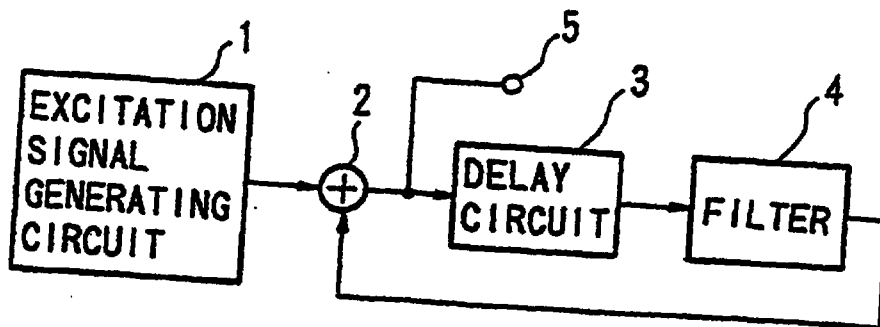


FIG.19 (PRIOR ART)

