



Published:

— *with international search report (Art. 21(3))*

APPARATUS AND METHOD FOR REPRODUCING AN AUDIO SIGNAL

BACKGROUND

[0001] Many contemporary electronic devices are designed to reproduce music and/or other audio signals. These electronic devices, such as, for example, laptops, portable audio players, cell phones, or the like, typically provide for the connection of various audio-related peripheral components. Examples of these peripheral components include headphones and microphones. The electronic device may include several connectors or jacks intended to receive and electrically interconnect with a plug of an audio-related peripheral component to thereby transfer audio signals between the portable electronic device and the audio-related peripheral. The jacks and plugs are typically electrically connected to a ground reference to minimize damage to the electronic device from electrostatic discharge (ESD).

[0002] While such a ground configuration may create robust ESD performance, it can also result in a ground loop condition that introduces undesirable signals when audio signals are played. Examples of undesirable signals include electrical noise present on a power source signal, noise created by digital circuitry, or noise induced within the system by other sources of electrical interference.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] Certain exemplary embodiments are described in the following detailed description and in reference to the drawings, in which:

[0004] Fig. 1 is a block diagram of one embodiment of an electronic device having an audio system with an improved audio grounding configuration in accordance with an exemplary embodiment of the present invention;

[0005] Fig. 2A is a cross-sectional end view of the audio output signal line of Fig. 1;

[0006] Fig. 2B is a cross-sectional side view of the audio output signal line of Fig. 2A;

[0007] Fig. 2C is a cross-sectional side view of another audio output signal line according to an exemplary embodiment of the present invention;

[0008] Fig. 3 is a cross-sectional view of the audio output connector of Fig. 1; and

[0009] Fig. 4 is a block diagram showing a method for improving the fidelity of a reproduced audio signal according to an exemplary embodiment of the present invention.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

[0010] Referring now to the drawings and particularly to Fig. 1, there is shown a block diagram of an audio system 100 having an improved grounding configuration in accordance with an exemplary embodiment of the present invention. The audio system 100 is one system of an electronic device 102, which may be any electronic device used at least in part to reproduce audio signals for presentation or listening by a user, such as, for example, a computer, laptop computer, cell phone, portable digital audio player or the like.

[0011] Those of ordinary skill in the art will appreciate that the functional blocks and devices shown in the figures are only one example of functional blocks and devices that may be implemented in an exemplary embodiment of the present invention. Moreover, other specific implementations containing different functional blocks may be chosen based on system design considerations.

[0012] The audio system 100 includes a printed circuit board (PCB) 110, such as, for example, a multi-layer printed circuit board, generally having various signal lines or traces transferring signals, including power, digital and audio signals, between the various functional components or blocks of audio system 100, as is more particularly described hereinafter. The audio system 100 further includes an audio control circuitry 120, such as, for example, an application specific integrated circuit, having an analog portion or circuitry 122 and a digital portion or circuitry 124. The analog portion or circuitry 122 of the audio control circuitry 120 is physically separate from the digital portion or circuitry 124 of the audio control circuitry 120. The audio system 100 further includes analog

amplifier circuitry 130, a first audio output connector or jack 140 and a second audio output connector or jack 150.

[0013] The PCB 110 includes a digital ground plane (DGP) 152 and an analog ground plane (AGP) 154, each being formed from, for example, a layer of copper or other conductive material disposed on, over, or within PCB 110. The DGP 152 is disposed entirely within a first or digital region 156 of PCB 110. Similarly, the AGP 154 is disposed entirely within a second or analog region 158 of PCB 110. The first region 156 and the second region 158, respectively, of the PCB 110 are separate non-overlapping mutually-exclusive respective regions of the PCB 110. Similarly, the DGP 152 and the AGP 154 are separate non-overlapping and mutually-exclusive with respect to each other.

[0014] As shown in Fig. 1, the PCB 110 is configured as a single PCB. However, as one of ordinary skill in the art will appreciate, PCB 110 can be alternately configured, such as, for example, a first PCB for the analog region 158 and a second PCB for the digital region 156.

[0015] Generally, digital signals and digital components of audio system 100 are disposed on or over (i.e., opposite), and have as a common ground reference, DGP 152. More particularly, digital power is provided via a digital power line 162 to the digital circuitry 124 of the audio control circuitry 120, digital input signals 164 are provided to the digital circuitry 124 of the audio control circuitry 120 via digital inputs 166, and digital audio output signals 168 are output via digital audio bus 170 from the digital circuitry 124 of the audio control circuitry 120. Each of the digital power line 162, the digital input signals 164, the digital inputs 166, the digital audio output signals 168, the digital audio bus 170 and the digital circuitry 124 of the audio circuitry controller 120 are disposed over and have the DGP 152 as a common electrical ground reference. Thus, only digital signals and components, and no analog signals or components, are disposed or routed on or over the DGP 152.

