PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 :		(11) International Publication Number:
H04R 29/00, 3/00, H03G 11/00	A1	WO 00/44200
		(43) International Publication Date: 27 July 2000 (27.07.00)

(21) International Application Number: PCT/US00/02274

(22) International Filing Date: 26 January 2000 (26.01.00)

(30) Priority Data:
09/236,900 26 January 1999 (26.01.99) US

(71) Applicant *(for all designated States except US)*: PHILIPS ELECTRONICS NORTH AMERICA CORPORATION [US/US]; 580 White Plains Road, Terrytown, NY 10591 (US).

(71)(72) Applicants and Inventors: LEVY, Paul S. [US/US]; 2533 West Gregg Drive, Chandler, AZ 85224 (US). SESSIONS, D.C. [US/US]; 14215 North 43rd Way, Phoenix, AZ 85032 (US).

(74) Agent: KREBS, Robert, E.; Burns, Doane, Swecker & Mathis, Llp, P.O. Box 1404, Alexandria, VA 22313-1404 (US).

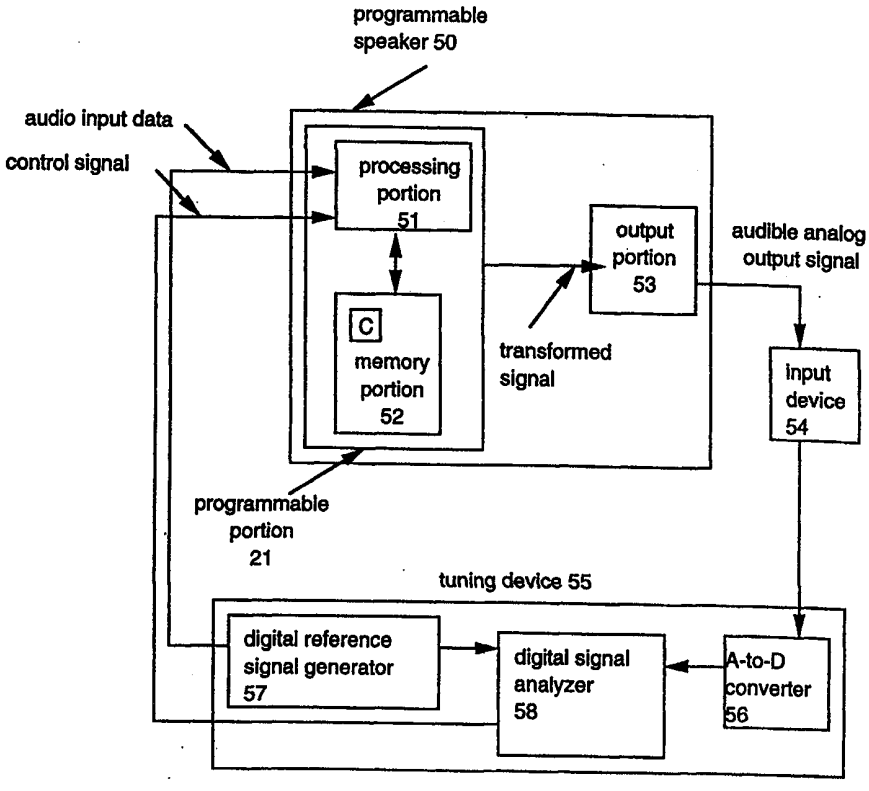
(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: INTELLIGENT SPEAKER TUNING USING NON-VOLATILE MEMORY

(57) Abstract

A non-intrusive system and method for tuning the speaker (50) is performed by applying a reference signal and a control signal to the input of the programmable speaker (50). A microphone (54) detects a sound corresponding to the input reference signal at the output (53) of the speaker and feeds it back to a tester (55) which analyzes the frequency response of the speaker (50) by comparing the input reference signal to the audible output signal (53) from the speaker (50). Depending on the results of the comparison, the tester provides to the speaker (50) an updated digital control signal with new characterization data which is then stored in the speaker memory (52) and used to again perform transform functions on the input reference signal. The tuning feedback cycle continues until the input reference signal and the audible output signal (53) from the speaker (50) exhibit the desired frequency response as determined by the tester.



FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	**ES**	Spain	**LS**	Lesotho	**SI**	Slovenia
AM	Armenia	**FI**	Finland	**LT**	Lithuania	**SK**	Slovakia
AT	Austria	**FR**	France	**LU**	Luxembourg	**SN**	Senegal
AU	Australia	**GA**	Gabon	**LV**	Latvia	**SZ**	Swaziland
AZ	Azerbaijan	**GB**	United Kingdom	**MC**	Monaco	**TD**	Chad
BA	Bosnia and Herzegovina	**GE**	Georgia	**MD**	Republic of Moldova	**TG**	Togo
BB	Barbados	**GH**	Ghana	**MG**	Madagascar	**TJ**	Tajikistan
BE	Belgium	**GN**	Guinea	**MK**	The former Yugoslav Republic of Macedonia	**TM**	Turkmenistan
BF	Burkina Faso	**GR**	Greece			**TR**	Turkey
BG	Bulgaria	**HU**	Hungary	**ML**	Mali	**TT**	Trinidad and Tobago
BJ	Benin	**IE**	Ireland	**MN**	Mongolia	**UA**	Ukraine
BR	Brazil	**IL**	Israel	**MR**	Mauritania	**UG**	Uganda
BY	Belarus	**IS**	Iceland	**MW**	Malawi	**US**	United States of America
CA	Canada	**IT**	Italy	**MX**	Mexico	**UZ**	Uzbekistan
CF	Central African Republic	**JP**	Japan	**NE**	Niger	**VN**	Viet Nam
CG	Congo	**KE**	Kenya	**NL**	Netherlands	**YU**	Yugoslavia
CH	Switzerland	**KG**	Kyrgyzstan	**NO**	Norway	**ZW**	Zimbabwe
CI	Côte d'Ivoire	**KP**	Democratic People's Republic of Korea	**NZ**	New Zealand		
CM	Cameroon			**PL**	Poland		
CN	China	**KR**	Republic of Korea	**PT**	Portugal		
CU	Cuba	**KZ**	Kazakstan	**RO**	Romania		
CZ	Czech Republic	**LC**	Saint Lucia	**RU**	Russian Federation		
DE	Germany	**LI**	Liechtenstein	**SD**	Sudan		
DK	Denmark	**LK**	Sri Lanka	**SE**	Sweden		
EE	Estonia	**LR**	Liberia	**SG**	Singapore		

INTELLIGENT SPEAKER TUNING USING NON-VOLATILE MEMORY

BACKGROUND OF THE INVENTION

Field of The Invention

The present invention relates to audio speakers, and more particularly to tuning speakers.

