US008409101B2

(12) **United States Patent**
Hongou et al.

(10) **Patent No.: US 8,409,101 B2**
(45) **Date of Patent: Apr. 2, 2013**

(54) **ULTRASONIC PROBE AND ULTRASONIC DIAGNOSTIC APPARATUS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 119 days.

(21) Appl. No.: **12/815,825**

(22) Filed: **Jun. 15, 2010**

(65) **Prior Publication Data**

US 2010/0331702 A1 Dec. 30, 2010

(30) **Foreign Application Priority Data**

Jun. 24, 2009 (JP) 2009-150037

(51) **Int. Cl.**
A61B 8/14 (2006.01)

(52) **U.S. Cl.** **600/459**; 600/437

(58) **Field of Classification Search** 600/437–469
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,748,985	A *	6/1988	Nagasaki	600/445
5,560,362	A *	10/1996	Sliwa et al.	600/439
5,961,465	A *	10/1999	Kelly et al.	600/459
6,053,912	A *	4/2000	Panescu et al.	606/40
6,436,130	B1 *	8/2002	Philips et al.	607/105
7,052,463	B2 *	5/2006	Peszynski et al.	600/459
7,918,799	B2 *	4/2011	Haveri	600/459
8,273,025	B2 *	9/2012	Shikata	600/437
2006/0100513	A1 *	5/2006	Hashimoto	600/437
2007/0232923	A1 *	10/2007	Asuri	600/459
2008/0077017	A1 *	3/2008	Hyuga	600/459
2010/0163083	A1 *	7/2010	Suzuki et al.	134/184
2011/0282211	A1 *	11/2011	Shikata	600/459

FOREIGN PATENT DOCUMENTS

CN	101317772	A	12/2008
JP	2007-275458	A	10/2007
WO	2006/033281	A1	3/2006
WO	2009/035907	A2	3/2009

OTHER PUBLICATIONS

CN Office Action and English translation for corresponding CN Application No. 201010206033.3 mailed on Feb. 14, 2012.
CN Office Action with English Summary for CN Application No. 201010206033.3 mailed on Dec. 21, 2012.

* cited by examiner

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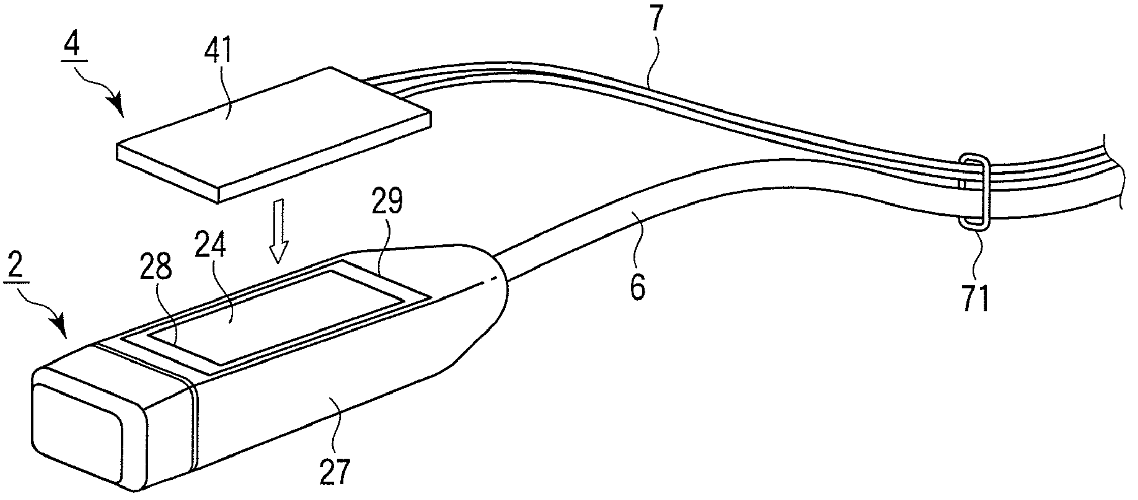
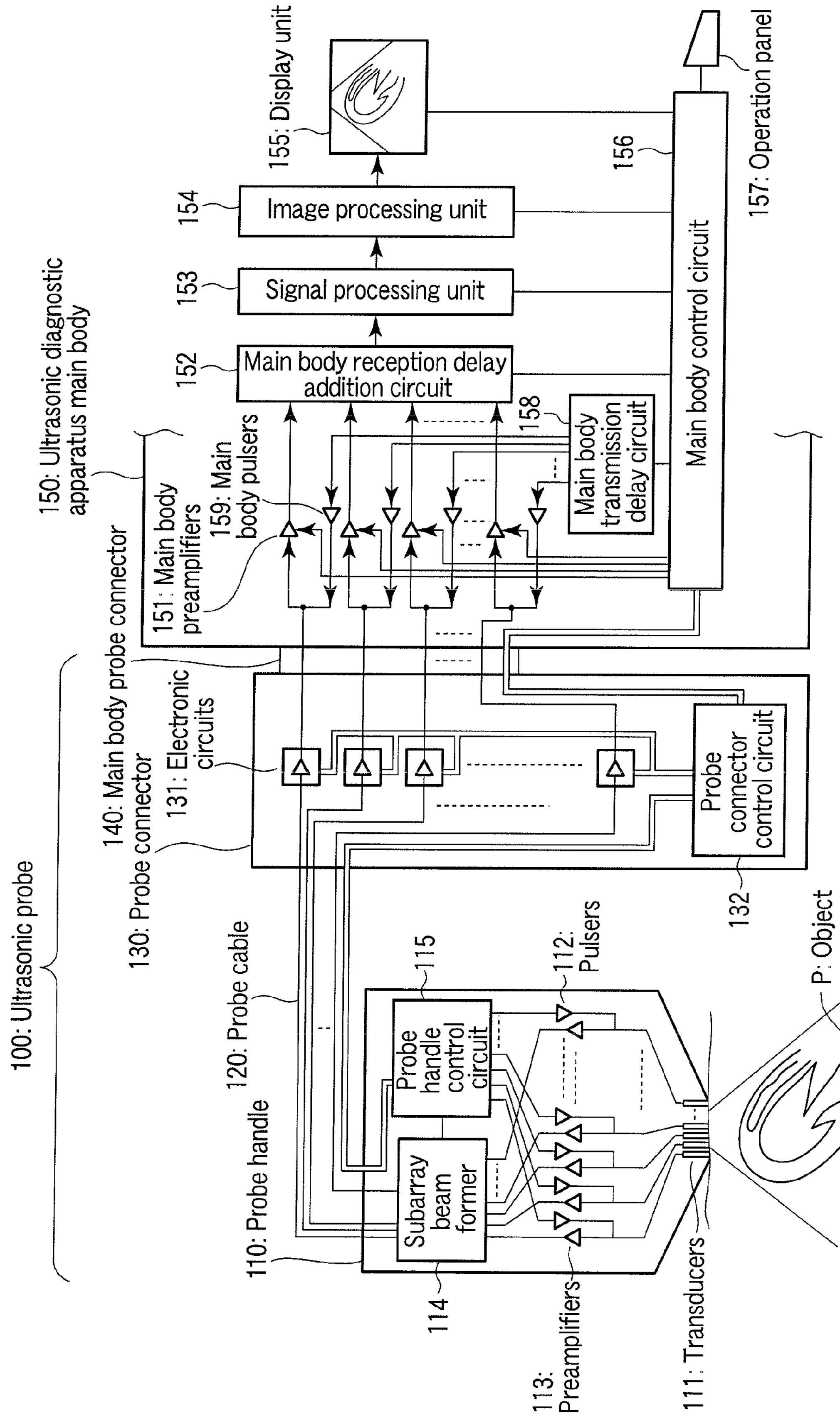
(57) **ABSTRACT**

According to one embodiment, an ultrasonic probe includes a probe unit and cooling unit. The probe unit is obtained by arranging, in a housing, a transducer unit which transmits and receives ultrasonic waves with an object to be examined, an electronic circuit unit which is connected to the transducer unit and performs electrical signal processing, and a heat transfer member which is made of a material having a heat transfer coefficient higher than that of the electronic circuit unit, and transfers heat of the electronic circuit unit to a housing surface. The cooling unit is detachably mounted on the housing of the probe unit, and cools the heat transfer member by passing a coolant in a channel formed inside the cooling unit.