[0016] Similarly, analog signals and analog components of audio system 100 are disposed on or over (i.e., opposite) and have as a common ground reference, AGP 154. Analog power is provided via an analog power line 182 to the analog

circuitry 122 of the audio control circuitry 120 and to the audio amplifier circuitry 130. One or more analog signal inputs 186 provide analog input signals to the analog circuitry 122 of the audio control circuitry 120 via analog signal inputs 186, and analog output signals are provided via analog outputs 190 from the analog circuitry 122 of audio control circuitry 120 to the audio amplifier circuitry 130.

[0017] The audio amplifier circuitry 130, in turn, provides first audio output signals 210 via a first audio output channel 220 to the first audio output jack 140 which, in turn, is intended for connection to an audio transducer, such as, for example, a speaker. The audio amplifier 130 further provides second audio output signals 224 via a second audio output channel 230 to the second audio output jack 150 which, in turn, is intended for connection to an audio transducer, such as, for example, headphones.

[0018] Each of the analog power lines 182, the analog signal inputs 186, the analog outputs 190, the audio amplifier circuitry 130, the first audio output signals 210, the first audio output channel 220, the first audio connector or jack 140, the second audio output signals 224, the audio output channel 230, the second audio output connector or jack 150, and the analog circuitry 122 of the audio circuitry controller 120 have AGP 154 as a common electrical ground reference. Thus, only analog signals and components, and no digital signals or components, are disposed or routed on or over the AGP 152.

[0019] The DGP 152 and the AGP 154 are physically and electrically separated along a first portion of their adjacent sections by a gap 174, which also separates the digital region 156 and the analog region 158 of the PCB 110. A connecting member 260 electrically connects together the DGP 152 and the AGP 154 to form a low-resistance electrical connection, or effective electrical short, between the DGP 152 and the AGP 154. The connecting member 260 is, in the exemplary embodiment shown, disposed within and bridges the gap 174.

[0020] The connecting member 260 thus forms a single-point electrical connection between the DGP 152 and the AGP 154. The connecting member 260 is an electrically conductive member having very low resistance, such as, for example, a strip or trace of copper or other conductive material. In one

exemplary embodiment, the connecting member 260 is formed of copper or other conductive metallic material having a width of from approximately 50 to approximately 120 mils, although one skilled in the art will appreciate that the connecting member 260 can be alternately formed.

[0021] The single-point connection between the DGP 152 and the AGP 154 acts to keep the ground potentials of the two ground planes at substantially the same level, and reduces the transfer to the AGP 154 of digital noise that may be present on DGP 152 or its associated circuitry. Further, by routing and disposing, respectively, only analog signals and components, and no digital signals or components, on or over AGP 152, audio system 100 further substantially reduces the susceptibility of the audio components and signals to degradation and/or distortion due to the presence of undesirable non-audio signals. Thus, a substantial improvement in the fidelity of the reproduced audio signals is achieved by audio system 100.

[0022] Fidelity of the reproduced audio signal may also be degraded, as noted above, when the analog output channel carrying the audio signals are structured or configured in a manner that renders the audio output channel and, thus, the audio output signals carried thereby susceptible to interference from non-audio signals that are either induced in the audio output channel or are the result of a ground loop between the audio signal ground of the audio output channel and a non-audio ground as can exist when the audio signal ground is connected to a non-audio ground which, as described above, is done in the interest of enhancing ESD characteristics of the audio output channel. By structuring and configuring the audio output channel in a manner that substantially reduces the susceptibility thereof to interference from such non-audio signals and eliminating any ground loops between the audio signal ground and non-audio ground, a further improvement in the fidelity of reproduced audio signals is achieved by audio system 100.

[0023] Referring now to Fig. 2A, the entirety of the analog output channel 230 is disposed within the analog portion 158 of the PCB 110. Generally, the analog output channel 230 extends in a substantially parallel manner relative to and

opposite the AGP 154, and does not extend beyond or outside of the AGP 154. More particularly, the analog output channel 230 includes left and right channels 310 and 320, respectively, an audio ground return channel 330 and a stitching element 340. In an exemplary embodiment of the present invention, each of the left and right channels 310 and 320, respectively, and the audio ground return channel 330 are elongate members extending in a substantially parallel manner relative to and opposite AGP 154. The audio ground return channel 330 may be disposed between the left and right channels 310 and 320, respectively.