State of The Art

In the manufacturing process of speakers it is desirable to build a speaker system, having a uniform and predictable input/output (I/O) response characteristic or I/O transfer function. Ideally, the analog audio signal coupled to the input of a speaker is what is heard on the output of the speaker. In reality, what is actually heard on the output of the speaker is the original audio signal plus some distortion caused by the construction of the speaker itself and the interaction of the components within it. Currently, there are many techniques performed during the manufacture of the speaker to minimize this distortion so as to provide the desired speaker response.

Figure 1 shows a simplified block diagram of a typical speaker 10 which includes a cabinet 11, a cross-over network 12, a set of amplifiers (Amp 13), and a set of transducers 14. An audio input signal is coupled to a cross-over network through a cabinet port. The cross-over network functions to break-up the frequency energy into several high, middle, and low frequency components and divert those frequency components to corresponding amplifiers and transducers. For instance, low-frequency components are coupled to big transducers (also referred to as woofers), the medium frequency components are coupled to the

mid-range transducers, and the high frequency components are coupled to the small transducers (also referred to as tweeters). The transducers fit into ports 14 within the cabinet and output an audible analog signal through the ports, often through a mesh screen. Hence, there are four primary independent manufacturing variables (i.e., cabinet, cross-over network, amplifiers, and transducers) that must be dealt with on a speaker-by-speaker (or lot-by-lot) basis to manufacture a reproducible speaker.

Currently, the techniques used to tune a speaker such as shown in Figure 1 are all mechanical, generally intrusive, and time-intensive since they are often performed by hand. For instance, one manner in which to tune a speaker's response is to adjust potentiometers within the cabinet so as to tune the cross-over network. The cross-over network is tuned to adjust the manner in which the frequency ranges are diverted to each transducer and to reduce the bleeding of frequency ranges into each other. Since these potentiometers often reside within the cabinet, this technique is relatively intrusive requiring hand-tuning while the speaker is disassembled. In addition, components, such a large inductors, within the crossover network might be physically moved to tweak affects caused by magnetic flux.

Another way in which a speaker is tuned is to use holes within the cabinet to affect the resonance of the cabinet by enlarging the holes until the desired resonance is achieved. The bass reflex of the cabinet can also be tuned by placing different length tubes into a passive output port of the cabinet to affect cabinet resonance.

The present invention is a reproducible, non-intrusive system and method of tuning a speaker which does not require independent physical tuning of each of

the physical manufacturing variables of the cabinet.

SUMMARY OF THE INVENTION

A programmable speaker and a system and method of tuning the speaker uses digital signal processing and stored characterization data to obtain the desired transfer function for the speaker. The programmable speaker includes a programmable portion having a processing portion and a memory portion for storing characterization data. The processing portion receives an input audio signal. The characterization data stored in the memory portion is accessed by the processing portion to perform a transform function on the input signal to generate a transformed signal which compensates for the distortion caused by a combination of physical elements of the speaker such as cabinet crossover network, and transducer distortion effects. As a result, each physical speaker element does not require individual tuning and instead an overall distortion compensation is achieved by performing the transform function on the input audio signal. The transformed signal is coupled to the output portion which produces an audible analog output signal representing the input signal compensated with the transform function according to the characterization data. In one embodiment, the characterization data is the weighting coefficients of the transform function.

A system for tuning the programmable speaker includes a microphone for receiving the audible output signal produced by the speaker and feeding it back to a tuning device. The tuning device includes a reference signal generator for providing a reference signal to the processing portion of the programmable speaker. The tuning device performs a comparison analysis between the audible output signal and the input reference signal and generates a control signal

including updated characterization data dependent on the comparison. The control signals are coupled to the programmable input portion of the speaker, are stored in the memory portion, and are used again to tune the speaker by performing the transform function on the input reference signal. The characterization data is used by the processing portion to minimize the distortion caused by the speaker by making the input and the output as similar as possible. This cycle of providing updated control signals, feeding back the output signal, and analyzing the signal to generate a new control signal is performed until the reference signal and the output signal match and/or exhibit the desired transfer function relationship.

In one embodiment, the reference signal is chosen so as to tune the speaker to have a given overall operational characteristic such as having a stronger bass (lower frequencies) or alternatively, a strong mid-range (mid-frequencies). In another embodiment, more than one reference signal may be used to tune the speaker to give the speaker a variety of operational characteristics.

In another embodiment, the processing portion performs a cross-over type transfer function so as to generate a plurality of digital signals each corresponding to a different frequency range to be diverted to a different output transducer of the speaker. In still another embodiment, the processing portion is implemented with a digital signal processing (DSP) unit and an associated DSP memory system. The DSP portion processes the input reference signal according to the characterization data accessed from a non-volatile memory. In another embodiment, the processing portion includes function specific hardware accelerator circuitry to perform mathematical operations used to implement the transform function such as addition and multiplication operations of signals so as

to minimize overall processing time of the audio input signal.