20 Claims, 6 Drawing Sheets





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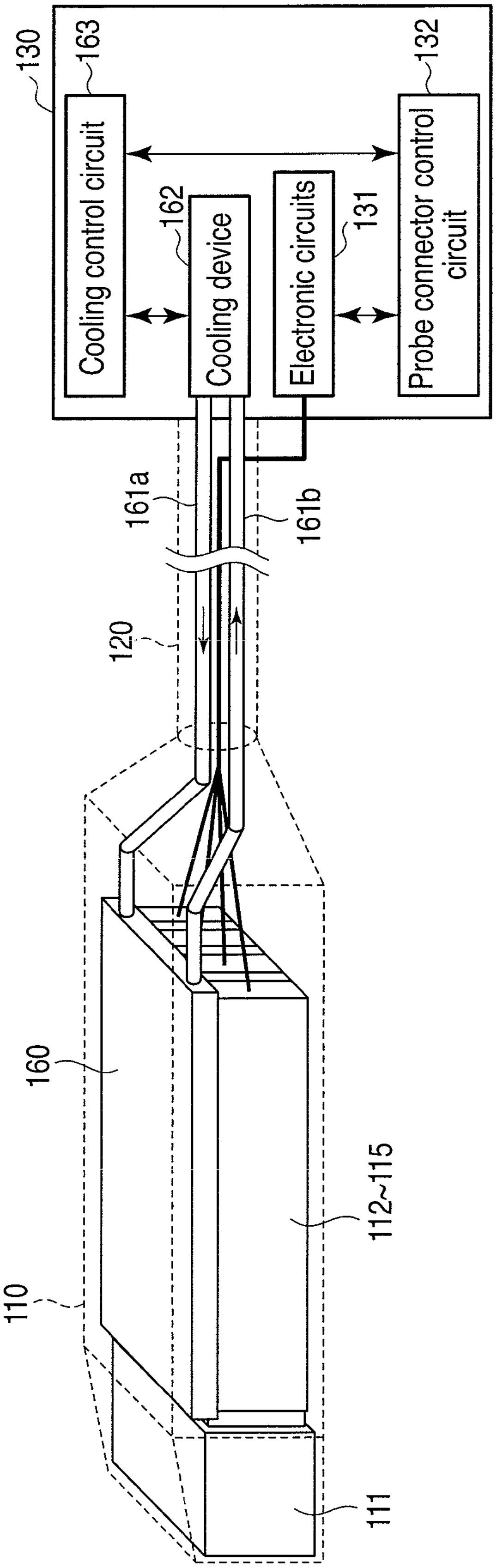
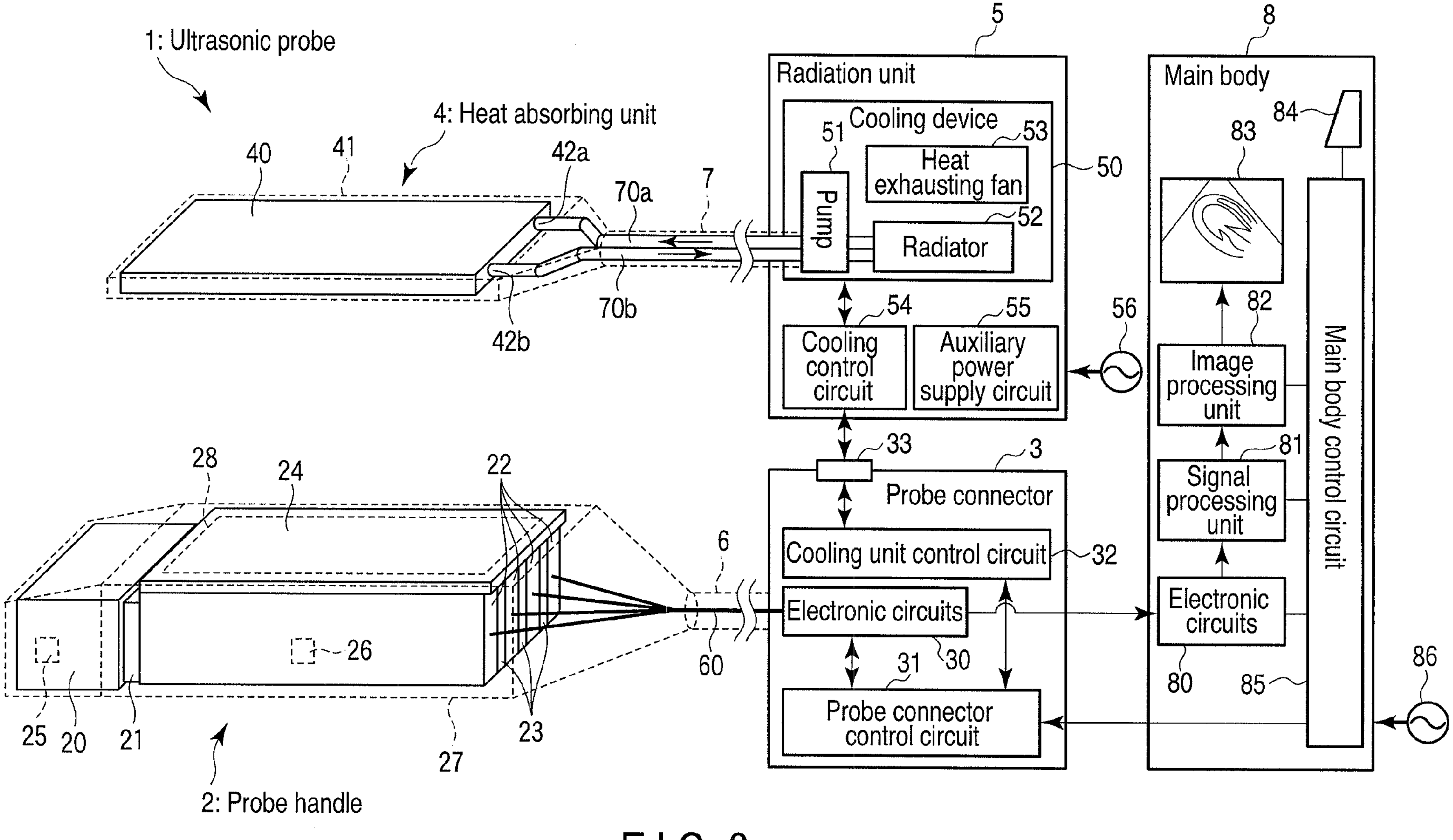


F I G. 2 RELATED ART


1: Ultrasonic probe
4: Heat absorbing unit
40
41
42a
42b
70a
70b
7
5
Radiation unit
Cooling device
51
Pump
53
Heat exhausting fan
52
Radiator
50
54
Cooling control circuit
55
Auxiliary power supply circuit
56
8
Main body
84
83
82
Image processing unit
81
Signal processing unit
Electronic circuits
80
85
Main body control circuit
86
33
3
Probe connector
Cooling unit control circuit
32
Electronic circuits
30
31
Probe connector control circuit
6
60
28
24
22
23
26
25
20
21
27
2: Probe handle

