

12 **EUROPEAN PATENT APPLICATION**

21 Application number: **80304625.9**

51 Int. Cl.³: **G 10 H 1/043**

22 Date of filing: **19.12.80**

30 Priority: **26.12.79 US 107203**
26.12.79 US 107220

71 Applicant: **CBS INC, 51, West 52nd Street, New York**
New York 10019 (US)

43 Date of publication of application: **08.07.81**
Bulletin 81/27

72 Inventor: **Schmoll, George F. III, 28 West Woodlawn**
Drive, Mundelein Illinois 60060 (US)
Inventor: **Finch, Robert A., R. 50 Martin Drive, Mundelein**
Illinois 60060 (US)

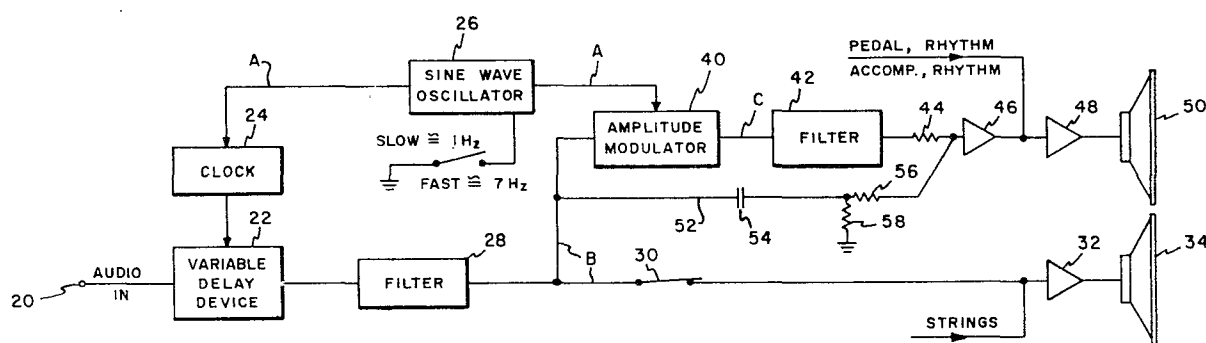
84 Designated Contracting States: **GB IT NL**

74 Representative: **Abbott, Leonard Charles et al, GILL**
JENNINGS & EVERY 53/64 Chancery Lane, London
WC2A 1HN (GB)

54 **An electronic circuit for simulating sound from a rotary loudspeaker.**

57 A device for electronically simulating vibrato and tremulant effects and the radiation effects produced by a rotary loudspeaker with the aid of two loudspeakers, (34, 50), in which a musical tone signal (20) is applied to a variable delay device (22) associated with one of the loudspeakers (34). The frequency modulated signal (B) produced by the variable delay device is also subjected to amplitude modulation in a modulator (40) controlled in synchronism with the variable delay device, and the resulting composite signal applied to the other loudspeaker (50). Additionally, the high frequency compo-

nents of the frequency modulated signal from the variable delay device may be summed in an amplifier (46), in an out of phase relationship, with the composite amplitude modulated signal (C) to simulate the effect of a rotating high frequency horn radiator. The sub-audio modulating signal, which may be for example at 1Hz for a «chorus» effect, or 7Hz for a «tremulant» effect, is produced by an oscillator (26), and the degree of amplitude- and/or frequency-modulation may be dependant on this sub-audio frequency.



ACTORUM AG

COMPLETE DOCUMENT



AN ELECTRONIC CIRCUIT FOR SIMULATING
SOUND FROM A ROTARY LOUDSPEAKER

This invention relates to a circuit for electronically modulating a musical tone signal, to simulate the radiation effects produced by a rotary loudspeaker.

5 The addition of pulsato, tremolo, chorus or other low frequency modulation effects to a musical tone signal enhances the richness of the resultant sounds. Pulsato may be produced using rotary sound channels, as shown in Leslie U.S. Pat. Nos. Re.23,323, 3,080,786 and
10 3,174,579, among others. In one of the several embodiments disclosed in Re.23,323, a high frequency speaker in the form of a directional horn and a lower frequency speaker are rotatably supported in a cabinet and are arranged to be rotated by respective motors. As the horn and low
15 frequency speaker are rotated, not necessarily synchronously, the pitch of the sound reaching the listener's ear varies and by appropriately choosing the speed of rotation, a pleasing pulsato effect is obtained. The patent teaches that best results are frequently obtained by rotating the
20 speakers at different speeds and in opposite directions, implying that the relative phase of the signals from the two speakers continuously varies. While possibly not recognized by the inventor at the time, it was subsequently observed that a somewhat different tremolo is produced at
25 higher frequencies than at the lower end of the spectrum, and that the high frequency rotating horn produces an effect comparable to that occurring in a pipe organ at the transition near the top end of the rank from wooden to metal pipes; the small metal pipes react much differently
30 to variations in air pressure and produce a different