In still another embodiment, the output drive portion includes a plurality of digital-to-analog converters for receiving the plurality of transformed signals generated by the cross-over transform function from the programmable portion and for converting them into a plurality of analog signals. The converted signals are coupled to an amplifier stage. The amplified signals are then coupled to the speaker transducers for outputting an audible signal corresponding to the transformed input signal.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention may be further understood from the following written description in conjunction with the appended drawings. In the drawings:

Fig. 1 shows a prior art simplified block diagram of a speaker;

Fig. 2 shows a block diagram of one embodiment of a speaker in accordance with the present invention;

Fig. 3 shows another embodiment of a speaker in accordance with the present invention including a digital signal processor and a non-volatile memory for storing weighting coefficients of a transform function;

Fig. 4 shows another embodiment of a speaker in accordance with the present invention in which more than one transform function is performed; and

Fig. 5 shows a block diagram of a system for tuning a programmable speaker according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 2 shows a programmable speaker 20 including a programmable portion 21 and an output portion 22. The programmable portion includes a processing portion 23 and a memory portion 24. The processing portion receives audio input data (either an analog signal or digital data stream) and performs a transform function (*T*) on the input data using characterization data (*C*) stored in the memory portion and outputs a transformed digital output signal according to the transform function and the characterization data. Transform functions are well known in the field of signal processing. The manner in which the transform function is performed on the input signal can include processing signals using function specific hardware, using a generalized microprocessor, and/or using a function specific digital signal processor.

The transformed digital output signal is coupled to the output portion 22 which converts it to an amplified audible analog output signal from the speaker. Hence, the speaker can be programmed to perform a transform function according to the characterization data stored in the memory portion to generate a transformed digital signal. The transform function and characterization data used to perform the transform function represents the inverse transform function which characterizes an overall distortion contributed by a combination of the physical elements of the speaker. Since the transform function performed by the programmable portion 21 represents an overall distortion caused by the elements of the speaker, the individual physical elements do not have to be intrusively and individually tuned and instead the speaker can be tuned by updating the characterization data stored in the memory portion of the speaker. Hence in another embodiment of the present invention, the speaker receives external control signals including new characterization data for programming/tuning the speaker once it is assembled. In accordance with this embodiment, a plurality of

speakers which are physically the same (i.e., made up of the same physical elements) can be tuned to sound differently dependent on the characteristic data stored in its memory portion.

Figure 3 shows a second embodiment of the speaker 30 of the present invention in which the programmable portion comprises a non-volatile memory 31 for storing the characterization data in the form of transform weighting coefficients and comprises a digital signal processing (DSP) unit 32, its associated memory system 33, and optional function specific acceleration circuitry 34. Audio input data is coupled to the DSP unit and the DSP unit accesses the current weighting coefficients from the non-volatile memory. The DSP unit performs an overall distortion transform function on the input data using the current weighting coefficients for compensating for the distortion caused by a combination of individual physical elements and their interaction in the speaker. In the embodiment shown in Figure 3, a single transform function is performed to compensate for a combination of physical elements to generate a transformed audio signal which is coupled to the output portion 35 to generate an audible, amplified analog output signal corresponding to the input audio data.

In another embodiment, the speaker includes a processing portion which performs more than one transform function to compensate for different types of distortion. For instance, in the embodiment of the speaker 40 shown in Figure 4 including a processing portion 41, a memory portion 42 and an output portion 43, a first transform function (*T1*) is performed using a first set of coefficients (*C1*) for compensating for a combination of physical elements in the speaker and a second cross-over type transform function (*T2*) is performed using a second set of coefficients (*C2*) for compensating for the speaker cross-over network distortion. In general, the cross-over type transform function performs a similar

function as a conventional cross-over network in a speaker in that it divides the audio input data into a plurality of signals having different frequency ranges. In addition, the cross-over type transform function compensates for distortion caused by other elements in the speaker which affect the cross-over function of the speaker. The result of the second cross-over type transform function is a plurality of distortion compensated transformed digital signals 44 each associated with a different frequency range and coupled to the output portion 43. In this embodiment, the output portion is embodied to include a digital-to-analog (D-to-A) signal converter stage 45 coupled to each of the plurality of transformed digital signals. Each D-to-A converter is coupled to an amplification stage 46. Each Amp outputs an amplified analog signal to a transducer 48 adapted for the frequency range of signal coupled to it. For instance, one transducer may be characterized in that it is adapted to receive lower frequency signals whereas another transducer may be characterized to receive higher frequency signals. The transducers then output an audible analog output signal which is distortion compensated. It should be understood that the speaker may include other elements not within the scope of the present invention. For instance, the output portion may include radiated EMI filters for regulatory compliance.

In one embodiment, a method of tuning the speaker shown in Figure 2 is performed by programming a memory portion in the speaker with characterization data, using the characterization data to perform a transform function on input audio date to generate a transformed signal in which the transform function represents the inverse transform function of an overall distortion caused by a combination of physical speaker elements, coupling the transformed signal to a speaker output stage, converting the transformed signal to an amplified analog audible signal, and outputting the audible signal from the speaker. In the case of tuning the speaker shown in Figure 3, the

characterization data is the weighting coefficients of the transform function. In the case of tuning a speaker shown in Figure 4, more than one set of weighting coefficients are programmed into the speaker memory.

One embodiment of a system for tuning a programmable speaker as shown in Figures 2-4 is shown in Figure 5 which includes a programmable speaker 50 including a processing portion 51, a memory portion 52 for storing characterization data, and an output portion 53. The processing portion 51 receives input audio data and an input control signal which includes characterization data. The processing portion 51 stores in the memory portion 52 updated characterization data (*C*) received in the control signal. In addition, the processing portion accesses the updated characterization data and uses it to perform its corresponding transform function to generate a transformed signal as described above. The transformed signal is coupled to the output portion 53 which generates a corresponding audible analog output signal.

The system for tuning a programmable speaker further includes an audio signal input device 54 for receiving the audible analog output signal from the speaker 50 and for providing a corresponding analog signal to a tuning device 55. The tuning device includes an analog-to-digital converting means 56 for converting the analog output signal from the speaker to a digital feedback signal. The tuning device 55 further includes a means for generating at least one digital reference audio signal 57 for providing to the speaker as the input audio data and a digital signal analysis means 58 for comparing the digital reference signal coupled to the input of the speaker to the digital feedback signal and, in response to the comparison, generating a control signal including updated characterization data. The updated comparison data is stored in the memory portion by the processing portion. The processing portion accesses the updated characterization

data to perform its corresponding transform function(s). The updated characterization data causes the transform function to be adjusted so as to tune the speaker to output an audible signal which has essentially the same the frequency, amplitude and phase response characteristics of the input reference signal. The output signal is again fed back and if the feedback signal is still different than the reference signal, the characterization data is updated and provided to the speaker and the transform function is performed with updated characterization data to generate a new output feedback signal until the output audible signal has essentially the same the frequency, amplitude and phase response characteristics as the reference signal. Once the input reference and output signals match, the last characterization data stored in the memory portion is used to perform the transform function on any audio input data which passes through the speaker until it is tuned again.