F I G. 3

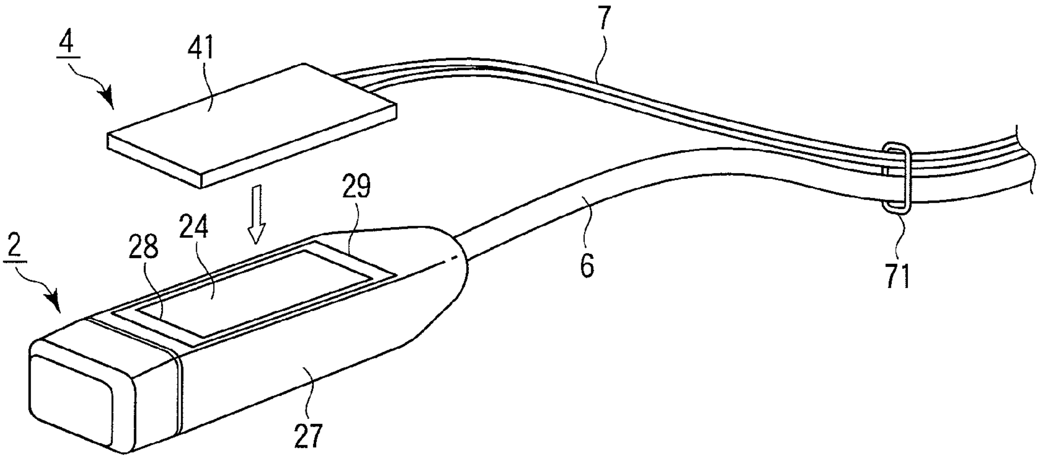


FIG. 4

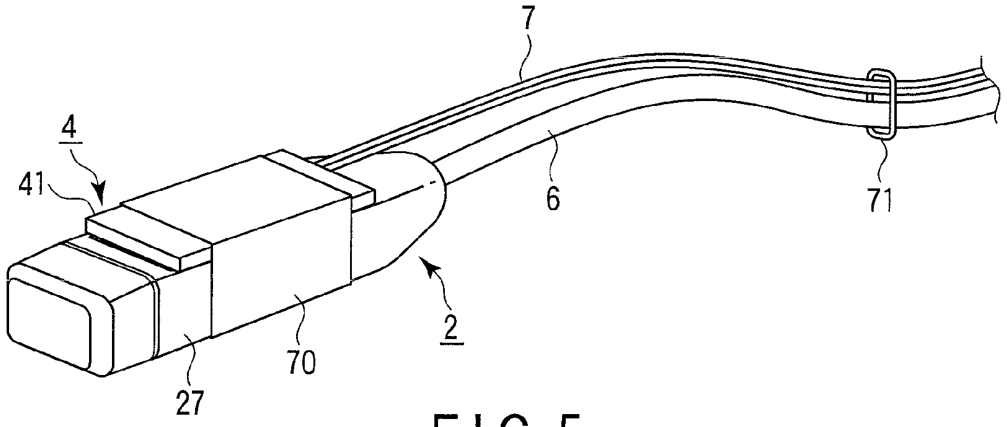


FIG. 5

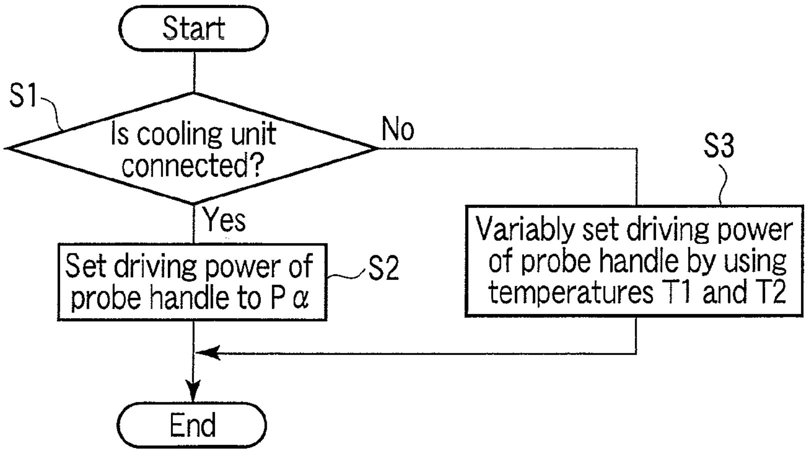


FIG. 6

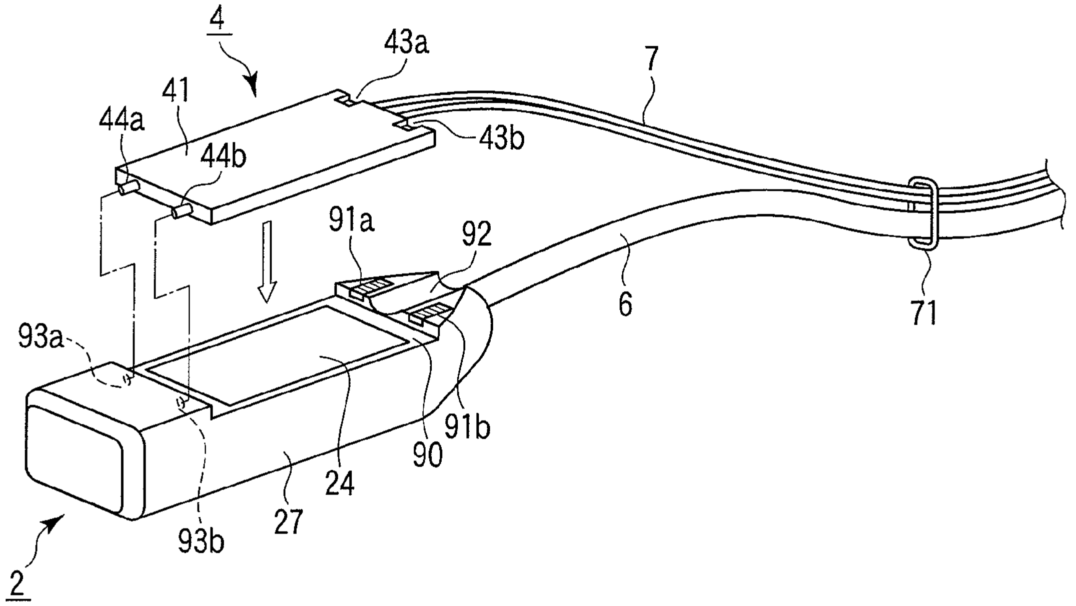

4
43a
7
41
44a
43b
44b
91a
92
6
71
93a
24
91b
90
27
93b
2

FIG. 7

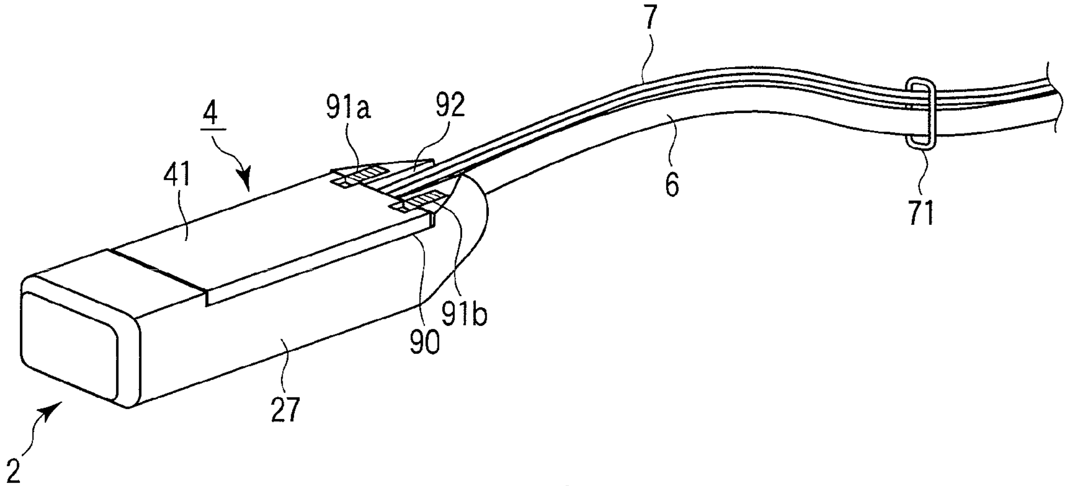

7
4
91a
92
41
6
71
91b
90
27
2

FIG. 8

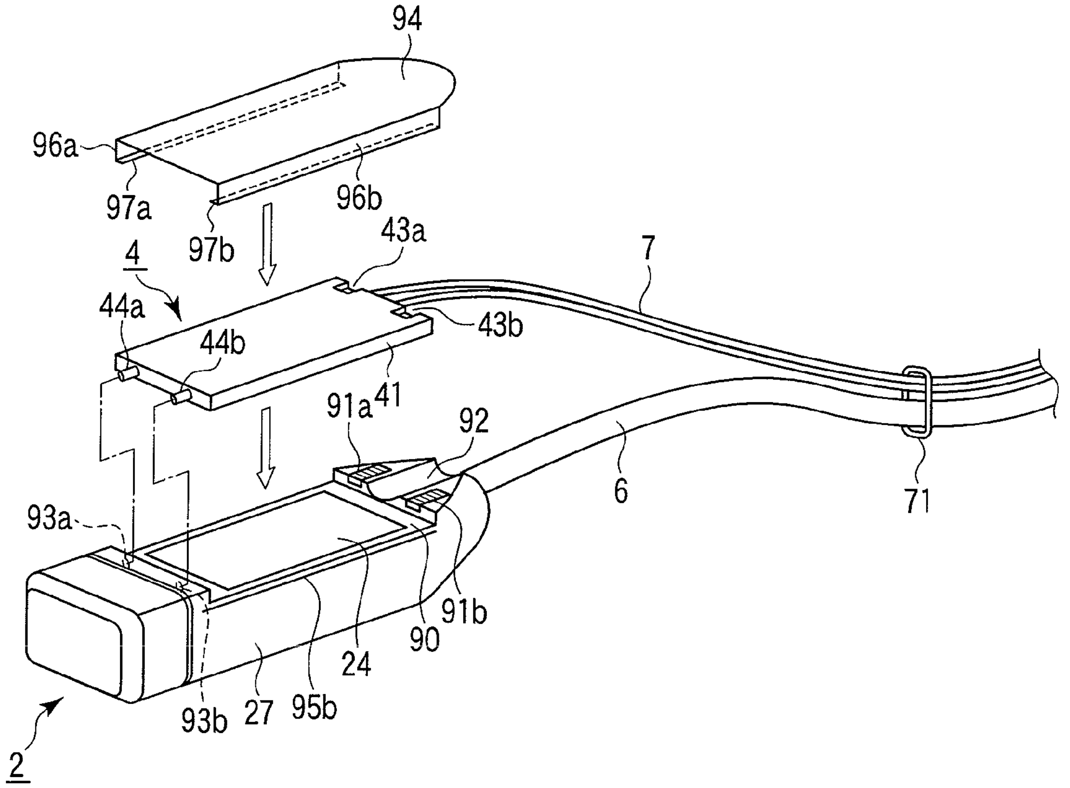

94
96a
97a
97b
96b
43a
7
4
44a
44b
43b
41
91a
92
6
71
93a
91b
90
24
93b
27
95b
2

FIG. 9

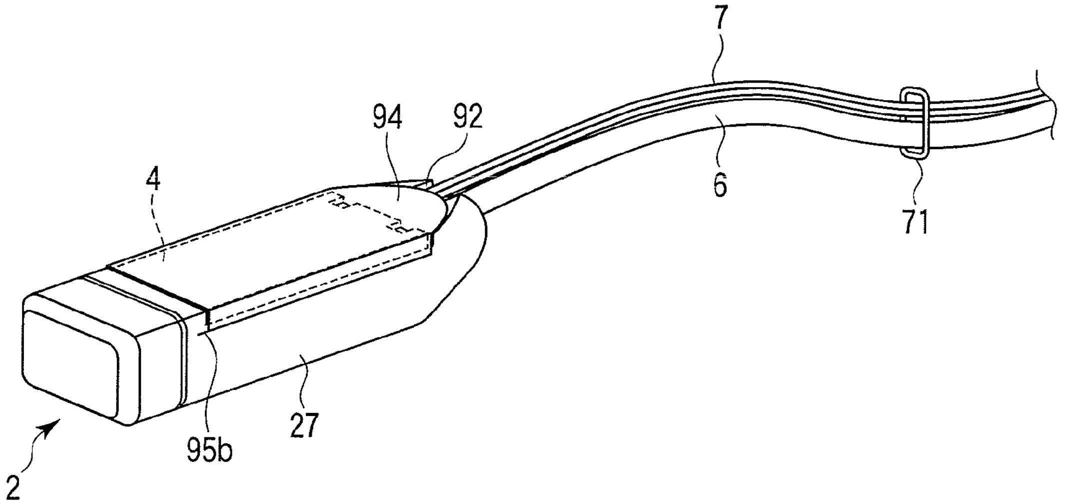

7
94
92
4
6
71
95b
27
2

FIG. 10

ULTRASONIC PROBE AND ULTRASONIC DIAGNOSTIC APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based upon and claims the benefit of priority from Japanese Patent Application No. 2009-150037, filed Jun. 24, 2009; the entire contents of which are incorporated herein by reference.

FIELD

Embodiments described herein relate generally to an ultrasonic probe for scanning an ultrasonic beam on an object to be examined, and an ultrasonic diagnostic apparatus which displays an image of the interior of the object in real time based on a signal obtained by the ultrasonic probe by scanning the ultrasonic beam.

BACKGROUND

Recently, two-dimensional array transducers are beginning to be used in ultrasonic probes, so the number of transducers has increased to several thousands, and the size of each individual transducer has extremely decreased. Connecting an ultrasonic probe directly to an ultrasonic diagnostic apparatus of this type requires a large-diameter cable in which very many electronic lines can be inserted. The use of this large-diameter cable interferes with operations, and makes it difficult to efficiently transmit a driving waveform to a microtransducer, and transmit a high-quality ultrasonic echo received by a microtransducer. For an ultrasonic probe using two-dimensional array transducers, therefore, the efficiency of the driving of microtransducers and the efficiency of the amplification of an ultrasonic echo are increased by incorporating electronic circuits such as a transmitting circuit and receiving circuit in a probe handle. In addition, the number of signal lines input to an ultrasonic diagnostic apparatus is often reduced by performing partial receiving beam forming for every several transducers and adding the results.

FIG. **1** shows the arrangement of an ultrasonic diagnostic apparatus of this type. This ultrasonic diagnostic apparatus includes an ultrasonic probe **100** including a probe handle **110** and a probe connector **130** connected to the handle **110** via a probe cable **120**, and an ultrasonic diagnostic apparatus main body **150** connected to the probe connector **130** via a main body probe connector **140**.

The probe handle **110** includes transducers **111** arranged in the form of an array, pulsers **112** for generating an ultrasonic beam having a predetermined directionality by driving the transducers **111**, preamplifiers **113** for performing processing such as low-noise amplification or buffering for satisfactorily transmitting very small ultrasonic echo signals received by the transducers **111**, a sub-array beam former **114** for adding output signals from the preamplifiers **113** by giving a delay time to each group of a few channels, thereby reducing the number of output signal lines from the probe handle **110**, and a control circuit **115** for controlling the individual components in the probe handle **110**.

The probe connector **130** includes electronic circuits **131** for performing additional processing such as amplification, buffering, or band adjustment on ultrasonic echo signals as needed, and a probe connector control circuit **132** for generating a control signal to be transmitted to the control circuit **115** of the probe handle **110**, based on a control signal transmitted from the ultrasonic diagnostic apparatus main body **150**.

The ultrasonic diagnostic apparatus main body **150** includes main body preamplifiers **151** for amplifying the ultrasonic echo signals to which the delay is added for each group of a few channels in the probe handle **110**, a reception delay addition circuit **152** for matching the timings of the amplified signals, a signal processing unit **153** for detecting the signals and extracting the envelope, an image processing unit **154** for transforming coordinates in accordance with the section of the object, a display unit **155** for displaying image data having the transformed coordinates, a main body control circuit **156** for controlling each unit, an operation panel **157** for accepting user's operations, a main body transmission delay circuit **158**, and main body pulsers **159**. The main body transmission delay circuit **158** and main body pulsers **159** operate a probe incorporating no electronic circuits when the probe is connected instead of the ultrasonic probe **100**. This ultrasonic diagnostic apparatus can also detect and process the Doppler shift frequency of an ultrasonic beam resulting from the movement of blood cells generated when ultrasonic waves are exchanged with a blood flow in an object to be examined, and display blood flow velocity information as a Doppler image.