[0024] Disposing the audio ground return channel 330 between the left and right channels 310 and 320, respectively, shields the audio ground return channel from exposure to non-audio signals that may otherwise be induced into the ground return channel 330. Further, by disposing the AGP 154 between the analog output channel 230 and a source of electrical interference, the AGP 154 shields the analog output channel 230 from induced non-audio signals emanating from the source of electrical interference.

[0025] The stitching element 340 electrically connects the audio ground return channel 330 and the AGP 154. As best shown in Fig. 2B, the stitching element 340 may comprise, in one exemplary embodiment, a continuous elongate element extending along and electrically connecting the entire length of the audio ground return channel 330 with a corresponding portion of AGP 154. As best shown in Fig. 2C, the stitching element 340 may be alternately configured as a plurality of spaced-apart stitching elements 340a, 340b, etc. (as shown in Fig. 2C), each of which electrically connect respective portions of the audio ground return channel 330 with corresponding portions of the AGP 154.

[0026] The left and right channels 310 and 320, respectively, and the AGP 154 are, in one exemplary embodiment hereof, each formed of conductive material, such as, for example, copper. Therefore, the AGP 154 shields the output channel 230 from electrical interference and the presence of unwanted and/or induced non-audio signals. Each of the left and right channels 310 and 320, respectively, and the ground return channel 330 are, in one exemplary embodiment hereof, also formed of a conductive material, such as, for example

copper, having appropriate dimensions based on relevant operating parameters of the audio system 100, such as, for example, audio output current and/or power, as will be appreciated by one of ordinary skill in the art.

[0027] As shown in Fig. 3, the audio output jacks 140 and 150, unlike conventional audio jacks, include electrically nonconductive outer shells 350 and 352, respectively, and inner shells 360, 362, respectively. In one exemplary embodiment of the present invention, the outer shells 350, 352 are formed at least in part from an electrically nonconductive material, such as, for example, plastic. The electrically nonconductive characteristic of the outer shells 350, 352 deprives any electrostatic charges that may come into contact with the outer shells 350, 352 of a highly-conductive path from the outer shells 350, 352 to ground, thereby providing enhanced ESD characteristics and removing the need to provide a short and direct low-resistance path from the outer shells 350, 352 to electrical ground. Thus, the audio ground return channel 330 is electrically isolated from chassis, system and digital ground.

[0028] Unlike conventional electronic devices, there is no need to tie via an effective electrical short the non-conductive outer shell 350, 352 to a chassis, system or digital ground in order to improve ESD or other characteristics of the electronic device 100. With outer shell 350, 352 and, thus, the audio ground return channel 330 isolated from chassis, system and digital grounds, the presence of non-audio signals within the audio ground return channel 330 is substantially reduced and, thereby, a further improvement in the fidelity of reproduced audio signals is achieved by audio system 100.

[0029] Additionally, an exemplary embodiment of the present invention has the advantage of reducing the “noise floor” of the reproduced audio signal. More particularly, the noise floor of the reproduced audio output signal is reduced by the combined desirable effects of disposing the audio output channel 230 opposite the AGP 154, tying the audio ground return channel 330 to the separate AGP 154, and by disposing the audio ground return channel 330 between the left and right channels 310 and 320.

[0030] Referring now to Fig. 4, a method for improving the fidelity of a reproduced audio signal according to an exemplary embodiment of the present invention is shown. The method is generally referred to by the reference number 400. At block 402, the method 400 begins.

[0031] The method 400 includes establishing separate and non-overlapping analog and digital ground channels, as shown at block 404. According to an exemplary embodiment of the present invention, the process of establishing separate and non-overlapping analog and digital ground references may be achieved by forming separate and mutually-exclusive, non-overlapping, analog and digital ground planes.

[0032] Analog audio signals and circuitry are exclusively associated with the analog ground plane, as shown at block 406. Associating analog and audio signals and analog circuitry exclusively with the analog ground plane may be achieved by disposing analog components and circuitry upon and/or over, and by routing analog signals on or over, the analog ground plane exclusively. Thus, only analog signals and components, and no digital signals or components, are disposed or routed on or over the analog ground plane.

[0033] At block 408, digital audio signals and circuitry are exclusively associated with the digital ground plane. Associating digital signals and digital circuitry exclusively with the digital ground plane may be achieved by disposing digital components and circuitry upon and/or over, and by routing digital signals on or over, the digital ground plane exclusively. Thus, only digital signals and components, and no analog signals or components, are disposed or routed on or over the digital ground plane.