and much deeper vibrato and tremulant effect than do the wooden pipes. While systems of the general configuration taught by Leslie have enjoyed wide and long-term acceptance, many investigators have attempted to electronically
5 simulate the desirable effect in order to eliminate the bulk and cost of the rotary speakers, and the attendant mechanical problems.

One such electronic system is known from U.S. Pat. No. 4,008,641 which has three channels each coupled
10 to a respective loudspeaker and each having an amplitude modulator therein. A tone signal to be modulated is applied directly to the amplitude modulator in one of the channels and through a delay circuit to the amplitude modulator in each of the other two channels. A sub-audio
15 frequency generator is coupled both to the amplitude modulator in the first channel, and to the delay circuit for frequency modulating the musical tone signals therein, and phase shifters are coupled between the frequency generator and the respective amplitude modulators in the
20 second and third channels for shifting the phase of the musical tone signal in these channels. The outputs of the amplitude modulators are acoustically reproduced, with the tone signal from the first channel being in the center of the reproduced sound image and the musical
25 tone signals from the other channels on opposite sides of the tone signal from the first channel. The sound emanating from the center speaker is loudest at the transition between sharp and flat of the frequency modulated signal, and one of the side speakers is loudest when the
30 frequency modulated signal is at its sharpest while the other side speaker is loudest when the FM signal is at its flattest; this produces the effect of rotation, but does not accurately simulate the acoustic effects produced by a rotary speaker. That is, when the FM modulated signal
35 is going sharp, the signal produced by one of the side speakers is more dominant than it should be. Moreover,

proper operation of the system is highly dependent on the relative placement of the speakers, and also requires rather specific positioning of the listener with respect to the speakers for him to perceive a rotating sound effect. This still holds if the centre speaker is removed, and the output of the centre amplitude modulator is shared between the outer channels, as shown in figure 6 of the specification.

A device for electronically simulating the radiation effects produced by a rotary speaker, which requires only two loudspeakers, is described in U.S. Pat. No.4,162,372. In this system, an input tone signal is frequency modulated at a sub-audio rate and the frequency modulated signal and the original signal are mixed and applied to two variable gain amplifiers, the outputs of which are applied to respective loudspeakers. The gains of the amplifiers are varied in phase opposition at the aforementioned sub-audio frequency, the modulating signal being applied to the amplifiers through a low-pass filter having a crossover at about 1.0Hz. so that the amplitude modulation is more pronounced at .7Hz than at 7Hz. This quite closely simulates the effect in a rotary speaker pulsato generator wherein amplitude modulation is less distinct in the "fast" mode than in the "slow" mode, but because the amplitude modulation occurs in both channels in synchronism, the system does not simulate the effect of a rotary speaker facing away from the listener. It simulates only the left-right component of the rotary motion.

Thus, these two known systems, while each simulates to a degree many of the characteristics of the sound produced when a rotary speaker is used to modulate a musical tone signal, fail to simulate other effects, with the consequence that neither accurately simulates the the pulsato and radiation effects produced by a rotary

loudspeaker. Moreover, the system of Pat. No.4,008,641 is relatively expensive to manufacture and, as has been previously noted, requires a particular placement of the loudspeaker relative to each other, and rather specific
5 positioning of the listener with respect to the speakers, to realise the desired results. .

It is an object of the present invention to provide a circuit for electronically modulating a musical tone signal to synthesize more fully the effects produced
10 by a rotary loudspeaker, where the positions of the transducers delivering the sound to the listener are not critical.

15

20

25

30

35

This is achieved in an electronic circuit for modulating a musical tone signal to produce an effect which simulates the radiation of sound by a rotary loudspeaker, comprising: means for generating a sub-audio
5 frequency, substantially sinusoidal, modulating signal; a frequency modulator responsive to the modulating signal to modulate the frequency of the musical tone signal, an amplitude modulator responsive to the modulating signal to modulate the amplitude of the musical tone signal,
10 means responsive to the output of the frequency modulator for applying a signal modulated substantially only in frequency to a first stationary transducer, for converting the frequency modulated signal into sound; and means responsive to the output of the amplitude modulator for applying the
15 amplitude-modulated musical tone signal to a second stationary transducer to convert the said amplitude-modulated signal into sound, the amplitude-modulated signal having a maximum amplitude when the frequency-modulated signal is in transition from sharp to flat relative to the
20 musical tone signal and having minimum amplitude when the frequency modulated signal is in transition from flat to sharp.