Since the ultrasonic wave transmitting and receiving processes are performed in the probe handle **110** as described above, electric power must be supplied to the built-in electronic circuits of the probe handle **110**. However, to obtain, from an object to be examined, high-quality ultrasonic signals that can contribute to diagnosis, it is necessary to maintain a high transmitting/receiving performance by supplying considerable electric power. Consequently, the built-in electronic circuits generate heat and raise the temperature. This state interferes with operations, and may damage the object because the heat is conducted to the surface in contact with the object. Furthermore, the built-in electronic circuits themselves may break.

If the amount of power supplied to the probe handle **110** is reduced, however, the performance degrades to make it impossible to obtain necessary information, thereby interfering with diagnosis. Recently, therefore, a two-dimensional (2D) array probe including a cooling unit for cooing a probe handle by circulating a coolant is particularly beginning to be used.

FIG. **2** shows an example of the cooling unit using a coolant. This cooling unit includes a heat absorbing unit **160** in which a coolant channel is formed, a cooling device **162** connected to the channel of the heat absorbing unit **160** by cooling tubes **161***a* and **161***b*, and a cooling control circuit **163** for controlling the cooling device **162**.

The cooling device **162** includes a pump for circulating the coolant, a radiator having a large number of radiation fins, and a cooling fan for supplying cooling air to the radiator. Under the control of the cooling control circuit **163**, the cooling device **162** circulates the coolant by driving the built-in pump, and cools the coolant by rotating the cooling fan. The cooled coolant is supplied to the heat absorbing unit **160**, and takes heat from circuits of a probe handle **110**. This prevents the temperature rise of the circuits.

When attaching the cooling unit as described above, however, a very small forced cooling system is necessary because the volume of the probe handle is only about 100 cc. This complicates the structure of the ultrasonic probe, and probably makes it impossible to secure a sufficient durability. Also, it is difficult to obtain a sufficient cooling performance because the installation space of the cooling unit is limited.

Furthermore, if the cooling unit fails, it is difficult to repair the fault cooling unit, so an expensive ultrasonic probe must be discarded.

Under the circumstances, demands have arisen for an ultrasonic probe in which the structure of a probe handle is a simple structure similar to a natural air cooling structure, and a forced cooling unit can easily be replaced even if it fails.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a view showing the arrangement of an ultrasonic diagnostic apparatus related to each embodiment;

FIG. **2** is a view showing the arrangements of a probe handle and probe connector related to each embodiment;

FIG. **3** is an exemplary view showing the arrangement of an ultrasonic diagnostic apparatus according to the first embodiment;

FIG. **4** is a perspective view showing the outer appearance before a probe handle and heat absorbing unit are assembled in the first embodiment;

FIG. **5** is a perspective view showing the outer appearance after the probe handle and heat absorbing unit are assembled in the first embodiment;

FIG. **6** is a flowchart showing the operation of a main body control circuit according to the first embodiment;

FIG. **7** is a perspective view showing the outer appearance before a probe handle and heat absorbing unit are assembled in the second embodiment;

FIG. **8** is a perspective view showing the outer appearance after the probe handle and heat absorbing unit are assembled in the second embodiment;

FIG. **9** is a perspective view showing the outer appearance before a probe handle and heat absorbing unit are assembled in the third embodiment; and

FIG. **10** is a perspective view showing the outer appearance after the probe handle and heat absorbing unit are assembled in the third embodiment.