[0034] An audio output channel is disposed opposite the analog ground plane at block 410. Disposing an audio output channel opposite the analog ground plane may be achieved by disposing the entire analog output channel opposite the analog ground plane. The audio output channel may be disposed in a substantially parallel manner relative to the analog ground plane.

[0035] Finally, the ground return channel of the audio output channel is electrically isolated from non-audio and non-analog ground, as shown at block

412. Electrically isolating from non-analog ground an audio ground return channel of the audio output channel may be achieved by disposing the ground return channel between the left and right channels of the audio output channel and, further, by electrically connecting the audio ground return channel to the analog ground. At block 414, the process ends.

CLAIMS

What is claimed is:

1. An electronic device having an audio system for reproducing audio signals, the electronic device having an analog region and a separate and non-overlapping digital region, the electronic device comprising:
 - an analog ground plane disposed within the analog region;
 - a digital ground plane disposed within the digital region;
 - digital circuitry disposed opposite the digital ground plane, wherein digital signals are routed on or over the digital ground plane;
 - analog circuitry disposed opposite the analog ground plane, wherein analog signals are routed on or over the analog ground plane; and
 - at least one audio output channel disposed opposite the analog ground plane.
2. The electronic device of claim 1, wherein the digital ground plane and the analog ground plane are electrically connected by a single-point contact.
3. The electronic device of claims 1 or 2, wherein the audio output channel is entirely disposed opposite the analog ground plane.
4. The electronic device of any of claims 1 through 3, wherein the audio output channel extends in a substantially parallel manner relative to the analog ground plane.
5. The electronic device of any of claims 1 through 4, wherein the audio output channel includes a left channel, a right channel, and a ground return channel, the ground return element being electrically connected to the analog ground plane.

6. The electronic device of claim 5, further comprising a stitching element electrically connecting the ground return channel with the analog ground plane, the stitching element comprising an elongate electrically-conductive member extending along and electrically connecting the entire audio ground return channel with a corresponding portion of the analog ground plane.

7. The electronic device of claim 5, further comprising a stitching element electrically connecting the ground return channel with the analog ground plane, the stitching element comprising a plurality of separate and spaced-apart stitching elements, each the stitching element electrically connecting respective portions of the audio ground return channel with corresponding portions of the analog ground plane.

8. The electronic device of claim 5, further comprising at least one audio output jack electrically connected to the audio output channel, a ground element of the at least one audio output jack being electrically connected to the analog ground plane via the audio output channel, the at least one audio output jack being electrically isolated from ground references other than the analog ground plane.

9. The electronic device of any of claim 5, further comprising at least one audio output jack electrically connected to the audio output channel, the audio output jack having an outer shell, the outer shell being electrically nonconductive.

10. A method for improving the fidelity of a reproduced audio signal, comprising:
providing separate and non-overlapping analog and digital ground plane structures;
associating analog and audio signals and circuitry with the analog ground plane exclusively;

associating digital signals and circuitry with the digital ground plane exclusively;
disposing an audio output channel opposite the analog ground plane; and
electrically isolating from non-analog ground an audio ground return channel of the audio output channel.

11. The method of claim 10, comprising electrically connecting the audio ground return channel to the analog ground plane exclusively.

12. The method of claims 10, comprising disposing the audio output channel such that it extends in a substantially parallel manner relative to the analog ground plane.

13. The method of claim 10, comprising connecting the digital ground plane and the analog ground plane via a single-point contact.

14. The method of any of claims 10 through 13, wherein the audio output channel includes a left channel, a right channel, and a ground return channel, the ground return element being electrically connected to the analog ground plane.

15. The method of claim 14, further comprising connecting the ground return channel with the analog ground plane via a stitching element that comprises an elongate electrically-conductive member extending along and electrically connecting the entire audio ground return channel with a corresponding portion of the analog ground plane.