In one embodiment, the analysis means includes a means for identifying the differences between the feedback signal and reference signal and selecting an appropriate digital reference signal to couple to P1 dependent on the identified differences. For instance, if the analysis means identifies that a given frequency range difference or amplitude difference is occurring, a specific digital reference signal may be selected to try to compensate for distortion which may be causing this type of difference.

In another embodiment, digital reference signals may be selected dependent on the type of sound that the speaker is to be used to play. For instance, audio signals of women vocalist tend to be primarily made up of high frequency elements. Hence, a speaker being tuned using the system as described in Figure 5 may use a digital reference signal that is primarily high frequency elements if the speaker is to be used to primarily play women vocalist's music.

In contrast, a speaker used to play jazz or male vocalist music may be tuned using a different digital reference signal. Hence, the means for generating a digital reference signal may include a library of reference signals which can be selected by a user or technician to tune a speaker. In accordance with this embodiment, a plurality of speakers which are physically the same (i.e., made up of the same physical elements) can be specifically tuned to sound differently dependent on the characteristic data stored in its memory portion.

In accordance with another embodiment of the present invention, a plurality of speakers are tuned in a manufacturing environment in which a current speaker in an assembly line is be tuned using characteristic data or transform coefficients which are determined from the previous speaker in the assembly line such that the tuning system can "learn" from previous tuning procedures to minimize the number of feedback loops required to tune each speaker. For instance, if a previous speaker is tuned in accordance with the feedback technique as described above and final characteristic data is determined, the determined characteristic data is "remembered" by the tuning system and then provided in the control signal coupled to the next speaker. By loading in an expected set of characteristic data, the next speaker may not require as many reiterative adjustments to the characteristic data for tuning.

In the preceding description, numerous specific details are set forth in order to provide a thorough understanding of the present invention. It will be apparent, however, to one skilled in the art that these specific details need not be employed to practice the present invention. In other instances, well known speaker structures and components have not been described in order to avoid unnecessarily obscuring the present invention.

Moreover, although the components of the present invention have been described in conjunction with certain embodiments, it is appreciated that the invention can be implemented in a variety of other ways. Consequently, it is to be understood that the particular embodiments shown and described by way of illustration is in no way intended to be considered limiting. Reference to the details of these embodiments is not intended to limit the scope of the claims which themselves recite only those features regarded as essential to the invention.

WHAT IS CLAIMED IS:

1. A programmable speaker comprising:

a programmable portion including a processing portion and a memory storage area for storing characterization data, said processing portion for performing a transform function on audio input data using said characterization data, said programmable portion receiving and processing said audio input data and outputting a transformed signal; and

an output portion for converting said transformed signal into an audible analog signal.

2. The speaker as described in Claim 1 wherein said programmable portion includes a means for receiving said characterization data from an external source and storing said received characterization data in said memory storage area.

3. The speaker as described in Claim 1 wherein said processing portion comprises a digital signal processing unit, its corresponding memory system, and function specific hardware for performing said transform function on said input data using said characterization data to generate said transformed signal.

4. The speaker as described in Claim 1 wherein said output portion includes a means for converting said transformed signal into a plurality of analog signals, an amplifier means for amplifying said plurality of analog signals, and a means for outputting said audible analog signal in response to said amplified plurality of analog signals.

5. The speaker as described in Claim 1 wherein said memory storage area is a non-volatile memory.

6. The speaker as described in Claim 1 wherein more than one transform function is performed on said input data by said processing portion each transform function using different characteristic data.

7. The speaker as described in Claim 1 wherein said characterization data is weighting coefficient values of said transform function.

8. The speaker as described in Claim 1 wherein said transform function comprises a cross-over type transform function and said transformed signal comprises a plurality of transformed signals each having an associated frequency range.

9. The speaker as described in Claim 8 wherein said output portion includes a means for converting said plurality of transformed signal to analog signals, an amplifier means for amplifying said plurality of analog signals, and a means for outputting said audible analog signal in response to said amplified plurality of analog signals.

10. A method of operating a programmable speaker including a processing portion and a memory portion essentially comprising the steps of:

storing in said memory portion characteristic data;

performing a transform function on audio input data using said characteristic data to generate a transformed signal, wherein said transform function is representative of an inverse transform function of a distortion caused by a combination of physical speaker elements and characteristics;

converting said transformed signal to an amplified audible analog signal which is distortion compensated for said combination of physical speaker elements; and

outputting said audible signal.

11. The method as described in Claim 10 wherein said step of performing said transform function comprises performing a cross-over network type transform function.

12. A system comprising:

a programmable speaker comprising:

a programmable portion including a processing portion, a memory storage area, and an output portion, said memory storage area for storing characterization data, said processing portion for performing a transform function on a reference audio signal using said characterization data, and outputting a transformed signal, and said output portion for converting said transformed signal into an audible analog signal;

a tuning portion comprising:

a means for receiving said audible analog signal and generating a corresponding feedback audio analog signal;

a means for generating said reference audio signal;

a signal analysis means for comparing said reference signal to said feedback signal and generating a control signal having updated characterization data dependent on determined differences between said reference signal and feedback signal, said control signal being provided to said programmable speaker wherein said updated characterization data is stored in said memory portion and used to perform subsequent transform functions on said reference signal.

13. The system as described in Claim 12 wherein said reference signal generator means generates different types of reference signals for providing to said processing portion.

14. The system as described in Claim 13 wherein said reference signal type is selected as said reference signal dependent on the manner in which said programmable speaker is to be tuned.