DETAILED DESCRIPTION

In general, according to one embodiment, an ultrasonic probe includes a probe unit and cooling unit. The probe unit is obtained by arranging, in a housing, a transducer unit which transmit and receives ultrasonic waves with an object to be examined, an electronic circuit unit which is connected to the transducer unit and performs electrical signal processing, and a heat transfer member which is made of a material having a heat transfer coefficient higher than that of the electronic circuit unit, and transfers heat of the electronic circuit unit to a housing surface. The cooling unit is detachably mounted on the housing of the probe unit, and cools the heat transfer member by passing a coolant in a channel formed inside the cooling unit.

The first, second, and third embodiments will be explained below with reference to the accompanying drawings. Note that in the following explanation, the same reference numerals denote constituent components having almost the same functions and arrangements, and a repetitive explanation will be made only when necessary.

(First Embodiment)

FIG. **3** is an exemplary view showing the arrangement of an ultrasonic diagnostic apparatus according to the first embodiment. This ultrasonic diagnostic apparatus includes an ultrasonic probe **1** and main body **8**. The ultrasonic probe **1** includes a probe handle **2** (probe unit) for transmitting and receiving ultrasonic waves, a probe connector **3** (connector unit) connected to the ultrasonic diagnostic apparatus main body, a heat absorbing unit **4** for absorbing heat generated by built-in electronic circuits of the probe handle **2**, and a radiation unit **5** for radiating the heat absorbed by the heat absorbing unit **4**. The probe handle **2** and probe connector **3** are connected via a flexible probe cable **6** (signal cable). The heat absorbing unit **4** and radiation unit **5** are connected via a flexible cooling cable **7**. Note that the heat absorbing unit **4** and radiation unit **5** construct a cooling unit according to this embodiment.

The arrangement of each unit will be explained below.

[Probe Handle]

The probe handle **2** is obtained by arranging, in a housing **27**, ultrasonic transducers **20** (a transducer unit), a connecting portion **21**, electronic circuits **22** (an electronic circuit unit), heat spreaders **23**, a heat sink **24**, and temperature sensors **25** and **26**.

The ultrasonic transducers **20** are obtained by arranging ultrasonic transducers into, e.g., an N×M array (N, M; integers). The ultrasonic transducers **20** transmit and receive ultrasonic waves with an object to be observed.

The electronic circuits **22** include pulsers, preamplifiers, subarray beam formers, and a probe handle control circuit (none of them is shown), and are connected to the ultrasonic transducers **20** via the connecting portion **21**. The pulsers are connected to the ultrasonic transducers **20**, and drive the ultrasonic transducers **20** in accordance with different timings generated by the probe handle control circuit, thereby generating an ultrasonic beam having a predetermined directionality. The ultrasonic beam generated from the ultrasonic transducers **20** is reflected by interfaces having different acoustic impedances, e.g., the boundaries of structures inside the object to be observed. The ultrasonic transducers **20** having received the reflected waves output weak ultrasonic echo signals. The preamplifiers perform processing such as low-noise amplification or buffering in order to satisfactorily transmit the weak ultrasonic echo signals output from the ultrasonic transducers **20**. The subarray beam formers add the output signals from the above-described preamplifiers by giving a delay time to each group of several channels, thereby reducing the number of output signal lines from the probe handle **2**. This reduces the number of signal lines **60** to be inserted into the probe cable **6**. The probe handle control circuit controls the operations of the pulsers, preamplifiers, and subarray beam formers described above. The operating conditions such as bias electric currents of the preamplifiers can individually be set by control signals from this control circuit.

The heat spreaders **23** are formed in tight contact with individual electronic substrates of the electronic circuits **22** so as to be interposed between the electronic substrates. The heat spreaders **23** guide heat generated by the electronic circuits **22** in operation to the heat sink **24**.

The heat sink **24** is a plate-like member having a size covering the electronic circuits **22** and heat spreaders **23**, and guides the heat conducted from the heat spreaders **23** to the housing surface of the probe handle **2**.

The heat spreaders **23** and heat sink **24** for guiding heat as described above have a structure mainly made of a material having a heat transfer coefficient higher than those of the electronic parts arranged in the housing **27** of the probe handle **2**. Examples are a structure obtained by coating the surface of a main body made of SiC with a multilayered metal film of Ni/Ti/Pt/Au, and a structure obtained by plating the surface of a Cu member with Au for preventing oxidation. Note that the heat spreaders **23** and heat sink **24** construct a heat transfer member according to this embodiment.

The temperature sensor **25** is set for the ultrasonic transducers **20**, and senses a temperature T**1** near the ultrasonic transducers **20**. The temperature sensor **26** is set in a predetermined position of the electronic circuits **22**, and senses a temperature T**2** of the electronic circuits **22**. Note that the temperature sensors **25** and **26** are respectively positioned to be able to sense the temperatures of positions where the temperatures rise most easily in the ultrasonic transducers **20** and electronic circuits **22**.

An opening **28** for exposing one surface of the heat sink **24** is formed in the surface of the housing **27** on the side where the heat sink **24** is installed.

[Probe Connector]

The probe connector **3** includes electronic circuits **30**, a probe connector control circuit **31**, a cooling unit control circuit **32** (detection unit), and a cooling unit control connector **33**. The probe connector **3** is connected to a control circuit and power supply circuit of the main body **8** of the ultrasonic diagnostic apparatus by a connecting mechanism (not shown), and operates by receiving power supply from the main body **8**.

The electronic circuits **30** performs, as needed, additional processing such as amplification, buffering, or band adjustment on ultrasonic echo signals transmitted from the probe handle **2** via the signal lines **60**.

The cooling unit control circuit **32** controls power supply to the cooling unit, and notifies the radiation unit **5** of the temperature T**1** sensed by the temperature sensor **25** and the temperature T**2** sensed by the temperature sensor **26**.

The cooling unit control connector **33** detachably connects the control circuit and power supply circuit of the probe connector **3** to those of the cooling unit.

The probe connector control circuit **31** controls the operation of the electronic circuits **30**, and generates a control signal to be transmitted to the probe handle **2**, based on a control signal transmitted from the main body **8**. The control circuit **31** also has a function of detecting the connection state of the cooling unit with respect to the cooling unit control connector **33**. Based on the detection result obtained by this function, the control circuit **31** notifies the main body **8** of the ultrasonic diagnostic apparatus of information indicating whether the cooling unit is connected, and the temperature T**1** sensed by the temperature sensor **25** and the temperature T**2** sensed by the temperature sensor **26**. This notification is performed when the connection state of the cooling unit has changed, or when the temperature T**1** or T**2** has changed to exceed a predetermined value from the value of the last notification. It is also possible to periodically perform the notification every predetermined period.

[Heat Absorbing Unit]

The heat absorbing unit **4** includes a plate-like heat exchanger **40** made of a material having a high heat transfer coefficient, and a case-like housing **41** covering the heat exchanger **40**.

A zigzagged coolant channel is formed inside the heat exchanger **40**. The heat absorbing unit **4** has a supply hole **42***a* for supplying a coolant (supply coolant) to the channel, and a discharge hole **42***b* for discharging the coolant from the channel. The supply hole **42***a* and discharge hole **42***b* are respectively connected to a supply pipe **70***a* and discharge pipe **70***b* (supply/discharge pipes) made of a flexible material such as silicone rubber or soft vinyl chloride resin. The supply pipe **70***a* and discharge pipe **70***b* are inserted into the cooling cable **7**. Note that the above-mentioned coolant is, e.g., a fluorine-based inert liquid that is thermally and chemically stable, and superior in electrical insulation properties and permeability.

The housing **41** has an opening (not shown) for exposing the heat exchanger **40**, in the surface to be attached to the probe handle **2**. This opening has almost the same width as that of the opening **28** in the housing **27** of the probe handle **2**.

[Radiation Unit]

The radiation unit **5** includes a cooling device **50** including a pump **51** (coolant circulating unit), radiator **52**, and heat exhausting fan **53**, a cooling control circuit **54** (cooling control unit), and an auxiliary power supply circuit **55**. Note that the radiator **52** and heat exhausting fan **53** construct a coolant cooling unit according to this embodiment.

The supply pipe **70***a* and discharge pipe **70***b* described above are connected to the pump **51** and radiator **52**. The pump **51** supplies the coolant to the internal channel of the heat exchanger **40** via the supply pipe **70***a*. In addition, the pump **51** collects the coolant and sends it to the radiator **52** via the discharge pipe **70***b*. The heat exhausting fan **53** supplies cooling air to the radiator **52**, and exhausts heat collected from the heat exchanger **40** by the coolant to the outside of the radiation unit **5** from an exhaust hole (not shown).