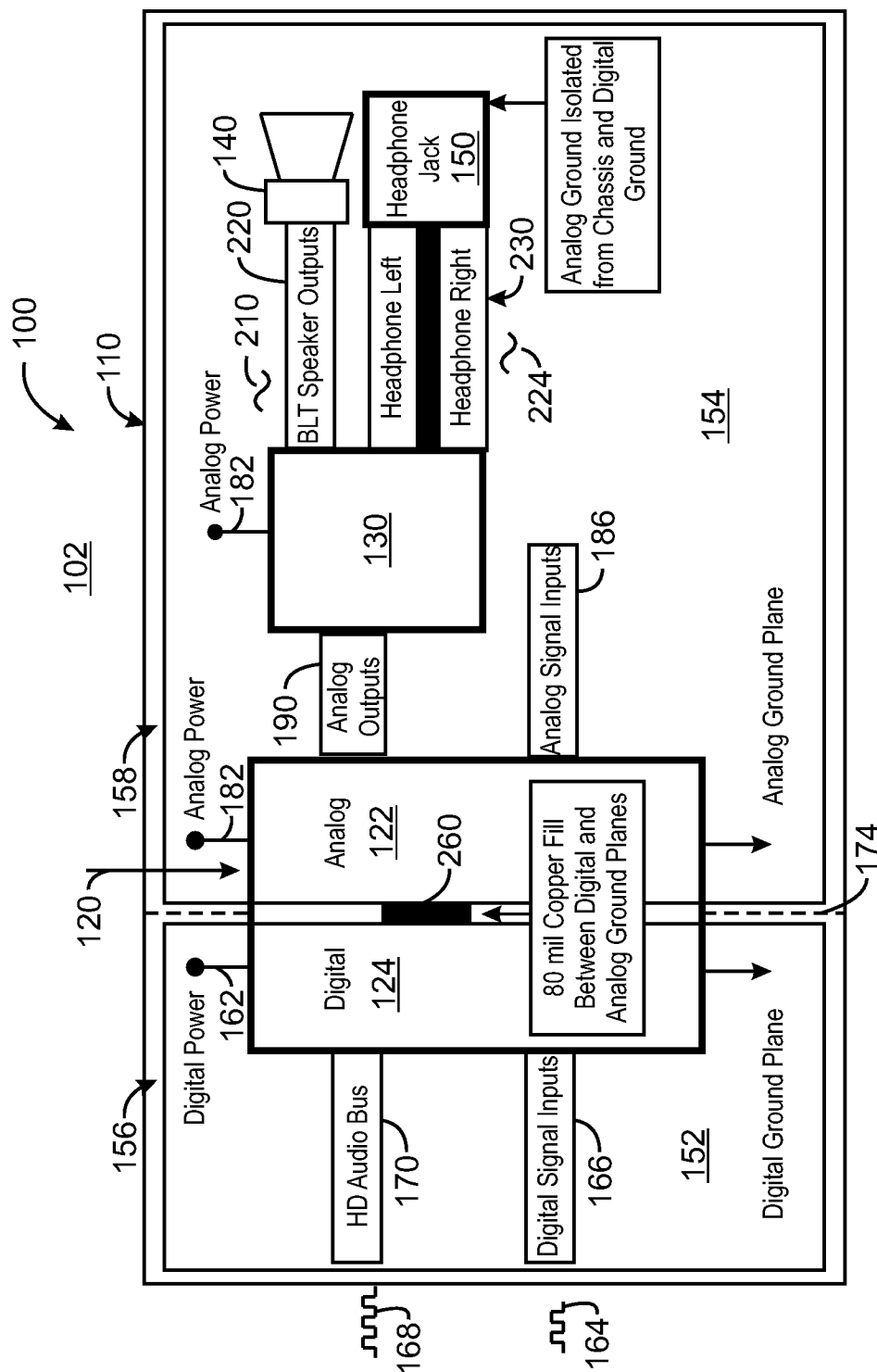


FIG. 1

2/6

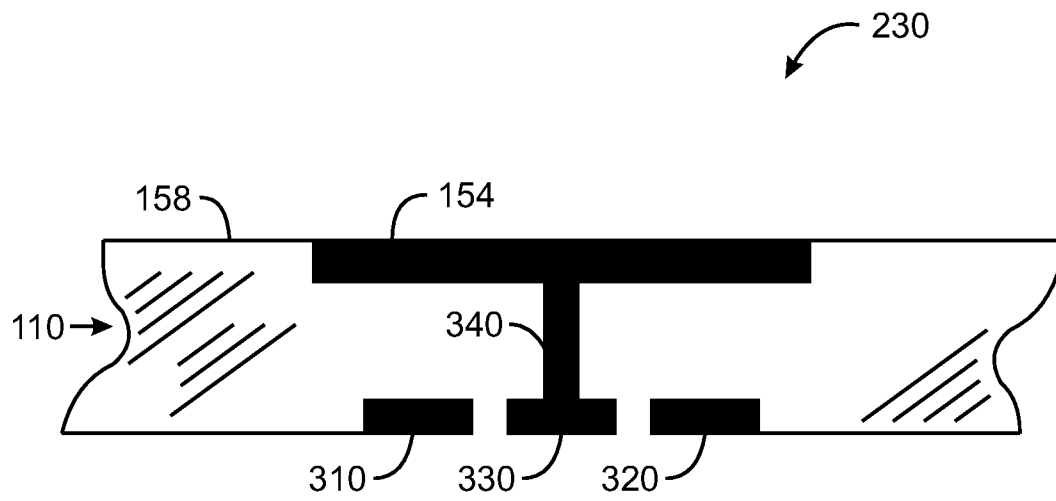