15. A system for tuning a programmable speaker including a processing portion, a memory portion, and an output portion, said processing portion for performing a transform function on audio input data and generating a transformed signal, said memory portion for storing characterization data, said output portion for receiving said transformed signal and outputting a corresponding audible analog signal, said system comprising:

a means for generating a reference audio signal and providing it to said processing portions as said audio input data;

a means for receiving said audible analog signal on said speaker output corresponding to said reference audio signal and generating a corresponding feedback audio analog signal;

a signal analysis means for comparing said reference audio signal to said feedback signal and generating a control signal having updated characterization data dependent on determined differences between said reference audio signal and said feedback signal, said control signal being provided to said programmable speaker wherein said updated characterization data is stored in said memory portion and used to perform subsequent transform functions on said reference audio signal resulting in subsequent updates of said characterization data until a desired transfer function relationship is achieved between said reference audio signal and said feedback signal.

16. The system as described in Claim 15 wherein said reference signal generator means generates different types of reference signals.

17. The system as described in Claim 16 wherein said reference signal type is selected as said reference signal dependent on the manner in which said programmable speaker is to be tuned.

18. A method for tuning a programmable speaker including a processing portion, a memory portion, and an output portion, said processing portion for performing a transform function on audio input data provided to said processing portion and generating a transformed signal, said memory portion for storing characterization data, said output portion for receiving said transformed signal and outputting a corresponding audible analog signal, said method comprising the steps of:

a) providing a reference audio signal to said processing portion as said audio input data;

b) detecting said audible analog signal from said programmable speaker output portion corresponding to said reference audio signal and generating a corresponding feedback audio analog signal;

c) comparing said reference audio signal to said feedback signal and generating a control signal having updated characterization data dependent on determined differences between said reference audio signal and feedback signal;

d) providing said control signal to said programmable speaker;

e) storing said updated characterization data in said memory portion;

f) using said updated characterization data to perform subsequent

transform functions on said reference audio signal and repeating steps a)-f) until final characterization data is determined and said reference audio signal and said feedback signal have a desired transfer function relationship.

19. A method for tuning a plurality of programmable speakers in assembly line manufacturing environment, each speaker including a processing portion, a memory portion, and an output portion, said processing portion for performing a transform function on audio input data provided to said processing portion and generating a transformed signal, said memory portion for storing characterization data, said output portion for receiving said transformed signal and outputting a corresponding audible analog signal, said method comprising the steps of:

tuning a current programmable speaker by:

a) providing a reference audio signal to said processing portion of said current speaker as said audio input data;

b) detecting said audible analog signal from said current programmable speaker output portion corresponding to said reference audio signal and generating a corresponding feedback audio analog signal;

c) comparing said reference audio signal to said feedback signal and generating a control signal having updated characterization data dependent on determined differences between said reference audio signal and feedback signal;

d) providing said control signal to said current programmable speaker;

e) storing said updated characterization data in said memory portion;

f) using said updated characterization data to perform subsequent transform functions on said reference audio signal and repeating steps a) - f) until final characterization data is determined and said reference audio

signal and said feedback signal have a desired transfer function relationship;

tuning a next programmable speaker in said assembly line by loading said final characterization data into said memory portion of said next programmable speaker and performing steps a) - f).

