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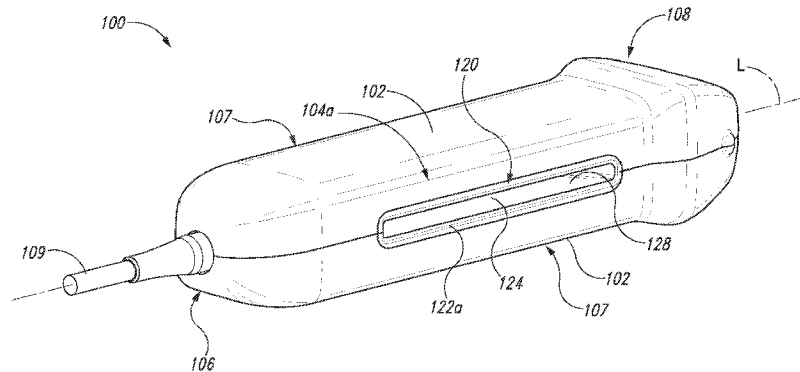


Fig. 1A

(57) Abstract: Systems and methods of transmitting heat away from an ultrasound probe are disclosed within. In one embodiment, a handheld ultrasound probe includes a transducer, electronics configured to drive the transducer, and a housing surrounding the transducer assembly and the electronics. A slot extending from a first side of the housing to a second side of the housing and can allow air to pass adjacent transducer and the electronics. The slot can be sized to inhibit accessibility of an operator's finger to an inner surface of slot.

WO 2015/191643 A1

## SYSTEMS AND METHODS FOR COOLING ULTRASOUND TRANSDUCERS

### CROSS-REFERENCES TO RELATED APPLICATIONS

**[0001]** This application is an international patent application claiming priority to United States Patent Application Serial No. 14/301,299 filed on June 10, 2014, and entitled " SYSTEMS AND METHODS FOR COOLING ULTRASOUND TRANSDUCERS," which is hereby incorporated herein in its entirety by reference.

### TECHNICAL FIELD

**[0002]** The disclosed technology relates generally to ultrasound probes, and more specifically to systems and methods of reducing heat of ultrasound probes.

### BRIEF DESCRIPTION OF THE DRAWINGS

**[0003]** FIG. 1A is an isometric side view of an ultrasound transducer configured in accordance with the disclosed technology.

**[0004]** FIGS. 1B and 1C are isometric side exploded views of the ultrasound transducer of FIG. 1A.

**[0005]** FIG. 1D is a side exploded view of the ultrasound transducer of FIG. 1A.

### DETAILED DESCRIPTION

**[0006]** The disclosed technology is generally directed to systems and methods of cooling ultrasound transducers. It will be appreciated that several of the details set forth below are provided to describe the following embodiments in a manner sufficient to enable a person skilled in the relevant art to make and use the disclosed embodiments. Several of the details described below, however, may not be necessary to practice certain embodiments of the technology. Additionally, the technology can include other embodiments that are within the scope of the claims but are not described in detail with reference to FIGS. 1A-D.

**[0007]** The disclosed technology can reduce an amount of heat emitted from an outer surface of an ultrasound probe. During an ultrasound procedure, for example, an ultrasound transducer in the probe generates, transmits and receives ultrasound

energy. Electronics in the probe (e.g., beamforming electronics) can process the signals and produce ultrasound data that can be used to form an ultrasound image. The generation of the ultrasound energy and processing of the ultrasound data can, in some instances, produce temperatures in excess of 60 degrees Celsius within the probe. Such temperatures may raise a temperature of at least a portion of the outer surface of the probe to a point of being uncomfortable or unsafe for an operator to hold and/or a patient to touch. Embodiments of the present technology include, for example, one or more conduits extending through an ultrasound probe allowing internal components to emit heat to air flowing through the conduit(s), thereby reducing a temperature along the outer surface of the probe and/or at the ultrasound transducer array.

**[0008]** In one embodiment, for example, a handheld ultrasound imaging probe includes a transducer assembly, electronics configured to drive the transducer and a housing surrounding the transducer assembly and the electronics. A heat spreader is positioned in the housing and configured to absorb heat from the transducer assembly and the electronics. A conduit extends from a slot in a first side of the housing to a slot in the second side of the housing and allows air to pass adjacent the heat spreader. In one aspect, the conduit has an interior surface sealed from an interior portion of the housing. One or both of the slots can be sized to prevent accessibility to the interior surface by a finger of an operator. For example, one of the slots can have a height that is significantly less than a width of the slot. In some aspects, the heat spreader can be bonded and/or integral to the conduit.