FIG. 2A

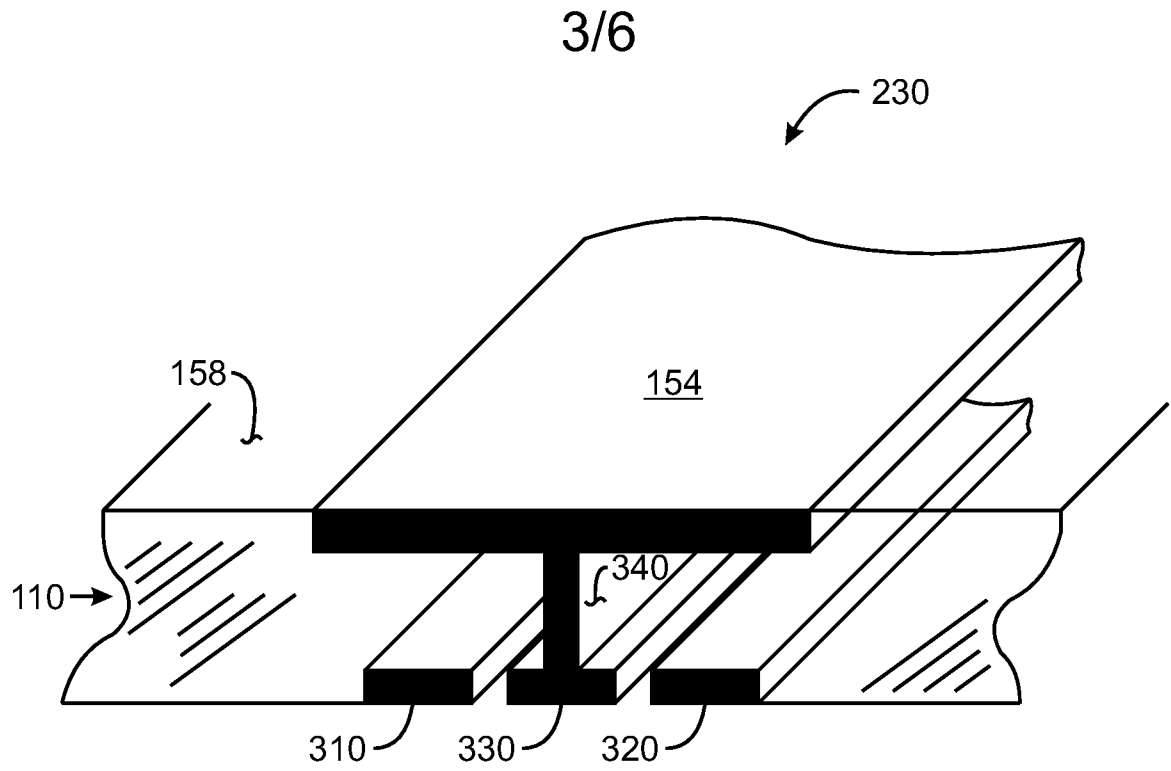


FIG. 2B

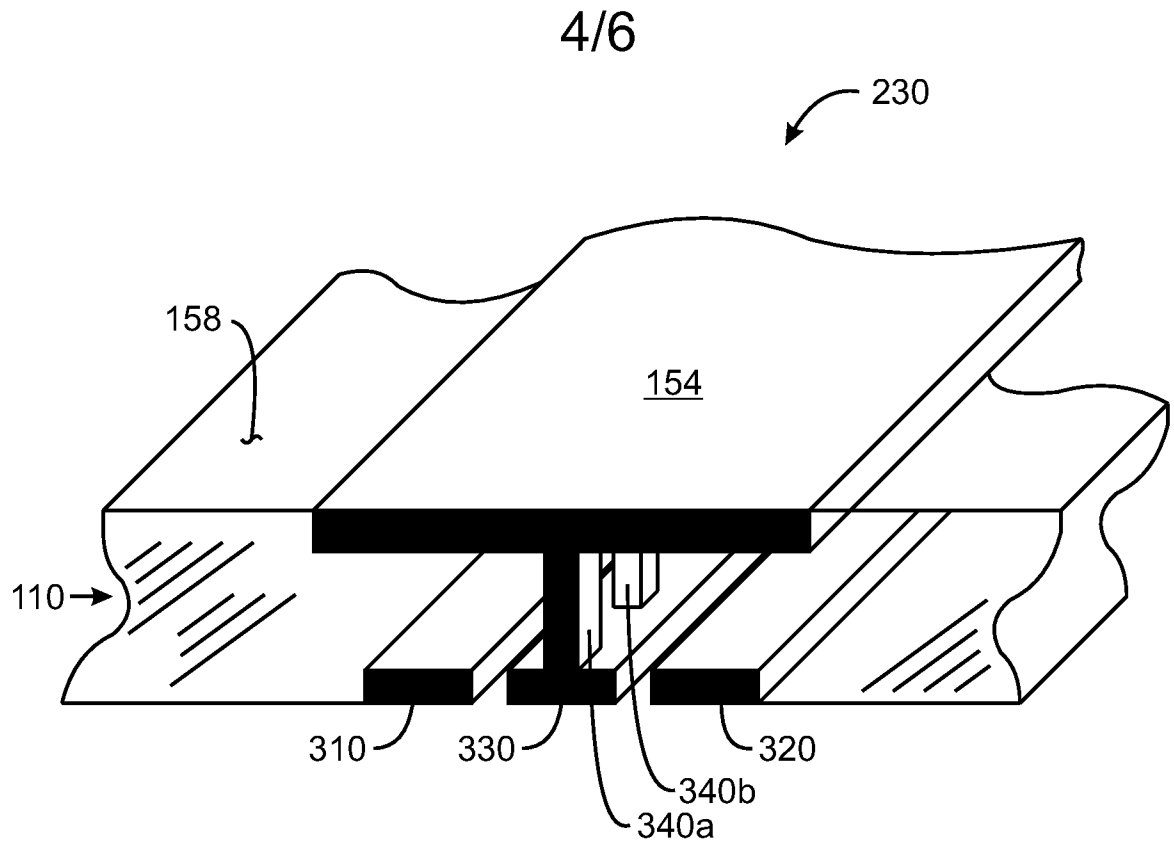