Based on the temperatures T**1** and T**2** notified from the probe connector **3**, the cooling control circuit **54** adjusts the flow rate of the coolant by controlling the output of the pump **51**, and adjusts the amount of air to be supplied to the radiator **52** by controlling the rotating speed of the heat exhausting fan **53**. More specifically, if the temperatures T**1** and T**2** exceed a predetermined threshold value Tα ($T\alpha < T1, T2$), the cooling control circuit **54** increases the output of the pump **51** and the rotating speed of the heat exhausting fan **53**. If the temperatures T**1** and T**2** become lower than the threshold value Tα ($T1, T2 < T\alpha$), the cooling control circuit **54** reduces the output of the pump **51** and the rotating speed of the heat exhausting fan **53**. Note that the threshold value Tα is set so as not to exceed the rated temperature of the ultrasonic transducers **20** or electronic circuits **22**. By thus controlling the cooling device **50** based on the temperatures T**1** and T**2**, it is possible to prevent the temperature rise of the probe handle **2**, and obtain a high ultrasonic transmitting/receiving performance.

The auxiliary power supply circuit **55** monitors the voltage of the power supplied from the probe connector **3**. If the voltage becomes lower than a necessary and sufficient value for the operation of the cooling unit, the auxiliary power supply circuit **55** is triggered to load operating power from an auxiliary power supply **56** such as a battery, and supplies the power to each unit of the radiation unit **5**. Note that a switch connected to the auxiliary power supply **56** may also be formed on the housing of the radiation unit **5**. In this case, the auxiliary power supply circuit **55** is triggered to switch the power supplies when the user manually operates the switch.

[Ultrasonic Diagnostic Apparatus Main Body]

The main body **8** of the ultrasonic diagnostic apparatus includes electronic circuits **80**, a signal processing unit **81**, an image processing unit **82**, a display unit **83**, an operation panel **84**, and a main body control circuit **85** (control unit). Each unit of the main body **8** operates by loading operating power from a power supply **86**.

The electronic circuits **80** include preamplifiers, pulsers, a reception delay addition circuit, a transmission delay addition circuit, and the like. The preamplifiers amplify ultrasonic echo signals having undergone the reception delay adding process performed for each group of several channels by the ultrasonic probe **1**. The reception delay addition circuit matches the timings of the ultrasonic echo signals amplified by the preamplifiers, and outputs the signals to the signal processing unit **81**.

The signal processing unit **81** detects the ultrasonic signals output from the electronic circuits **80**, and extracts the envelope. The image processing unit **82** performs coordinate conversion, tone processing, or the like on the ultrasonic signals from which the envelope is extracted by the signal processing unit **81**, in accordance with the section of an object to be observed, and outputs the signals to the display unit **83**. Based on the data output from the image processing unit **82**, the display unit **83** displays the diagnostic image of the object. The operation panel **84** accepts various user's operations.

The main body control circuit **85** controls each unit of the main body **8**, and outputs control signals concerning the driving of the probe handle **2** to the probe connector control circuit **31**.

[Shapes of Probe Handle and Heat Absorbing Unit]

The shapes of the probe handle **2** and heat absorbing unit **4** will be explained below with reference to FIGS. **4** and **5**. FIG. **4** is a perspective view showing the outer appearances of the probe handle **2** and heat absorbing unit **4** before they are assembled. FIG. **5** is a perspective view showing the outer appearances of the probe handle **2** and heat absorbing unit **4** after they are assembled.

As shown in FIG. **4**, the housing of the probe handle **2** has a recess **29** (guiding portion) indicating the attaching position of the heat absorbing unit **4**. The opening **28** of the housing **27** is positioned on the bottom surface of the recess **29**, and the upper surface of the heat sink **24** is exposed from the opening **28**. Since the exposed surface of the heat sink **24** probably touches the skin of a user or patient, it is desirable to form an insulating protective film. However, if the internal structure of the probe handle **2** can insulate the heat sink **24**, priority may be given to the thermal conductivity to the heat absorbing unit **4** without forming any protective film.

When attaching the heat absorbing unit **4** to the probe handle **2**, the housing **41** of the heat absorbing unit **4** is positioned on and pressed against the above-mentioned recess **29**. The inclined portions of the recess **29** abut against the housing **41** of the heat absorbing unit **4**, and guide the heat absorbing unit **4** to the position where the heat absorbing unit **4** is in contact with the portion to which heat is transferred by the heat sink **24**. In this state, the probe handle **2** and heat absorbing unit **4** are fixed by winding a fixing belt **70** (fixing portion) as shown in FIG. **5**. Consequently, the exposed surface of the heat sink **24** is brought into tight contact with the heat exchanger **40** exposed from the opening surface of the housing **41** of the heat absorbing unit **4**. Even when a force is applied to the heat absorbing unit **4** in a direction to slide the heat absorbing unit **4** on the housing **27** of the probe handle **2**, the heat absorbing unit **4** is not easily removed from the fixing position because the side surfaces of the housing **41** of the heat absorbing unit **4** are pushed against the inclined portions of the recess **29**.

The fixing belt **70** is a member suited to fixing the heat absorbing unit **4** to the probe unit **2**. Examples are a member obtained by attaching a hook-and-loop fastener to a belt-like elastic member, and a ring-like elastic member. Also, when using an insulating member having a size completely covering the housing **41** of the heat absorbing unit **4** attached to the probe handle **2**, the probability that the exposed surface of the heat sink **24** touches a human body can be eliminated without forming any insulating protective film on the exposed surface of the heat sink **24**. This can further improve the cooling performance of the cooling unit. Furthermore, when coating the exposed surface of the heat sink **24** with a thermal conductor such as silicone grease, it is possible to prevent an air layer from being formed between the heat sink **24** and heat exchanger **40**, and increase the thermal conductivity from the heat sink **24** to the thermal exchanger **40**.

Note that the probe cable **6** and cooling cable **7** are bound by a cable binder **71** so as not to interfere with the diagnosing operation by unbound cables.

When the cooling unit is thus attached to the probe handle **2** and probe connector **3**, the pump **51** and heat exhausting fan **53** of the cooling device **50** are driven based on the sensed temperatures T1 and T2 of the temperature sensors **25** and **26** notified from the probe connector **3** as described previously. In this state, the coolant passing through the internal channel of the heat exchanger **40** cools the heat sink **24**. The radiator **52** and heat exhausting fan **53** cool the coolant heated by the heat exchanger **40**.

[Operation of Main Body Control Circuit]

The driving of the ultrasonic probe **1** by the main body control circuit **85** will be explained below.

When the user enters an instruction to start image sensing by operating the operation panel **84**, the main body control circuit **85** executes the process of setting the driving power of the ultrasonic probe **1**. FIG. **6** shows a flowchart of this process.

Immediately after the process is started, the main body control circuit **85** first determines whether the cooling unit is connected to the cooling unit control connector **33** (step S1). This processing is performed based on the information that is notified from the probe connector control circuit **31** as described previously, and indicates whether the cooling unit is connected.

If the probe connector control circuit **31** notifies the main body control circuit **85** of information indicating that the cooling unit is connected, the main body control circuit **85** determines that the cooling unit is connected (Yes in step S1). In this case, the main body control circuit **85** sets the driving power of the probe handle **2** to a prescribed value Pα (step S2). The prescribed value Pα is, e.g., electric power required to drive the probe handle **2** so as to obtain a highest-quality ultrasonic echo signal.

On the other hand, if the probe connector control circuit **31** notifies the main body control circuit **85** of information indicating that no cooling unit is connected, the main body control circuit **85** determines that no cooling unit is connected (No in step S1). In this case, the main body control circuit **85** variably sets the driving power of the probe handle **2** by using the temperatures T1 and T2 so as not to exceed the prescribed value Pα (step S3). For example, when the temperatures T1 and T2 are lower than the threshold value Tα, the main body control circuit **85** sets the driving power of the probe handle **2** to the prescribed value Pα. When the temperatures T1 and T2 are higher than the threshold value Tα, the main body control circuit **85** decreases the driving power of the probe handle **2** in proportion to one of the temperatures T1 and T2.

After setting the driving power as described above, the main body control circuit **85** terminates the process of this flowchart. After that, the main body control circuit **85** notifies the probe connector control circuit **31** of a control signal for driving the probe handle **2** by the driving force set by the processing in step S2 or S3. The probe connector control circuit **31** drives the probe handle **2** based on the control signal notified from the main body control circuit **85**.

Note that the process shown in the flowchart of FIG. **6** is periodically executed even after the driving of the probe handle **2** is started, and the driving power of the probe handle **2** is set in accordance with the temperatures T1 and T2 sensed on each occasion. The period need only be set at a value by which even when the temperatures T1 and T2 abruptly rise, the probe handle **2** can be driven such that the temperature T1 does not exceed the rated temperature of the ultrasonic transducers **20**, and the temperature T**2** does not exceed the rated temperature of the electronic circuits **22**.

The arrangement described above can achieve the following effects.

In the ultrasonic probe **1** according to this embodiment, the cooling unit is detachable from the probe handle **2** and probe connector **3**. Even when the cooling unit fails, therefore, the cooling unit need only be repaired or replaced without discarding the ultrasonic probe **1**.