**[0009]** In another embodiment of the disclosed technology, a handheld ultrasound imaging probe includes a housing having a first side portion opposite a second side portion, and an ultrasound transducer array and a circuit disposed within the housing. A first aperture in the first side portion is in fluid communication with a second aperture in the second side portion via a conduit extending through the housing. The conduit includes a sealed interior surface that defines a cavity. In one aspect, the first and second apertures are sized to prevent accessibility by a finger of an operator to the cavity and the interior surface of the conduit. In another aspect, the ultrasound transducer includes a front end and a rear end, and the conduit includes a distal end and a proximal end. An exterior surface at the distal end of the conduit is shaped to define a recess that receives at least a portion of the ultrasound transducer. In some

aspects, a thermally conductive material is disposed in the housing between an exterior surface of the conduit and the circuit. The thermally conductive material can have a higher thermal conductivity than the housing. In other aspects, the housing is configured to dissipate heat at a temperature less than or equal to a first temperature, and the interior surface of the conduit is configured to dissipate heat at a second temperature greater than the first temperature. In further embodiments, the interior surface of the conduit includes a plurality of grooves. In still further embodiments, the probe includes a second conduit through the housing that includes an interior surface that defines a second cavity. A third aperture is in fluid communication with a fourth conduit via the second cavity. The third and fourth apertures extend along different outer surfaces of the enclosure.

**[0010]** In yet another embodiment of the disclosed technology, a handheld imaging probe includes an ultrasound transducer array, beamforming electronics and an enclosure at least partially surrounding the transducer array and beamforming electronics. The enclosure includes a first opening and a second opening within different sides of the enclosure. The probe further includes a passive heat exchanger positioned in thermal communication with the transducer array and the beamforming electronics. The heat exchanger includes a sealed tube extending between the first and second openings, a heat spreader positioned at least proximate and/or near the tube, and an air passage defined by an inner surface of the tube. The tube is configured to convey thermal energy away from the ultrasound transducer, the beamforming electronics and the heat spreader via air flowing in and out of the tube through the air passage. In one aspect, the first and second openings are sized to inhibit accessibility of an operator's finger to the inner surface of the tube. In another aspect, the heat spreader has a higher thermal conductivity than the enclosure.

**[0011]** FIG. 1A is an isometric side view of an ultrasound transducer probe 100 configured in accordance with one embodiment of the disclosed technology. FIGS. 1B and 1C are exploded isometric side views of the probe 100. FIG. 1D is an exploded side view of the probe 100. Referring first to FIGS. 1A-1D together, the probe 100 includes a housing 102 (e.g., an enclosure, a body, a shell, etc.) that defines a cavity 103. The housing 102 includes a first housing portion 102a (e.g., an upper portion) attached or otherwise bonded to a second housing portion 102b (e.g., a lower portion). The housing 102 further includes a first side portion 104a and a second side portion

104b on opposite sides of a longitudinal axis L extending through a proximal end portion 106, an intermediate portion 107 and a distal end portion 108 of the housing 102. A first aperture 122a (e.g., an opening, a hole, etc.) forms an elongated slot that extends longitudinally along the first side portion 104a. A second aperture 122b (e.g., an opening, a hole, etc.) forms an elongated slot that extends longitudinally along the second side portion 104b. The first and second apertures 122a and 122b are configured to inhibit and/or block entry of a finger (e.g., an operator's finger, a patient's finger, etc.) therethrough. The first and second apertures 122a and 122b each have a length that extends between the proximal end portion 106 and the distal end portion 108 and a width that extends between the first housing portion 102a and the second housing portion 102b. In one embodiment, one or both of the length or the width of either the first aperture 122a or the second aperture 122b has a dimension less than a diameter of typical finger (e.g., less than about 5mm). In some embodiments, for example, one or both of the first and second apertures 122a and 122b can include a length (e.g., between about 10mm and about 100mm, between about 15mm and about 35mm, or about 25mm) significantly greater than a width (e.g., between about 2mm and about 20mm, between about 3mm and about 5mm, or about 4mm). In further embodiments, a grid and/or a mesh screen, for example, can be disposed within one or both of the first and second apertures 122a and 122b to inhibit entry of a finger.