In one circuit for carrying out the invention, the musical tone signal applied to the amplitude modulator
25 is derived from the output of the frequency modulator, whereby the signal applied to the second stationary transducer is an amplitude-modulated, frequency-modulated tone signal.

In another circuit, the frequency modulator and
30 the amplitude modulator receive the musical tone signal from a common source, and the amplitude modulator produces an amplitude-modulated tone signal substantially only during positive half-cycles of the modulating signal.

Preferably, the two stationary transducers are
35 loudspeakers mounted in close proximity.

In each of these forms of the electronic circuit, one transducer receives a signal which has undergone

frequency modulation and whose amplitude is substantially unmodulated by the circuit, while another transducer receives a signal which has undergone amplitude modulation. In this way, the sound produced by the transducers
5 synthesizes the Doppler effect and the attenuation of the sound which are features of a rotary loudspeaker, and the effect is superior to that produced in either of the specifications described above.

Other objects, features and advantages of the
10 invention will become apparent, and its construction and operation better understood, from the following detailed description, taken in conjunction with the accompanying drawings, in which:

Figure 1 is a block diagram of one embodiment
15 of the invention for modulating a tone signal to produce radiation for modulating a tone signal to produce radiation effects simulative of those produced by a rotary speaker;

Figure 2 is a series of waveforms of signals
20 at various points in the system of Figure 1, useful in explaining the operation of the system;

Figure 3 is a diagrammatical representation
of a rotary speaker, useful in illustrating how the system of the present invention produces the radiation effects of a rotary speaker;

25 Figure 4 is a block diagram of a second embodiment of the invention;

Figure 5 is a series of waveforms of signals
at the points A, B and C in Figure 4; and

Figure 6 is a circuit diagram showing how the
30 amplitude modulation is performed in the circuit of Figure 4.

The nature of the sound effects produced by a rotary speaker, which the present invention electronically simulates to a high degree, will be seen from consideration of Figure 3, wherein a speaker 10 is mounted within a cabinet 12 for rotation about a vertical axis, in the direction indicated by the arrows. In the illustrated position of the speaker, namely, with its radiating surface directed toward the back of the cabinet, no direct sound reaches a listener L positioned in front of the cabinet; only sound reflected from the walls of the cabinet is heard by the listener. As the speaker rotates toward position 2, the source of the sound is approaching the listener and due to Doppler effect is perceived as going sharp, and when position 2 is reached and passed, some direct sound reaches the listener along direct sound line 14. The amplitude of the direct sound increases with continued angular displacement of the speaker, along with an increase in the perceived frequency, to a maximum amplitude when the speaker is facing the listener, namely, at position 3. Upon further rotation from position 3 position 4, the sound signal reaching the listener decreases in amplitude and its frequency is perceived as going flat, and as speaker 10 leaves the direct sound line 16, the amplitude of the direct signal is reduced toward zero, and the perceived frequency continues going flat, until position 1 is again reached, at which only indirect reflected sound reaches the listener. Conventionally, a rotary speaker is rotated at one of two speeds, namely, to produce modulation at about 0.7 Hz for "slow" pulsato, or to produce 7.0Hz modulation for "fast" pulsato.

Referring now to Figure 1, a first embodiment of the present invention receives a musical tone signal at an input terminal 20 which is applied to the input of a variable

delay device 22, which may be any of several known variable phase shift devices, and may, for example, take the form of a "bucket brigade" delay line, a form of shift register. Variable delay device 22 is driven by
5 a clock 24 which generates a periodic series of pulses at a given frequency, and the given clock frequency is varied by a sinusoidal modulation wave, shown in Figure 2A, from a modulation signal generator 26, which may be an oscillator the frequency of which is selectable to
10 be either approximately 1.0Hz or approximately 7.0Hz for "slow" and "fast" operation, respectively. The illustrated form of variable delay device is described in U.S. Patent No. 3,749,837. The output of variable delay device 22 is applied to a filter 28 which removes from the
15 modulated audio signal the clock pulses which have been impressed on the signal by the variable delay device. The variable delay device causes the time phase of the input tone signal to advance or recede in accordance with the increase or decrease of the varying voltage of the
20 modulating wave, and consequently there is a frequency variation in accordance with the variation of the voltage of the modulating wave per unit time. More specifically, as shown in Figure 2B, as the voltage of the modulating wave is descending in value the variable delay device
25 causes the time phase of the tone signal to recede and causes the modulated signal to be flat with respect to the input signal, and during periods when the modulating wave is ascending in value, the phase of the musical tone signal is advanced, causing the frequency modulated
30 signal to be sharp with respect to the input audio frequency. The periods during which the frequency modulated signal is sharp and flat are indicated in the diagram immediately below waveform (B), it being understood that the degree of sharpness or flatness is not constant
35 throughout the respective periods but varies in accordance with the voltage of the modulation wave per