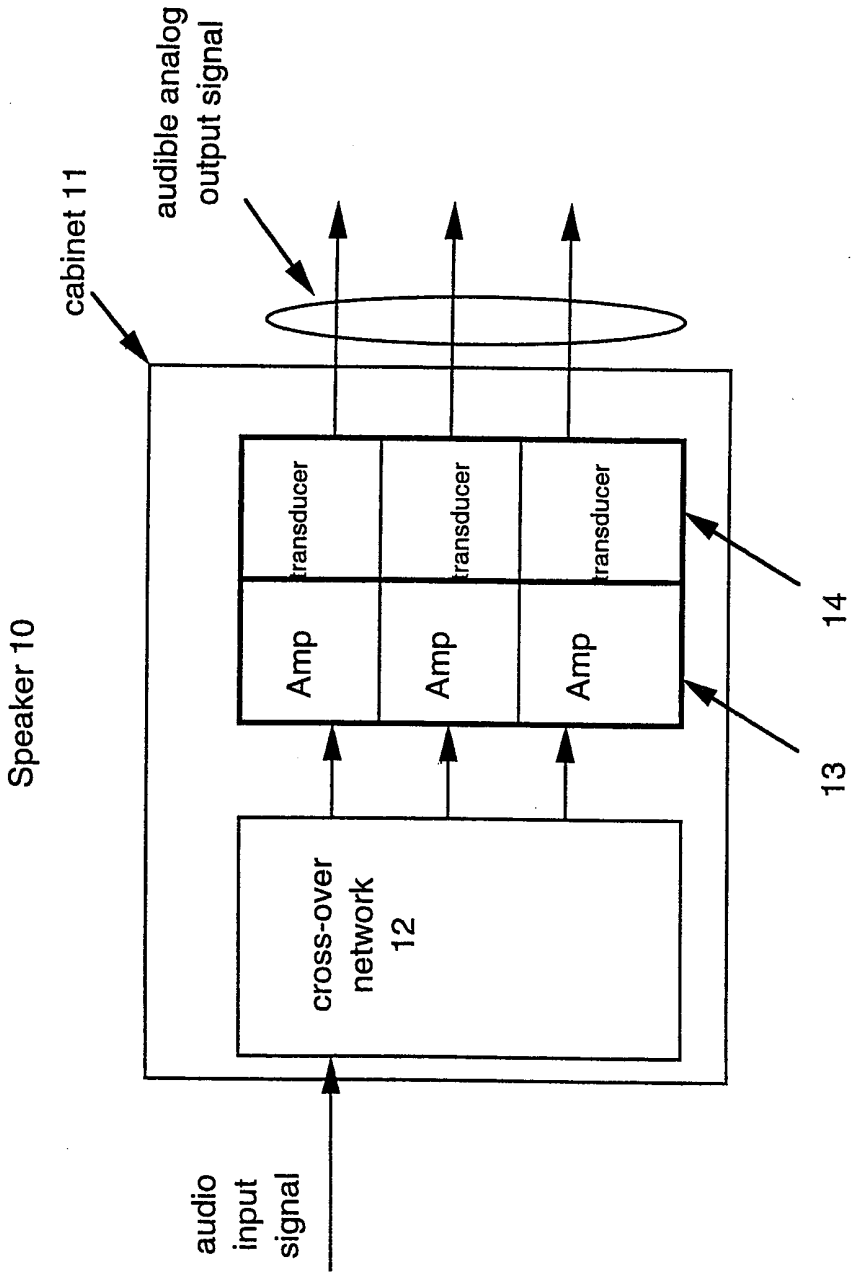


Figure 1
PRIOR ART

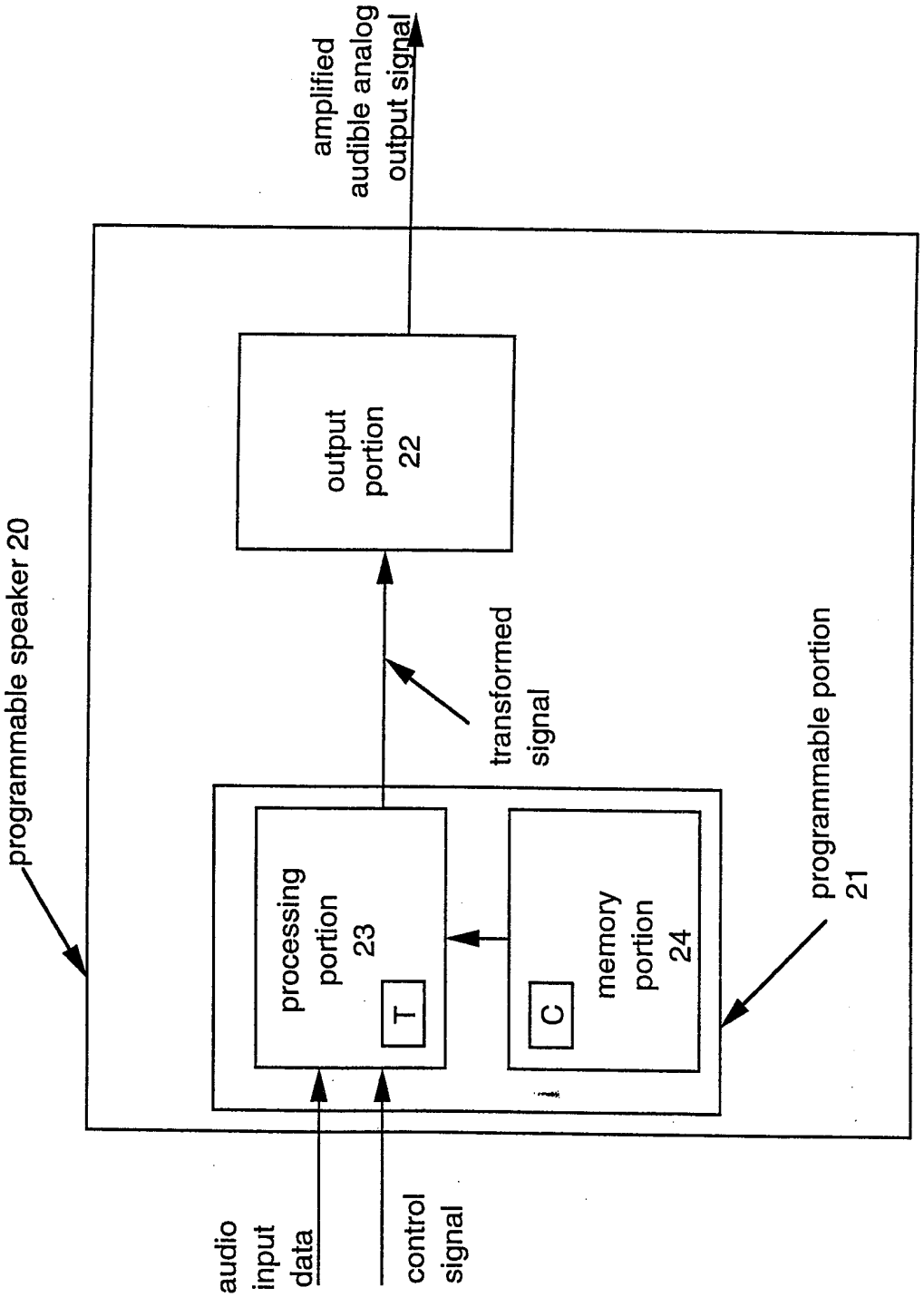

amplified
audible analog
output signal
output
portion
22
programmable speaker 20
transformed
signal
processing
portion
23
T
memory
portion
24
C
programmable portion
21
audio
input
data
control
signal