**[0012]** The housing 102 is configured to at least partially surround an ultrasound transducer assembly 110 (e.g., a single element ultrasound transducer, a one-dimensional ultrasound transducer array, a multi-dimensional ultrasound transducer array, etc.) positioned at least proximate the distal end portion 108. The transducer assembly 110 is electrically connected to system electronics 114 (identified separately as first system electronics 114a, second system electronics 114b and third system electronics 114c). The electronics 114 can include, for example, one or more digital signal processors, beamformers (e.g., analog and/or digital beamformers), image processors (e.g., one or more processors capable of processing B-mode images, M-mode images, Doppler images, etc.), electronic filters, etc. A cable 109 at the proximal end portion 106 communicatively couples the transducer assembly 110 and the system electronics 114 to an external computer and/or display (not/shown).

**[0013]** A conduit 120 (e.g., a duct, tube, etc.) extends through the housing 102 from the first aperture 122a toward the second aperture 122b. The conduit 120

includes a first conduit opening 130a (e.g., an inlet/outlet) and a second conduit opening 130b positioned adjacent the first aperture 122a and the second aperture 122b, respectively. The conduit 120 further includes a proximal end portion 125a opposite a distal end portion 125b. The distal end portion 125b includes an exterior surface defining a pocket or recess configured to receive at least a portion of the transducer assembly 110. In the illustrated embodiment, the conduit 120 is shown positioned in the intermediate portion 107 of the probe 100. In other embodiments, however, the conduit 120 can be positioned at any suitable location within the housing 102. Moreover, the probe 100 in FIGS. 1A-1D includes a single conduit 120. In other embodiments, however, the probe 100 can include a plurality of conduits 120 extending through the housing 102.

**[0014]** An interior surface 128 of the conduit 120 defines a fluid path 124 (e.g., an air pathway, air passage, cavity, through hole, etc.) between the first aperture 122a and the second aperture 122b. The interior surface 128 of the illustrated embodiment is sealed such that air within the conduit 120 cannot flow into the cavity 103. In some embodiments, however, the interior surface 128 can be at least partially open (e.g., via one or more holes or vents) to allow air in the fluid path 124 to flow in and out of the cavity 103. The interior surface 128 can be made from a material (e.g., copper, a copper alloy, aluminum, stainless steel, etc.) having a thermal conductivity greater than a material from which the housing 102 is formed. In other embodiments, however, the interior surface 128 can be made of any suitable heat-resistant material (e.g., thermally conductive materials capable of withstanding temperatures greater than 100 degrees Celsius). In further embodiments, the interior surface 128 can include one or more features (e.g., channels, grooves, ridges, notches, etc.) along at least a portion thereof to increase the surface area thereof, thereby increasing heat dissipation.

**[0015]** A first heat spreader 118a and a second heat spreader 118b are positioned adjacent the conduit 120 and in thermal communication with the interior surface 128, the transducer assembly 110, the electronics 114. The first and second heat spreaders 118a and 118b can comprise, for example, copper, an alloy of copper and/or any other suitable thermally conductive material (e.g., aluminum, graphite, composites that include aluminum and/or copper, etc.). The first and second heat spreaders 118a and 118b are configured to absorb heat from the transducer assembly 110 and in the electronics 114 and transmit heat to the interior surface 128. In some embodiments, for

example, the first and second heat spreaders 118a and 118b are directly bonded to the conduit 120 and/or at least partially integrated into the conduit 120. In other embodiments, however, the heat spreaders 118a and 118b are fully integrated with the conduit 120.

**[0016]** The generation of ultrasound energy by the transducer assembly 110 during an ultrasound measurement procedure and/or the processing of ultrasound signals by the electronics 114 can produce significant amounts of heat. For example, during an ultrasound procedure, the transducer assembly 110 and electronics 114 may emit sufficient heat to raise a temperature at the interior surface 128 above for example, 60 degrees Celsius, which could be unsafe to touch. As explained above, however, first and second apertures 122a and 122b are configured to inhibit entry of a finger, thus reducing and/or blocking access to the interior surface 128 to an operator's and/or patient's touch. The disclosed technology therefore is expected to increase an amount of heat that can be produced and/or dissipated by the probe 100 compared to other ultrasound probes without the housing 102 being uncomfortable or unsafe to touch or hold.