unit of time, with maximum sharpness and flatness occurring at zero-crossings of the modulation wave. The resulting frequency-modulated tone signal is applied through a switch 30 (the purpose of which will be explained presently) to a suitable power amplifier 32 for amplification prior to acoustic reproduction in a first loudspeaker 34.

The frequency-modulated signal (B) at the output of filter 28 is also applied to the input of an amplitude modulator 40 wherein it is amplitude-modulated by the sinusoidal modulating signal (A) of the same frequency and phase as that employed to control variable delay device 22. Amplitude modulator 40, which may be of conventional design, is operative to provide approximately 80% modulation of the frequency-modulated input signal to produce a composite signal, substantially as illustrated in waveform (C) of Figure 2, the amplitude of which is maximum at transitions from sharp to flat of the frequency-modulated signal and minimum at transitions from flat to sharp. The amplitude modulator inverts the phase of the applied input signals so that the phase of the frequency- and amplitude-modulated signal at the output of the modulator is shifted by 180° relative to the input signal. Higher frequency components of the composite signal are removed by a filter 42, the output of which is coupled via a resistor 44 to the input terminal of a summing amplifier 46. The signal appearing at the output of amplifier 46 is further

30

35

amplified in a suitable power amplifier 48 and applied to a second loudspeaker 50 for acoustical reproduction.

The frequency-modulated signal appearing at the output of filter 28, in addition to being applied to amplitude modulator 40, is applied over line 52 through a capacitor 54 and a resistor 56 to the input of summing amplifier 46. The junction of capacitor 54 and resistor 56 is connected through a resistor 58 to ground potential. The frequency-modulated signal applied over this path to summing amplifier 46 is of constant amplitude, and because of the phase inversion in amplitude modulator 40, is in phase opposition with the amplitude-modulated FM signal applied to the summing amplifier via resistor 44. The values of capacitor 54 and resistor 58 are selected to transmit only the higher frequencies of the audio spectrum; as a consequence, such high frequency signals applied to summing amplifier 46 via resistor 56, as determined by the values of capacitor 54 and resistor 58, are amplitude modulated in summing amplifier 46 by the amplitude modulated FM signal from modulator 40. Only the high frequencies are affected and the modulation occurs 180° out of phase relative to the amplitude modulation of the main signal from amplitude modulator 40. The resulting composite envelope for the high audio frequencies, typically, from about 3KHz to the point at which the low pass filter 42 attenuates strongly, is essentially as illustrated in waveform (D) of Figure 2, in which the amplitude modulation is approximately 100% and in opposite phase relative to the amplitude modulation of lower frequencies in the system, depicted by waveform (C). The percentage of modulation varies with frequency, being lower at the lower end of the high frequency portion of the spectrum and increasing

- 11 -

with frequency until a frequency is reached at which 100% modulation is approached or met; that is, where the amplitude of the high frequency signal summed into amplifier 46 via resistor 56 is substantially equal to
5 the amplitude of the signal summed in through resistor 44 from amplitude modulator 40. The electrical mixing of the composite signals (C) and (D) with the resultant reinforcement and cancellation of signal elements on a somewhat random basis gives much deeper and broader
10 vibrato and tremulant effects to the very high frequencies in the system as compared to the effects produced at low- and mid- range frequencies. The effect at high frequencies is quite simulative of that produced by the high frequency horn in the above-described Leslie system and also
15 somewhat simulates the effects of reflections within the cabinet of a rotary speaker system, which is not totally sound transparent.

While the just-described channel simulates by electrical mixing the effects of a rotating high frequency
20 horn and the other desirable tremulant effects, the production of effects produced by a rotary loudspeaker depends on the acoustic mixing of the modulated tone signals produced by both speakers. The acoustically mixed musical tone signals will have complicated modulation
25 effects, and they will at the same time have a rotation sound effect due to the described phase relationships between the frequency-modulated signal reproduced by speaker 34 and the composite amplitude-modulated FM signal reproduced by speaker 50. Although the placement of
30 speakers 34 and 50 with respect to each other is not critical to obtain an acceptable spatial effect, they should be reasonably close to each other.