FIG. 2C

5/6

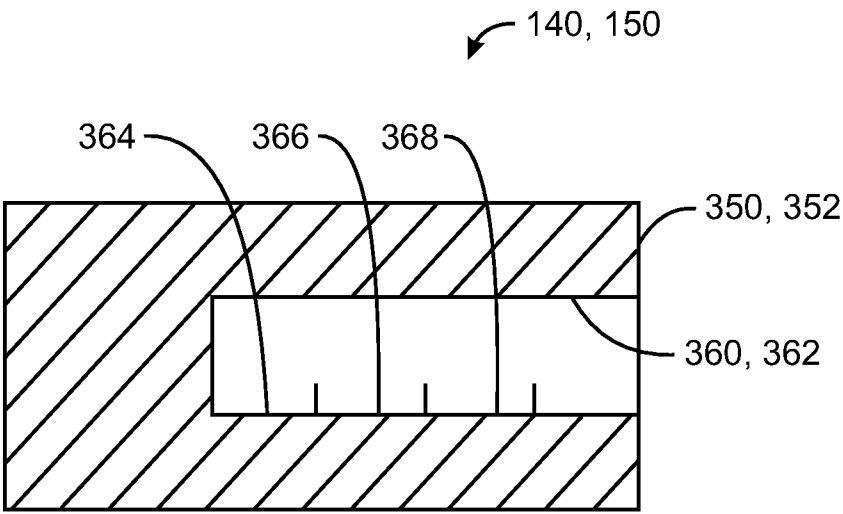
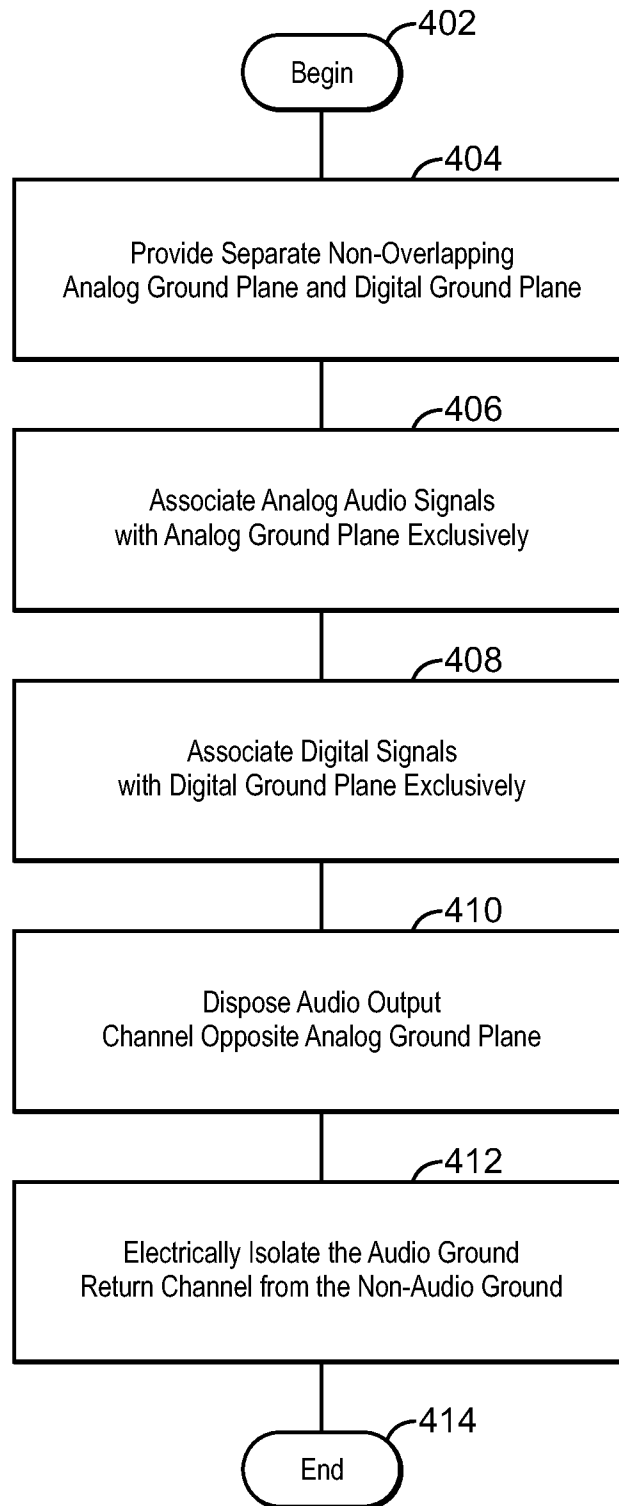