Figure 2

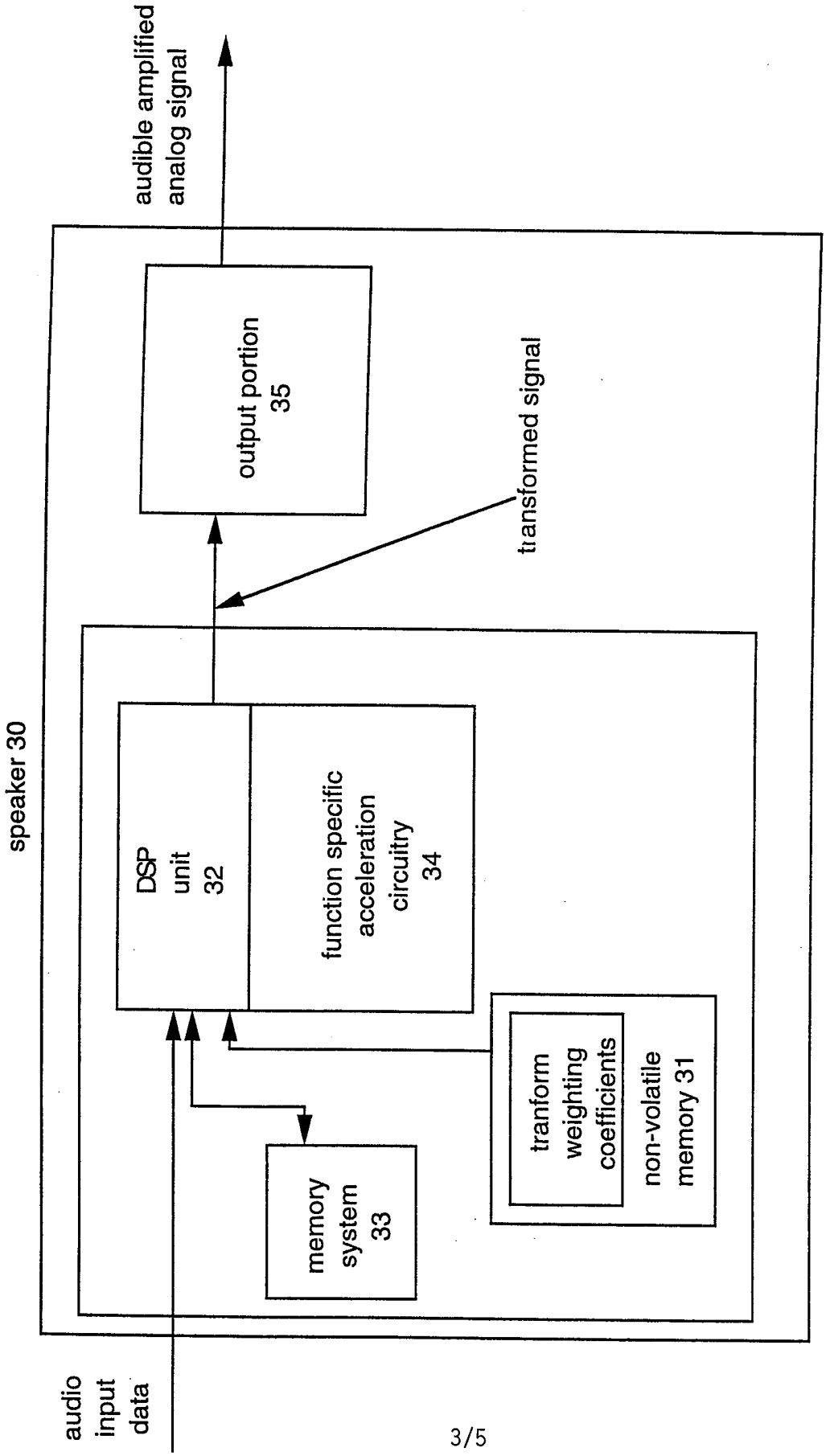

audible amplified analog signal
output portion 35
transformed signal
speaker 30
DSP unit 32
function specific acceleration circuitry 34
tranform weighting coefficients
non-volatile memory 31
memory system 33
audio input data