- 12 -

Relating the waveforms of Figure 2 to the diagrammatical representation of a rotary speaker, with the numerals 1, 2, 3 and 4 on the modulation waveform (A) corresponding to like numbered positions of the rotary speaker, the manner in which the present circuit
5 simulates the radiation effects of a rotary speaker will now be described. At position 1 (when the speaker is facing the back of the cabinet) there is only a relatively low amplitude output from the amplitude
10 modulator 40 (i.e. very little direct sound), and the reflected sound from a rotary speaker is simulated by the output of speaker 34, in which the frequency-modulated tone signal starts to go sharp at point 1. At point 2, corresponding to the 90° position of the rotary speaker,
15 there begins to be a significant output from the amplitude modulation channel, which increases in amplitude as the voltage of the modulation wave increases from point 2 to point 3. Meanwhile, the output of the frequency modulation channel is still sharp, thereby to simulate
20 the effect of the rotary speaker rotating toward the listener in going from position 2 to position 3. At point 3 on waveform (A), corresponding to the rotary speaker facing front, the signal reproduced by speaker 50 is a maximum amplitude, and the frequency-modulated
25 signal reproduced by speaker 34 is in transition from sharp to flat, thereby simulating the effect of a rotary speaker starting to move away from the listener. At point 4 on waveform (A), corresponding to the position at which a rotary speaker is leaving the direct sound line 16 to the
30 listener, the amplitude of the amplitude-modulated FM signal is decreasing in amplitude, and the frequency-modulated signal continues to go flat, thus simulating the

effect produced by a rotary speaker when going from position 4 back to position 1. The acoustically mixed musical tone signals create the perception that the mixed signal is coming from a common source. The resultant signal has complicated modulation effects, which, together with the cyclical increase and decrease in perceived amplitude and the cyclical variations in frequency from sharp to flat in the described time relationship with the changes in amplitude, simulate to a high degree the modulation effects produced by a rotary speaker. The rotational effect is perceived by the listener throughout a wide angle of positions in front of the loudspeakers; that is, the effectiveness of the system is not significantly dependent on the position of the listener with respect to the loudspeakers. In an organ system embodying the invention, speaker 50 is of the sealed enclosure type having good response at low frequencies, into which are mixed, along with the composite amplitude-modulated signal from summing amplifier 46, pedal signals, rhythm signals, accompaniment rhythms and signals representing other organ sounds. Signals representing brighter voices, such as strings, are mixed with the frequency-modulated signal from filter 28 for reproduction by speaker 34, which desirably has a better high frequency response than speaker 50. Typically, only the tibia-representing signals are applied to input terminal 20 and processed to produce the rotary loud-speaker radiation effects.

An advantageous feature of this embodiment is that the power amplifier 32 and speaker 34 can readily be eliminated from the system by opening switch 30, and the remainder of the system used to provide a tremolo by reproducing only the composite signal consisting of the amplitude-modulated FM signal, modulated in synchronism with each other. Although elimination of the frequency modulation channel detracts from the simulation of

rotation effects, the balance of the system nevertheless produces a very pleasant tremolo effect which is quite acceptable in an inexpensive organ utilizing a single speaker. The previously described characteristic of the modulation at the upper end of the audio frequency spectrum due to the summing of the high frequencies out of phase with the amplitude- and frequency-modulated main signal still obtains whether or not speaker 34 is used. Thus, the system to the left of switch 30 in Figure 1 can be utilized as a building block for producing tremulant effects in an inexpensive organ otherwise requiring only one speaker, and which by adding only another speaker will provide a rotational radiation effect.

The second embodiment of the invention is shown in Figures 4 to 6. The circuit of Figure 4 differs from figure 1 in that the amplitude modulator input is taken from the audio input terminal 20. Amplifier 48 and loudspeaker 50 then reproduce a signal which is modulated only in amplitude and not in frequency. The high pass filter 54, 58 and the summing amplifier 46 of Figure 1 are not shown here, but they could be included in the circuit of Figure 4.