FIG. 3

6/6



400
FIG. 4

A. CLASSIFICATION OF SUBJECT MATTER**G11B 20/10(2006.01)i**

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)

G11B 20/10; B60L 1/00; G09G 3/10; H01H 47/00; H01L 29/00; H01L 39/00; H05K 3/00; H05K 9/00

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

(Chinese Patents and application for patent)

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

eKOMPASS(KIPO internal) & Keywords: electronic, device, analog, digital, ground, plane, electrostatic, discharge, audio, and channel

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2008-0099887 A1 (EUN-SEOK SONG et al.) 01 May 2008 See paragraph [0027] - paragraph [0032]; claim 1; and figure 2.	1-3, 10-15
A	US 2009-0080135 A1 (MAJOR DONALD EDWARD) 26 March 2009 See paragraph [0029] - paragraph [0037]; claims 1 - 14; and figures 2 - 5.	1-3, 10-15
A	US 5231308 A1 (ALFONS FISCH) 27 July 1993 See column 2, line 60 - column 4, line 18; claims 1 - 5.	1-3, 10-15
A	US 2007-0235832 A1 (YING-XIN WANG) 11 October 2007 See paragraph [0013]; claim 1; and figure 1.	1-3, 10-15
A	US 2005-0231124 A1 (JIN-HYUN CHOI et al.) 20 October 2005 See paragraph [0030] - paragraph [0032]; claim 1; and figure 3.	1-3, 10-15



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

20 MAY 2010 (20.05.2010)

Date of mailing of the international search report

20 MAY 2010 (20.05.2010)

Name and mailing address of the ISA/KR

Korean Intellectual Property Office
Government Complex-Daejeon, 139 Seonsa-ro, Seo-gu,
Daejeon 302-701, Republic of Korea

Facsimile No. 82-42-472-7140

Authorized officer

BYUN, SUNG CHEAL

Telephone No. 82-42-481-8262



INTERNATIONAL SEARCH REPORTInternational application No.
PCT/US2009/057341**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☒ Claims Nos.: 4-9
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2009/057341

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2008-0099887 A1	01.05.2008	CN 101174611 A CN 101174611 A0 JP 2008-112992 A KR 10-0817070 B1	07.05.2008 07.05.2008 15.05.2008 26.03.2008
US 2009-0080135 A1	26.03.2009	None	
US 5231308 A1	27.07.1993	EP 0429695 A1 EP 0429695 B1 JP 03-189370 A	05.06.1991 11.11.1992 19.08.1991
US 2007-0235832 A1	11.10.2007	CN 101048032 A	03.10.2007
US 2005-0231124 A1	20.10.2005	KR 10-0635060 B1 KR 10-2005-0090709 A US 07502021 B2	17.10.2006 14.09.2005 10.03.2009