Since the heat absorbing unit **4** of the cooling unit is independent of the probe handle **2**, a simple structure similar to a natural air cooling structure can be used as the structure of the probe handle **2**. This makes it possible to well ensure the durability of the structure of the probe handle **2**.

Also, since the heat absorbing unit **4** need not be installed in the internal limited space of the probe handle **2**, the large-sized heat absorbing unit **4** having a sufficient cooling performance can be used. Therefore, it is possible to drive the probe handle **2** by using high electric power that generates a large amount of heat, and obtain high-quality ultrasonic echo signals.

Furthermore, the driving power of the probe handle **2** is automatically adjusted in accordance with the connection state of the cooling unit with respect to the main body **8**. Therefore, the user need not perform any cumbersome operation of, e.g., setting the driving power by checking the connection state of the cooling unit. In addition, even if the user forgets to connect the cooling unit to the probe connector **3** or a connection error occurs, the driving power is set such that the temperatures T**1** and T**2** do not exceed the rated temperatures of the ultrasonic transducers **20** and electronic circuits **22**, respectively. Accordingly, the probe handle **2** can be protected against overheating.

(Second Embodiment)

The second embodiment will be explained below with reference to the accompanying drawings.

An ultrasonic probe according to this embodiment differs from the first embodiment in that a recess **29** is formed such that a housing **27** of a probe handle **2** and the upper surface of a heat absorbing unit **4** form an almost flat surface when attaching the heat absorbing unit **4** to the probe handle **2**, and the probe handle **2** and heat absorbing unit **4** have a fixing mechanism. The circuit configuration and the like of an ultrasonic probe **1** are the same as those of the first embodiment, so a repetitive explanation will be omitted by denoting the same components by the same reference numerals.

FIG. **7** is a perspective view showing the outer appearances of the probe handle **2** and heat absorbing unit **4** according to this embodiment.

In this embodiment, a recess **90** is formed to have a depth that is almost the same as the thickness of the heat absorbing unit **4**. A pair of stoppers **91***a* and **91***b* and a guide groove **92** are formed in the inner wall of the recess **90** on the side connected to a probe cable **6**. A pair of fixing holes **93***a* and **93***b* are formed in the inner wall of the distal end of the probe handle **2**.

The stoppers **91***a* and **91***b* are slide-type stoppers in which long projecting members are fitted in grooves formed in the housing of the probe handle **2**, and slidably held in the direction to a position where the heat absorbing unit **4** is attached. The guide groove **92** is a circular groove formed from the side wall of the recess **90** to one end of the side connected to the probe cable **6**, and having a curvature larger than that of a cooling cable **7**.

A pair of grooves **43***a* and **43***b* are formed in the side wall of a housing **41** of the heat absorbing unit **4** on the side connected to the cooling cable **7**. A pair of fixing pins **44***a* and **44***b* are formed on the side wall opposite to the former side wall.

The grooves **43***a* and **43***b* are respectively formed in positions corresponding to the stoppers **91***a* and **91***b*, and have shapes to be fitted on the projecting members of the stoppers **91***a* and **91***b*. The fixing pins **44***a* and **44***b* are respectively formed in positions corresponding to the fixing holes **93***a* and **93***b*, and have shapes to be fitted in the fixing holes **93***a* and **93***b*.

Note that the stoppers **91***a* and **91***b*, fixing holes **93***a* and **93***b*, grooves **43***a* and **43***b*, and fixing pins **44***a* and **44***b* construct the fixing mechanism according to this embodiment.

When attaching the heat absorbing unit **4** having the shape as described above to the probe handle **2**, the fixing pins **44***a* and **44***b* are respectively inserted into the fixing holes **93***a* and **93***b*, thereby bringing the bottom surface (having an opening) in tight contact with the exposed surface of a heat sink **24** of the probe handle **2**. The projecting members of the stoppers **91***a* and **91***b* are slid and fitted in the grooves **43***a* and **43***b*. In the state, the cooling cable **7** is positioned in the guide groove **92**. Therefore, the cooling cable **7** does not interfere with the attachment of the heat absorbing unit **4**.

When the heat absorbing unit **4** is thus attached to the probe handle **2**, as shown in FIG. **8**, the upper surface of the housing **27** of the probe handle **2** and the housing **41** of the heat absorbing unit **4** form an almost flat surface. In this state, the side walls of the recess **90** regulate the movement of the heat absorbing unit **4** in the longitudinal direction of the probe handle **2**, and the fixing pins **44***a* and **44***b*, fixing holes **93***a* and **93***b*, and stoppers **91***a* and **91***b* regulate the movement of the heat absorbing unit **4** in the lateral direction of the probe handle **2** and the direction of the exposed surface of the heat sink **24**.

The arrangement described above can achieve the following effects.

The ultrasonic probe **1** according to this embodiment includes the means for fixing the heat absorbing unit **4** to the probe handle **2**. This obviates the need to prepare an additional fixing member unlike in the first embodiment, and facilitates attaching the cooling unit. This also saves the user the trouble of managing an additional fixing member such as the one used in the first embodiment.

Furthermore, when the heat absorbing unit **4** is attached, the housing **41** of the heat absorbing unit **4** does not protrude from the housing **27** of the probe handle **2**. Even when the heat absorbing unit **4** is attached, therefore, it is possible to maintain the same operability of the probe handle **2** as that when the heat absorbing unit **4** is not attached.

In addition, this embodiment of course achieves the same effects as those of the first embodiment.

(Third Embodiment)

The third embodiment will be explained below with reference to the accompanying drawings.

An ultrasonic probe **1** according to this embodiment differs from the second embodiment in that a probe handle **2** includes a cover **94** for covering a position where a heat absorbing unit **4** is to be attached. The circuit configuration and the like of the ultrasonic probe **1** are the same as those of each embodiment described above, so a repetitive explanation will be omitted by denoting the same components by the same reference numerals.

FIG. **9** is a perspective view showing the outer appearances of the probe handle **2**, heat absorbing unit **4**, and cover **94**.

The shape of the probe handle **2** is almost the same as that of the second embodiment except that a pair of grooves **95***a* and **95***b* (FIG. **9** shows only the groove **95***b*) are formed in the two side surfaces in the lateral direction of a housing **27**, along the bottom surface of a recess **90**.

The cover **94** is a plate-like member whose width in the lateral direction is almost the same as that of the probe handle **2**, and the two end portions of this plate-like member along the longitudinal direction are bent inward. Guide portions **97***a* and **97***b* as the distal end portions of bent portions **96***a* and **96***b* are respectively fitted in the grooves **95***a* and **95***b* of the probe handle **2**. Note that the cover **94** is made of an insulating material having a low thermal conductivity, e.g., plastic.

When attaching the cover **94**, the heat absorbing unit **4** is first attached to the probe handle **2** as shown in FIG. **8** described previously. Then, the cover **94** is pushed from the side on which the heat absorbing unit **4** is attached. Consequently, the guide portions **97***a* and **97***b* are respectively fitted in the grooves **95***a* and **95***b*, and the cover **94** is fixed to the housing **27** of the probe handle **2**.

When the heat absorbing unit **4** and cover **94** are thus attached to the probe handle **2**, as shown in FIG. **10**, the upper surface of the housing **27** of the probe handle **2** and the upper surface of the cover **94** form an almost flat surface, and the cover **94** completely covers the heat absorbing unit **4** attached to the probe handle **2**. Note that a method of attaching the cover **94** to the housing **27** is not limited to the method using the guide portions **97***a* and **97***b* and grooves **95***a* and **95***b*, and can also be another method.

The arrangement described above can achieve the following effects.

In the ultrasonic probe **1** according to this embodiment, even when the heat absorbing unit **4** is attached to the probe handle **2**, the heat absorbing unit **4** is not exposed because the cover **94** covers the whole attaching portion. Therefore, the cooling unit does not interfere with the operation of the probe handle **2**.

Also, when the cover **94** is attached to the probe handle **2** regardless of whether to attach the heat absorbing unit **4**, the portion to which the heat absorbing unit **4** is to be attached does not touch the skin of an operator or patient. Accordingly, the exposed surface of a heat sink **24** heated to a high temperature or the heat absorbing unit **4** does not burn an operator or patient by touching him or her.

In addition, this embodiment of course achieves the same effects as those of the embodiments described above.

(Modifications)

Various modifications can be made from the arrangements disclosed in the above-mentioned embodiments. Practical modifications are as follows.

(1) That is, in each embodiment described above, the control circuits of the probe connector **3** and radiation unit **5** are connected via the cooling unit control connector **33**, and the cooling control circuit **54** controls the cooling device **50** based on the temperatures T**1** and T**2** notified from the probe connector **3**. However, the control circuits of the radiation unit **5** and probe connector **3** may also be unconnected independent control systems. In this case, an operation unit including switches and the like is formed on, e.g., the housing of the radiation unit **5**, and the user manually inputs control information to the cooling device **50**. It is also possible to always operate the pump **51** and heat exhausting fan **53** of the cooling device **50** under predetermined conditions.