The musical tone signal is modulated in the other channel by a variable delay device controlled by the modulation wave from modulation signal generator 26, which, depending upon the nature of the variable delay device, is either in phase or in phase opposition with the modulating wave applied to the amplitude modulator. In order to simulate the characteristic of a rotary speaker that the Doppler effect is more pronounced for "fast" operation than for "slow", the amplitude of the modulating wave supplied to delay device 22 preferably is larger for "fast" operation than for "slow". The signal produced by the frequency-modulating delay device 22 has a waveform F in Figure 5 similar to waveform B in Figure 2, and is reproduced by amplifier 32 and loudspeaker 34.

- 15 -

To further simulate the effect in a rotary speaker that the Doppler shift is larger in the "fast" mode than in the "slow" mode, a larger amplitude modulation wave is applied to the variable delay device when simulation
5 of "fast" operation is desired than for "slow" operation. The amplitude of the modulation wave applied to the amplitude modulator is also large for "fast" operation, but is not necessarily the same amplitude as the modulating signal applied to the variable delay device.

10 An amplitude modulator for achieving the output signal depicted in waveform (E) is obtainable with the modulator illustrated in Figure 6, in which the sine wave signal output of oscillator 26 is amplified in an amplifier 62 operated from a split supply so as to
15 reference its output to +v and -v, each typically having a value of 12 volts. The sine wave signal from amplifier 62 is applied through a resistor 64 as a voltage control signal to a current controlled amplifier which may, for example, be an LM3080 operational transconductance amplifier,
20 commercially available in integrated circuit from National Semiconductor and others. The LM 3080 is a programmable transconductance block having differential inputs and high impedance push-pull outputs. The device has high input impedance and its transconductance is
25 directly proportional to the amplifier bias current. In the present application the device is operated from the positive side (+v) of the split supply, with half of the voltage of the positive supply applied through a resistor 68 to the minus (-) input and through a resistor
30 69 to the plus (+) input, to which the musical tone signal is also applied through a resistor 60. The output terminal of the device, represented by terminal 63, is connected via a resistor 65 to half supply voltage to provide operating load for the amplifier. With amplifier
35 62 operated from a split supply, and the LM3080 device

operated from a single positive supply, only the positive half cycles of the modulating sine wave, applied to the amplifier bias input of the device, affect the gain of amplifier, whereby an amplitude-modulated output tone
5 signal is produced only during positive half cycles of the modulating wave.

When the frequency of oscillator 26 is switched from a frequency of about 7 Hz ("fast" mode) to about 0.7 Hz ("slow" mode), the value of resistor 64 is
10 increased thereby to reduce the gain of amplifier 66 to provide a modulated signal of lower amplitude for "slow" operation than for "fast". This may be accomplished by a switch 67 connected to partially shunt resistor 64 when "fast" operation is desired.

15 Both methods described above for enhancing the effect of the Doppler shift can be employed in the first embodiment of the invention shown in figure 1. The degree of modulation produced in the variable delay device (frequency modulator) 22 and in the amplitude modulator 40
20 can be increased for fast sub-audio modulating frequencies, e.g. 7Hz, and decreased for slow frequencies, e.g. 1Hz.

Among the several embodiments of rotatable tremulant sound producers described in the aforementioned Re.23,323 are two which each use a single speaker to
25 produce the tremulant effect. In the arrangement shown in Figure 14 a stationary speaker delivers sound to a rotating directional horn which, because of the bend of the horn, causes some attenuation of high frequencies contained in the sound delivered by the speaker to the horn.
30 In the embodiment shown in Figure 21 a speaker is enclosed in a casing filed with sound absorbent material to prevent sound radiation from the back of the speaker, a directional horn is mounted on the front of the casing for cooperation with the speaker, and the whole assembly is supported to be driven
35 in rotation about a vertical axis. In this case, the shape of the horn is such that there is little or no attenuation

- 17 -

of high frequencies. The present invention affords the option of simulating either one or the other of these electro-mechanical systems. Should simulation of the stationary speaker-rotating horn arrangement be desired,
5 filters 42 and 28 are provided in their respective channels to attenuate high frequencies contained in the amplitude-and frequency- modulated signals, respectively having a gradual rolloff at about 2000 Hz. On the other hand, if it is desired to simulate the rotating speaker/
10 horn arrangement, filters 42 and 28 are omitted.