**[0017]** In operation, a coolant C (e.g., air, water and/or another suitable coolant) can enter the conduit 120, flow through the fluid path 124 and absorb heat generated by components in the probe 100 before exiting the conduit 120. The coolant C, for example, can enter the conduit 120 at a first temperature through either of the first conduit opening 130a or the second conduit opening 130b. As the coolant C flows through the fluid path 124 in the conduit 120, the coolant C can absorb heat transmitted from, for example, the transducer assembly 110 and/or the electronics 114 via the heat spreaders 118a and 118b and the interior surface 128 thereby convectively cooling the probe 100 and one or more components contained therein.

**[0018]** From the foregoing, it will be appreciated that specific embodiments of the invention have been described herein for purposes of illustration, but that various modifications may be made without deviating from the scope of the invention. For example, although the conduit 120 between the first and second apertures 122a and 122b is shown as a single continuous opening, it will be appreciated that multiple conduits connecting multiple holes or slots can be provided along the length of the probe 100. Accordingly, the invention is not limited except as by the appended claims.

## CLAIMS

I/We claim:

1. A handheld ultrasound imaging probe, comprising:  
a transducer assembly;  
electronics configured to drive the transducer;  
a housing surrounding the transducer assembly and the electronics;  
a heat spreader configured to absorb heat from the transducer assembly and the electronics; and  
at least one conduit extending from a first side of the housing to a second side of the housing, wherein the conduit is configured to allow air to pass adjacent the heat spreader.
2. The probe of claim 1 wherein the conduit has an interior surface sealed from an interior portion of the housing.
3. The probe of claim 2 wherein the conduit extends from a first slot in a first side of the housing to a second slot in a second side of the housing, and wherein the first and second slots are sized to prevent accessibility to the interior surface by a finger of an operator.
4. The probe of claim 3 wherein the first and second slots each have a length and a width, wherein the length is significantly less than the width.
5. The probe of claim 1 wherein the heat spreader is bonded to the conduit.
5. The probe of claim 1 wherein the heat spreader is integral to the conduit.
7. A handheld ultrasound imaging probe, comprising:  
a housing having a first side portion opposite a second side portion;  
an ultrasound transducer assembly and a circuit disposed within the housing;

a first aperture in the first side portion in fluid communication with a second aperture in the second side portion via a conduit extending through the housing, wherein the conduit includes a sealed interior surface that defines a cavity.

8. The ultrasound probe of claim 7 wherein the first and second apertures are configured to prevent accessibility by a finger of an operator to the cavity and the interior surface of the conduit.

9. The ultrasound probe of claim 7 wherein an exterior surface at the distal end of the conduit includes a recess that is configured to receive at least a portion of the ultrasound transducer.

10. The ultrasound probe of claim 7, further comprising a thermally conductive material disposed in the housing that is adjacent the conduit, wherein the thermally conductive material has a higher thermal conductivity than the housing.

11. The ultrasound probe of claim 7 wherein the housing is configured to dissipate heat at a temperature less than or equal to a first temperature, and wherein the interior surface of the conduit is configured to dissipate heat at a second temperature greater than the first temperature.

12. The ultrasound probe of claim 7 wherein the surface of the conduit includes a plurality of grooves.

13. The ultrasound probe of claim 7 wherein the conduit is a first conduit and the cavity is a first cavity, and further comprising:

a second conduit through the housing, wherein the second conduit includes an interior surface that defines a second cavity; and

a third aperture in fluid communication with a fourth conduit via the second cavity, wherein the third and fourth apertures extend along different outer surfaces of the enclosure.