Figure 3

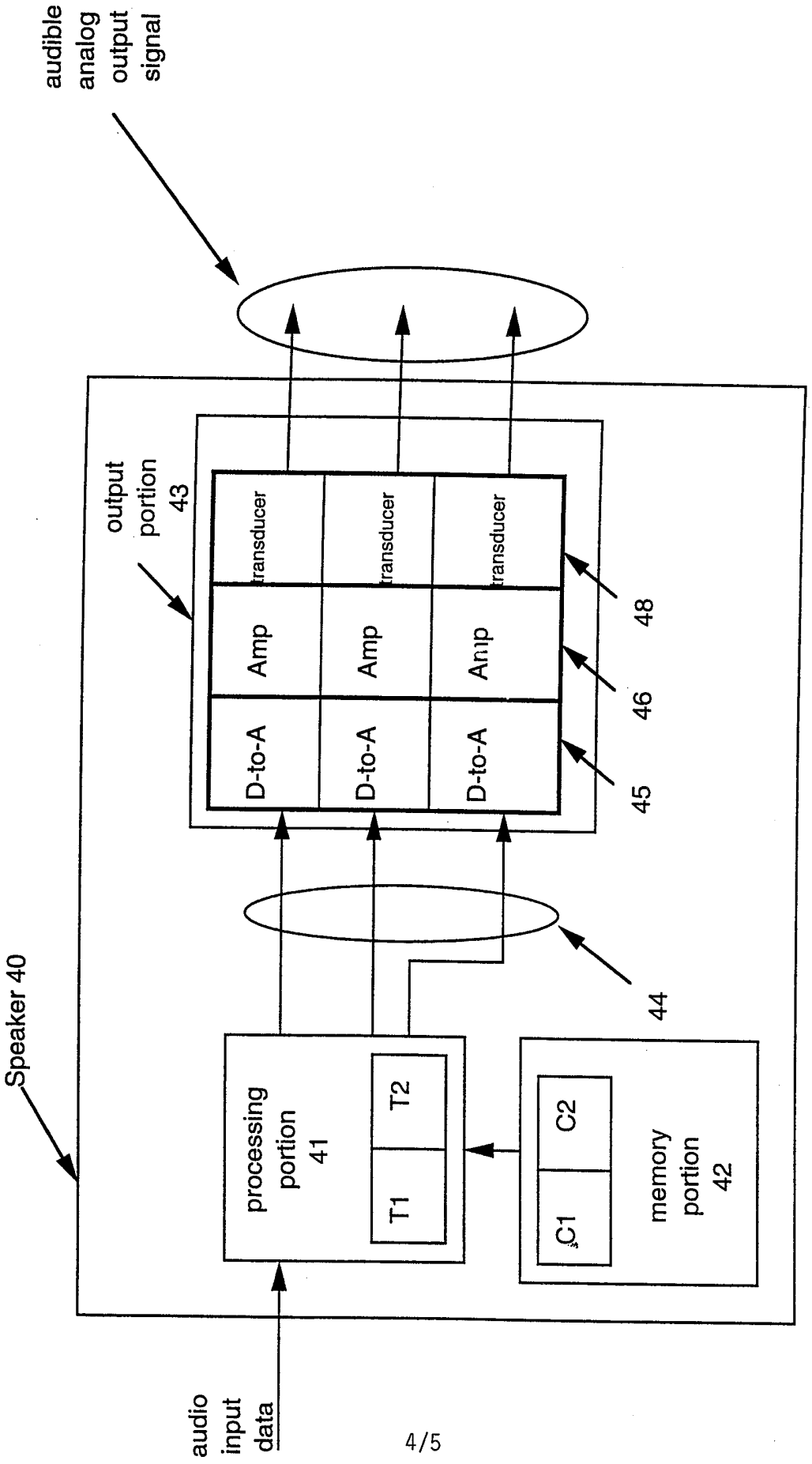

audible analog output signal
Speaker 40
output portion 43
transducer
transducer
transducer
Amp
Amp
Amp
D-to-A
D-to-A
D-to-A
48
46
45
44
processing portion 41
T1
T2
memory portion 42
C1
C2
audio input data

Figure 4

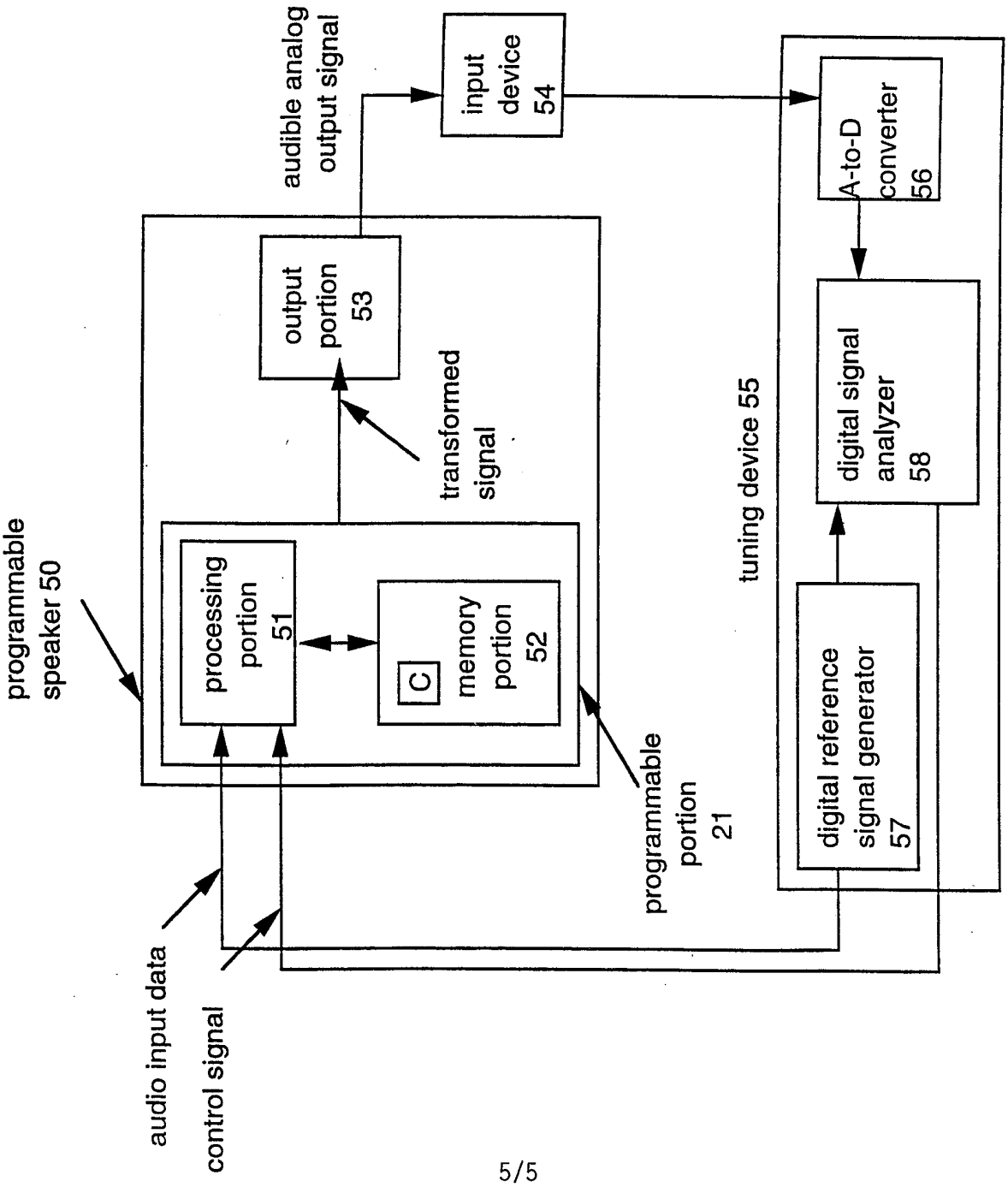

programmable speaker 50
audio input data
control signal
processing portion 51
C
memory portion 52
output portion 53
transformed signal
audible analog output signal
input device 54
programmable portion 21
tuning device 55
A-to-D converter 56
digital signal analyzer 58
digital reference signal generator 57

Figure 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/02274

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :H04R 29/00, 3/00; H03G 11/00;
US CL :381/59, 55, 58, 96

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 381/59, 55, 58, 72, 74, 96, 97, 98, 101, 103

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,185,805 A (CHIANG) 09 February 1993, figure 3.	1-3,5-7,10
X	US 5,430,802 A (PAGE) 04 July 1995, figures 1 and 2.	1-3, 6, 7, 10
---		---
Y		4, 5
X	US 5,694,476 A (KLIPPEL) 02 December 1997, figures 1 and 2.	1-3, 7, 10, 12-19
---		---
Y		4, 5
X	US 5,511,129 A (CRAVEN et al) 23 April 1996, Figures 1a and 1b	1-4, 6-11

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search	Date of mailing of the international search report
05 MAY 2000	24 May 2000
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer PING LEE Telephone No. (703)305-3900

Form PCT/ISA/210 (second sheet) (July 1998)*