15

20

25

30

35

CLAIMS

1. An electronic circuit for modulating a musical tone signal to produce an effect which simulates the radiation of sound by a rotary loudspeaker (10, figure 3), comprising: means for generating a sub-audio frequency, substantially sinusoidal, modulating signal (A); a frequency modulator (22) responsive to the modulating signal to modulate the frequency of the musical tone signal, an amplitude modulator (40) responsive to the modulating signal to modulate the amplitude of the musical tone signal, means responsive to the output (B or F) of the frequency modulator (22) for applying a signal modulated substantially only in frequency to a first stationary transducer (34), for converting the frequency-modulated signal into sound; and means responsive to the output (C or E) of the amplitude modulator for applying the amplitude-modulated musical tone signal to a second stationary transducer (50) to convert the said amplitude-modulated signal into sound, the amplitude-modulated signal having a maximum amplitude when the frequency modulated signal is in transition from sharp to flat (3) relative to the musical tone signal and having minimum amplitude when the frequency-modulated signal is in transition from flat to sharp (1).

25

30

2. An electronic circuit in accordance with claim 1, wherein the musical tone signal applied to the amplitude modulator is derived from the output of the frequency modulator, whereby the signal applied to the second
5 stationary transducer is an amplitude-modulated, frequency-modulated tone signal (C).
3. An electronic circuit in accordance with claim 2, wherein the amplitude modulator inverts the phase of the signal which it receives from the frequency modulator,
10 the circuit including a high-pass filter (54,58, figure 1) connected to receive the frequency-modulated signal, and a summing amplifier (46) connected to receive the output of the amplitude modulator and also connected to receive from the filter the higher frequencies of the frequency-
15 modulated signal, without phase inversion, whereby the higher frequency components undergo a further amplitude modulation (D) in the summing amplifier.
4. An electronic circuit according to claim 3, wherein the high-pass filter attenuates the frequency-modulated
20 signal to a degree depending on the frequency, so that the percentage amplitude modulation in the summing amplifier varies with the frequency of the higher-frequency components.
5. An electronic circuit according to claim 3 or 4, wherein the high-pass filter is a resistance-capacitance
25 filter which passes frequencies above about 3 KHz.
6. An electronic circuit (Figure 4) according to claim 1, wherein the amplitude modulator produces an amplitude-modulated tone signal (E, figure 5) substantially only during positive half-cycles of the modulating signal.
- 30 7. An electronic circuit according to any one of the preceding claims, wherein the frequency of the modulating signal is selectable to be either in the range 0.7Hz to 1 Hz or about 7 Hz, to simulate the slow or fast operation of a rotary speaker.
- 35 8. An electronic circuit in accordance with any one of the preceding claims, wherein the degree of frequency

modulation in the frequency modulator is larger when the frequency of the modulating signal is greater.

9. An electronic circuit according to any one of the preceding claims wherein the degree of amplitude modulation in the amplitude modulator is larger when the frequency of the modulating signal is greater.

10. An electronic circuit according to any one of the preceding claims, wherein the frequency modulator is in the form of a bucket-brigade shift register and a clock (24) connected to the shift register for generating a periodic series of pulses at a given frequency, and wherein the modulating signal is applied to the clock for varying the given frequency of the clock.

11. A sound reproducing system for simulating the radiation of sound by a rotary loudspeaker, comprising an electronic circuit in accordance with any one of Claims 1 to 10, connected to two stationary transducers in the form of loudspeakers mounted in close proximity.