14. A handheld imaging probe, comprising:  
an ultrasound transducer assembly communicatively coupled to beamforming electronics; and  
an enclosure at least partially surrounding the transducer assembly and the electronics, wherein the enclosure includes a first opening and a second opening within different sides of the enclosure; and  
a passive heat exchanger positioned in thermal communication with the transducer array and the electronics, wherein the heat exchanger includes a tube extending from the first opening toward the second opening.
15. The imaging probe of claim 14 wherein the passive heat exchanger further includes:  
a heat spreader positioned adjacent the tube, wherein the heat spreader has a higher thermal conductivity than the enclosure; and  
a cavity defined by an interior surface of the tube, wherein the tube is configured to convey thermal energy away from the ultrasound transducer, the beamforming electronics and the heat spreader via air flowing in and out of the tube through the cavity.
16. The imaging probe of claim 14 wherein the first and second openings each have a length and a width, wherein the length is significantly longer than the width.
17. A method of fabricating a probe having an ultrasound transducer and beamforming electronics, comprising:  
providing an enclosure that surrounds an ultrasound transducer coupled to beamforming electronics, wherein the enclosure includes a first aperture and at least a second aperture, and wherein the first and second apertures each include a first dimension less than a diameter of an operator's finger; and  
positioning a duct within the enclosure to extend from the first aperture toward the second aperture and proximate the transducer and the beamforming electronics.

18. The method of claim 17 wherein the duct includes an interior surface that defines an air passage, and wherein the duct is arranged to transfer heat away from the ultrasound transducer and the beamforming electronics via air flowing in and out of the duct through the air passage.

19. The method of claim 17, further comprising bonding a thermally conductive member to an exterior surface of the duct.

20. The method of claim 17 wherein providing the enclosure includes providing an enclosure made of a first material, and wherein positioning the duct within the enclosure includes positioning a duct made of a second material with a greater thermal conductivity than the first material.

21. A handheld ultrasound imaging probe comprising:  
a housing;  
a transducer disposed in the housing; and  
electronics within the housing, wherein the transducer and electronics are positioned around an open slot in the housing that includes a heat dissipating surface, wherein the housing is configured so that a user's hand touches an outer surface of the housing and not the heat dissipating surface of the slot during use.