20

25

30

35

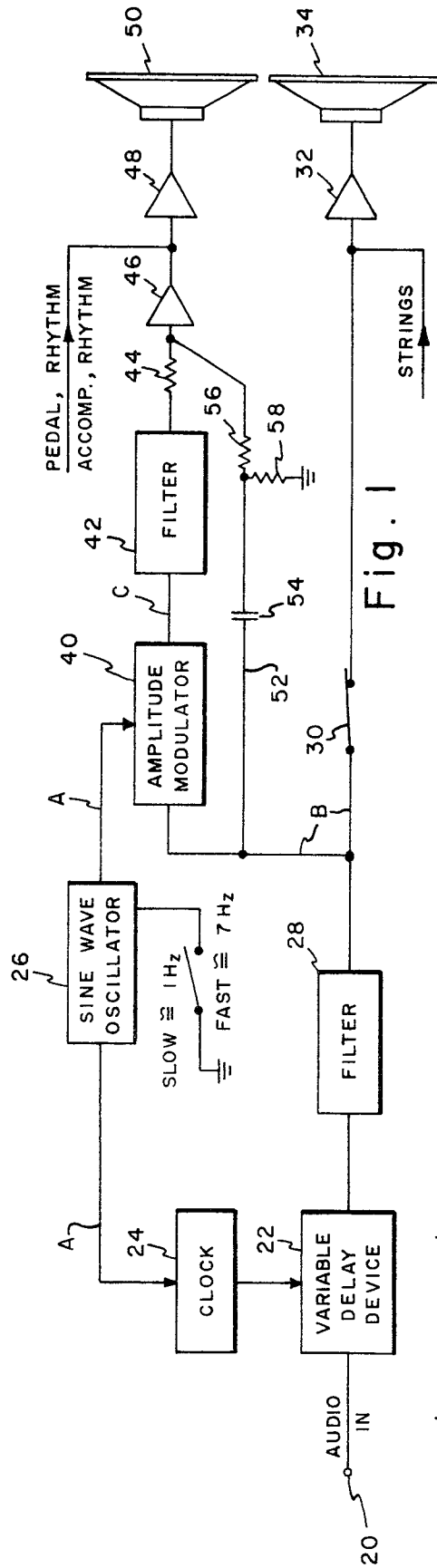


Fig. 1

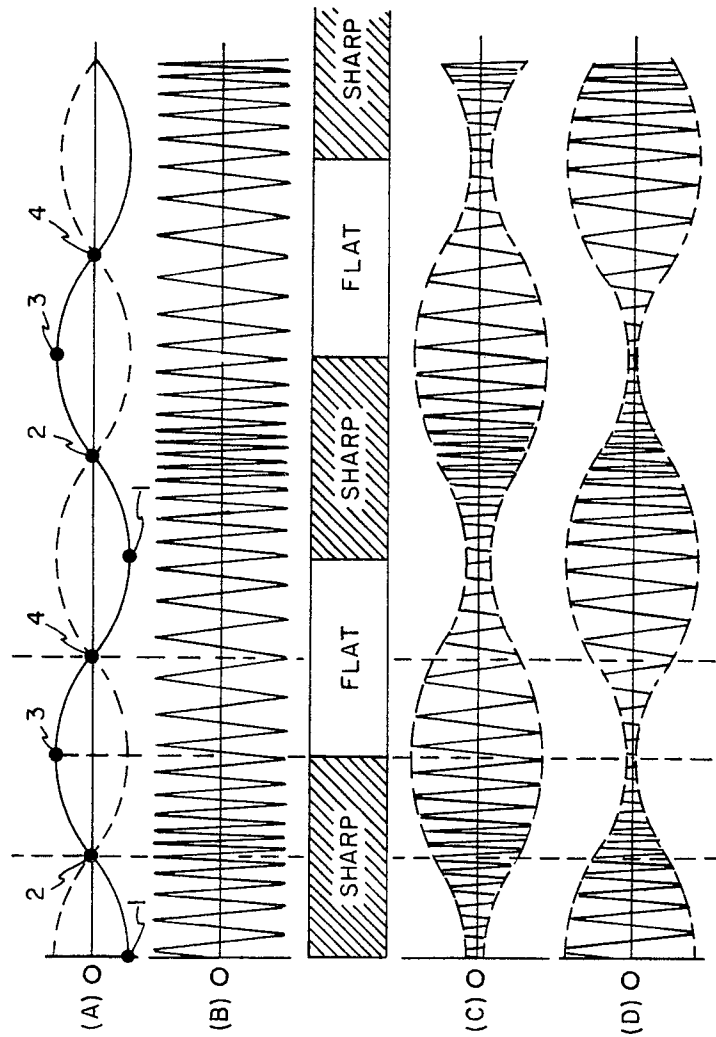


Fig. 2

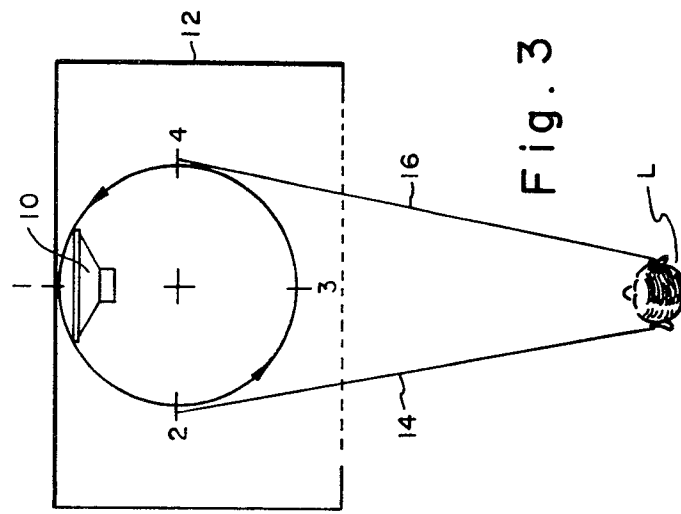


Fig. 3