1/4

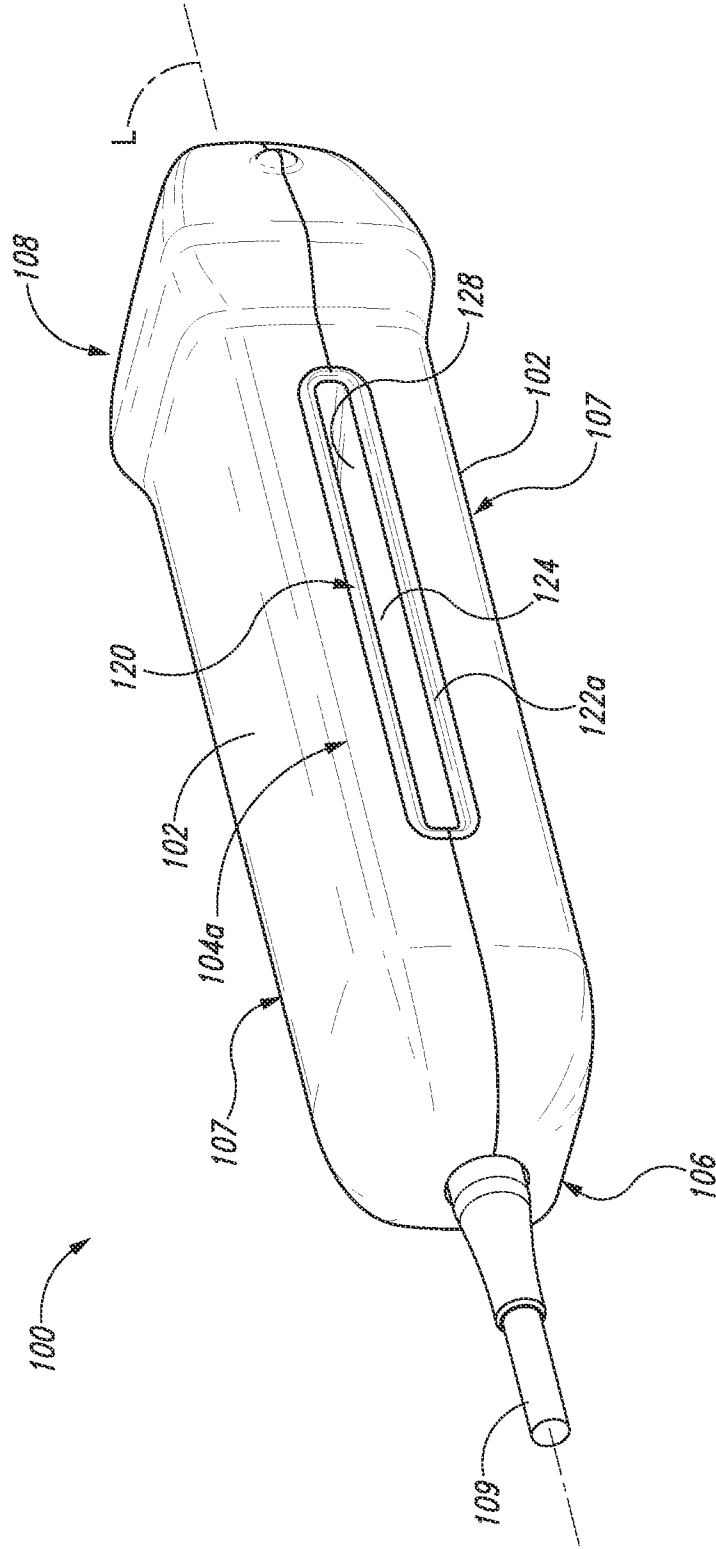


Fig. 1A

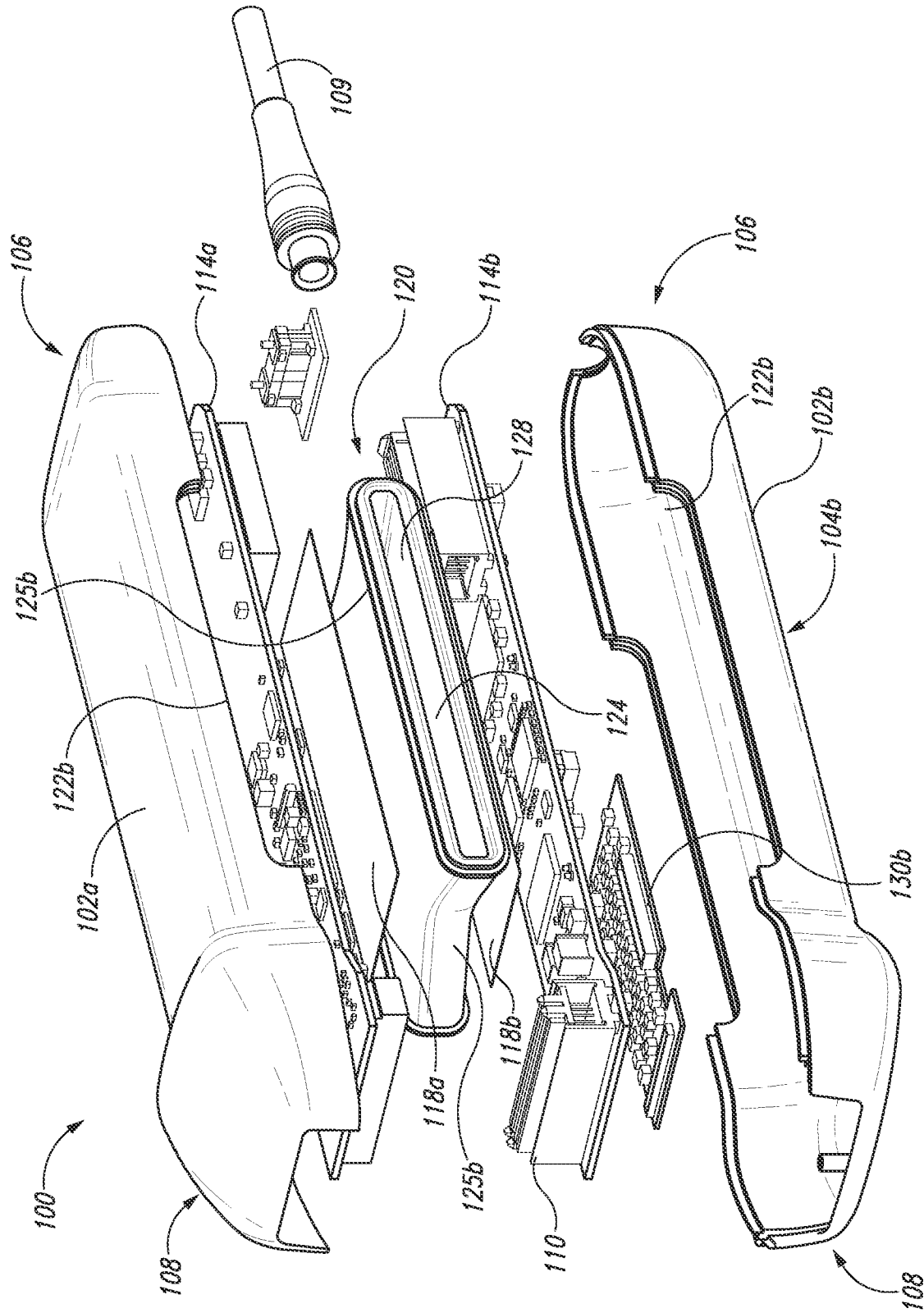


Fig. 1B



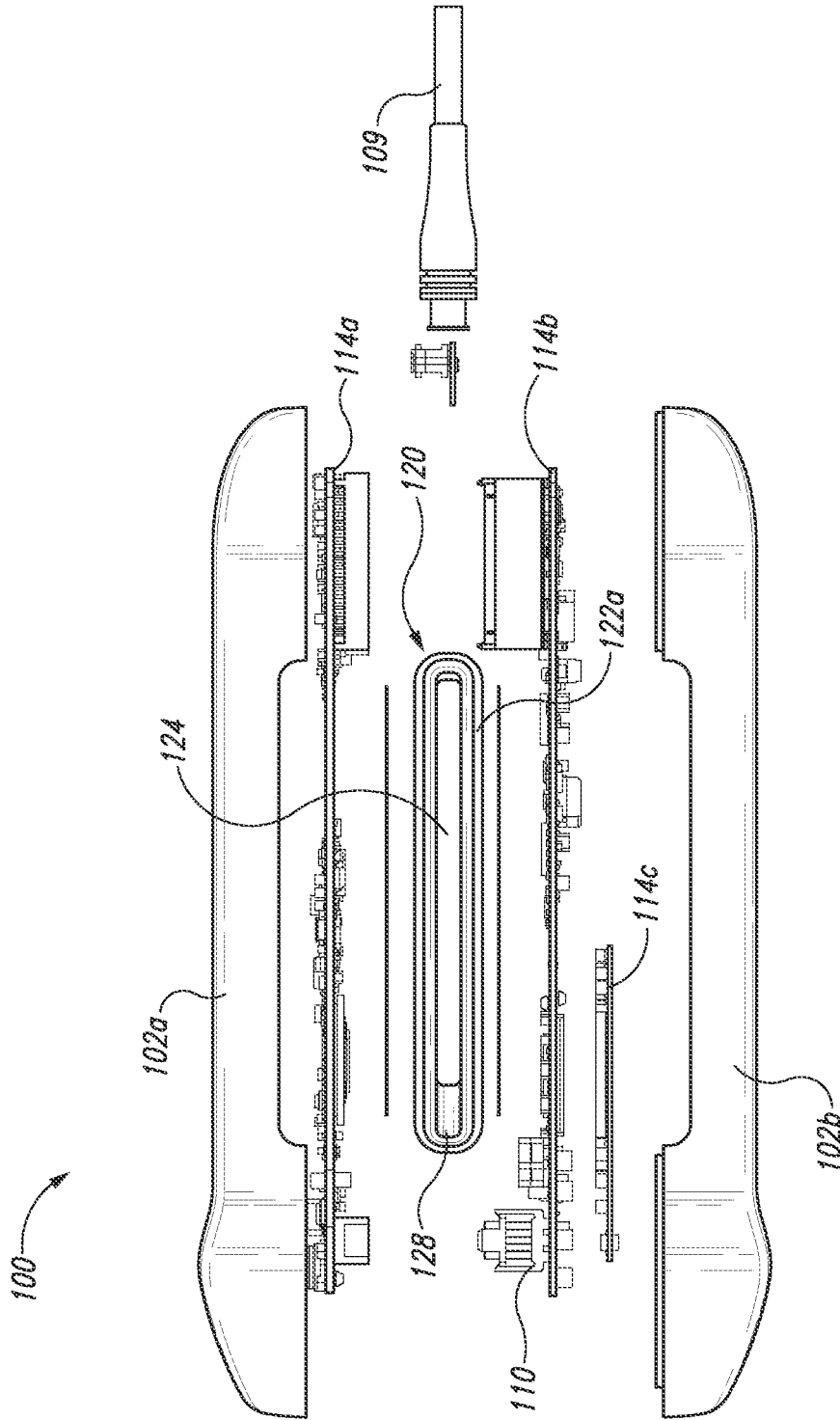


Fig. 1D

**A. CLASSIFICATION OF SUBJECT MATTER****A61B 8/00(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)  
A61B 8/00; G10K 9/125; A61B 17/32Documentation 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 modelsElectronic data base consulted during the international search (name of data base and, where practicable, search terms used)  
eKOMPASS(KIPO internal) & Keywords: ultrasound, heat, air, fluid, conduit**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5961465 A (WALTER PATRICK KELLY, JR. et al.) 05 October 1999 See abstract, column 2, line 34-column 3, line 26 and figures 1a-2b.	1-21
A	US 2005-0273127 A1 (THEODORE NOVAK et al.) 08 December 2005 See abstract, paragraphs [0029]-[0033] and figures 2,3.	1-21
A	JP 2010-088610 A (TOSHIBA CORP et al.) 22 April 2010 See abstract, paragraphs [0015]-[0021] and figures 3-5.	1-21
A	US 2012-0223618 A1 (DENNIS DEAN CLARK et al.) 06 September 2012 See abstract, paragraphs [0023]-[0028], claims 1,2 and figures 4-8.	1-21
A	US 2014-0058270 A1 (RICHARD EDWARD DAVIDSEN et al.) 27 February 2014 See abstract, paragraphs [0015]-[0018] and figures 1-7.	1-21

 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 another citation or other special reason (as specified)

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

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

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

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

"&amp;" document member of the same patent family


Date of the actual completion of the international search

16 September 2015 (16.09.2015)

Date of mailing of the international search report

**16 September 2015 (16.09.2015)**

Name and mailing address of the ISA/KR


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**INTERNATIONAL SEARCH REPORT**

Information on patent family members

International application No.

**PCT/US2015/034980**

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5961465 A	05/10/1999	JP 3061292 U	17/09/1999
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JP 2010-088610 A	22/04/2010	JP 5258493 B2	07/08/2013
US 2012-0223618 A1	06/09/2012	CN 102598118 A CN 102598118 B EP 2499636 A1 EP 2499636 B1 JP 2013-509934 A JP 5750115 B2 RU 2012124064 A RU 2540456 C2 US 9076955 B2 WO 2011-055315 A1	18/07/2012 10/12/2014 19/09/2012 04/09/2013 21/03/2013 15/07/2015 20/12/2013 10/02/2015 07/07/2015 12/05/2011
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Note: For the claim 6, the claim was renumbered by this authority because claim 5 is found twice and claim 6 is found missing.

专利名称(译)	用于冷却超声换能器的系统和方法		
公开(公告)号	<a href="#">EP3154437A1</a>	公开(公告)日	2017-04-19
申请号	EP2015806744	申请日	2015-06-09
[标]申请(专利权)人(译)	富士胶片索诺声公司		
申请(专利权)人(译)	FUJIFILM SONOSITE , INC.		
当前申请(专利权)人(译)	FUJIFILM SONOSITE , INC.		
[标]发明人	NIEMINEN GREG WILLSIE TODD MCCORMACK EVAN		
发明人	NIEMINEN, GREG WILLSIE, TODD MCCORMACK, EVAN		
IPC分类号	A61B8/00		
CPC分类号	A61B8/08 A61B8/4455 A61B8/4483 A61B8/546 F28D15/00 F28D2021/0028 F28F1/04 G01S7/52079 G01S15/899 Y10T29/49007		
优先权	14/301299 2014-06-10 US		
其他公开文献	EP3154437A4		
外部链接	<a href="#">Espacenet</a>		

#### 摘要(译)

在其中公开了从超声探头传输热量的系统和方法。在一个实施例中，手持式超声探头包括换能器，配置成驱动换能器的电子器件，以及围绕换能器组件和电子器件的壳体。槽从壳体的第一侧延伸到壳体的第二侧并且可以允许空气通过相邻的换能器和电子器件。槽的尺寸可以设计成阻止操作者的手指接近槽的内表面。