(2) In each embodiment described above, the cooling unit operating power is supplied from the probe connector **3** via the cooling unit control connector **33**, and, if the voltage of this power supply drops, the auxiliary power supply circuit **55** loads power from the auxiliary power supply **56**. However, it is also possible to supply no operating power from the probe connector **3** to the radiation unit **5**, and supply power to the radiation unit **5** from a power supply system entirely independent of the probe connector **3** and the main body **8** of the ultrasonic diagnostic apparatus.

Increasing the independence of the radiation unit **5** and probe connector **3** as described in modifications (1) and (2) obviates the need to form the cooling unit control connector **33** and cooling unit control circuit **32** in the probe connector **3**, and simplifies the structure of the ultrasonic probe **1**. Also, when it is no longer necessary to supply power from the probe connector **3** to the cooling unit, a large part of the power supplied from the main power supply **34** can be used to drive the probe handle **2**. This stabilizes the ultrasonic transmitting/receiving performance.

(3) When it is desirable to acquire images superior in spatial resolution and temporal resolution, higher electric power must be supplied to the probe handle **2**, and this increases the amount of heat generated by the electronic circuits **22**. Since this makes the cooling performance necessary to improve, the cooling unit must be enlarged, and the size and weight of the unit pose problems. If these problems arise, it is only necessary to appropriately use an auxiliary tool such as a support arm for supporting the probe handle **2**.

While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel methods and systems described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the methods and systems described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

What is claimed is:

1. An ultrasonic probe comprising:

a probe unit obtained by arranging, in a housing, a transducer unit which transmits and receives ultrasonic waves with an object to be examined, an electronic circuit unit which is connected to the transducer unit and performs electrical signal processing, and a heat transfer member which is made of a material having a heat transfer coefficient higher than that of the electronic circuit unit, and transfers heat of the electronic circuit unit to a housing surface;

a cooling unit which is detachably mounted on the housing of the probe unit, and cools the heat transfer member by passing a coolant in a channel formed inside the cooling unit; and

a fixing member located on the housing and the cooling unit having a predetermined number of elements for engaging the cooling unit to the housing at a predetermine location, at least one of the elements being movable for locking the cooling unit on the housing.

2. The probe according to claim **1**, wherein the heat transfer member comprises:

a heat sink formed to expose one surface to the housing surface; and

heat spreaders which are formed between electronic circuits constructing the electronic circuit unit, and transfer heat of the electronic circuits to the heat sink.

3. The probe according to claim **1**, wherein the cooling unit comprises:

a heat absorbing unit which is attached to the housing of the probe unit; and

a radiation unit which is connected to the heat absorbing unit by coolant supply/discharge pipes, and cools the coolant heated by the heat absorbing unit.

4. The probe according to claim **3**, wherein the probe unit further comprises a guiding portion which guides the heat absorbing unit to a position where the heat absorbing unit abuts against a portion on the housing surface to which heat is transferred by the heat transfer member.

5. The probe according to claim **3**, wherein the probe unit further comprises a fixing portion which fixes the heat absorbing unit to the housing by bringing the heat absorbing unit in tight contact with a position to which heat is transferred by the heat transfer member.

6. The probe according to claim **3**, wherein the probe unit further comprises a detachable cover which covers the heat absorbing unit attached to the housing of the probe unit.

7. The probe according to claim **3**, wherein the radiation unit comprises:

a coolant circulating unit which circulates the coolant between the heat absorbing unit and the coolant circulating unit via the supply/discharge pipes; and

a coolant cooling unit which cools the coolant circulated by the coolant circulating unit.

8. The probe according to claim **7**, which further comprises a connector unit which is connected to the probe unit via a communication cable, and transmits and receives signals with an ultrasonic diagnostic apparatus main body, and

in which the coolant circulating unit and the coolant cooling unit operate by receiving power from a power supply different from a power supply which supplies power to the connector unit and the ultrasonic diagnostic apparatus main body.

9. The probe according to claim **7**, further comprising:

a temperature sensor which senses a temperature of the probe unit; and

a cooling control unit which controls the coolant circulating unit and the coolant cooling unit based on the temperature sensed by the temperature sensor.

10. An ultrasonic probe comprising:

a transducer unit which transmits and receives ultrasonic waves with an object to be examined;

an electronic circuit unit which is connected to the transducer unit and performs electrical signal processing;

a heat transfer member which is made of a material having a heat transfer coefficient higher than that of the electronic circuit unit, and transfers heat of the electronic circuit unit to a housing surface; and

a fixing portion which fixes, to a housing, a heat absorbing unit which cools the heat transfer member by circulating a coolant, by bringing the heat absorbing unit in tight contact with a portion to which heat is transferred by the heat transfer member, wherein the fixing portion having a predetermined number of elements for detachably engaging the heat absorbing unit to the housing at a predetermine location, at least one of the elements being movable for locking the heat absorbing unit on the housing.

11. The probe according to claim **10**, further comprising a guide portion which guides the heat absorbing unit to a position where the heat absorbing unit abuts against a portion on the housing surface to which heat is transferred by the heat transfer member.

12. The probe according to claim **10**, further comprising a detachable cover which covers the heat absorbing unit fixed to the housing by the fixing portion.

13. An ultrasonic diagnostic apparatus comprising:

a probe unit obtained by arranging, in a housing, a transducer unit which transmits and receives ultrasonic waves with an object to be examined, an electronic circuit unit which is connected to the transducer unit and performs electrical signal processing, and a heat transfer member which is made of a material having a heat transfer coefficient higher than that of the electronic circuit unit, and transfers heat of the electronic circuit unit to a housing surface;

a cooling unit which is detachably mounted on the housing of the probe unit, and cools the heat transfer member by passing a coolant in a channel formed inside the cooling unit;

a fixing member located on the housing and the cooling unit having a predetermined number of elements for engaging the cooling unit to the housing at a predetermine location, at least one of the elements being movable for locking the cooling unit on the housing;

a temperature sensor which senses a temperature of the probe unit;

a detection unit which detects a connection state of the cooling unit with respect to the probe unit; and

a control unit which operates the probe unit by prescribed power when the detection unit detects connection of the cooling unit, and operates the probe unit by power corresponding to the temperature sensed by the temperature sensor when the detection unit does not detect connection of the cooling unit.

14. The apparatus according to claim **13**, wherein the heat transfer member comprises:

a heat sink formed to expose one surface to the housing surface; and

heat spreaders which are formed between electronic circuits constructing the electronic circuit unit, and transfer heat of the electronic circuits to the heat sink.

15. The apparatus according to claim **13**, wherein the cooling unit comprises:

a heat absorbing unit which is attached to the housing of the probe unit; and

a radiation unit which is connected to the heat absorbing unit by coolant supply/discharge pipes, and cools the coolant heated by the heat absorbing unit.

16. The apparatus according to claim **15**, wherein the probe unit further comprises a guide portion which guides the heat absorbing unit to a position where the heat absorbing unit abuts against a portion on the housing surface to which heat is transferred by the heat transfer member.

17. The apparatus according to claim **15**, wherein the probe unit further comprises a fixing portion which fixes the heat absorbing unit to the housing by bringing the heat absorbing unit in tight contact with a position to which heat is transferred by the heat transfer member.

18. The apparatus according to claim **15**, wherein the probe unit further comprises a detachable cover which covers the heat absorbing unit attached to the housing of the probe unit.

19. The apparatus according to claim **15**, wherein the radiation unit comprises:

a coolant circulating unit which circulates the coolant between the heat absorbing unit and the coolant circulating unit via the supply/discharge pipes; and

a coolant cooling unit which cools the coolant circulated by the coolant circulating unit.

20. The apparatus according to claim **19**, which further comprises a connector unit which is connected to the probe unit via a communication cable, and transmits and receives signals with an ultrasonic diagnostic apparatus main body, and

in which the coolant circulating unit and the coolant cooling unit operate by receiving power from a power supply different from a power supply which supplies power to the connector unit and the ultrasonic diagnostic apparatus main body.

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专利名称(译)	超声波探头和超声波诊断仪		
公开(公告)号	US8409101	公开(公告)日	2013-04-02
申请号	US12/815825	申请日	2010-06-15
[标]申请(专利权)人(译)	株式会社东芝 东芝医疗系统株式会社		
申请(专利权)人(译)	株式会社东芝 东芝医疗系统公司		
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IPC分类号	A61B8/14		
CPC分类号	A61B8/14 G10K11/004 A61B8/546		
优先权	2009150037 2009-06-24 JP		
其他公开文献	US20100331702A1		
外部链接	Espacenet USPTO		

摘要(译)

根据一个实施例，超声探头包括探头单元和冷却单元。探头单元通过在壳体中布置有与待检查对象发送和接收超声波的换能器单元，连接到换能器单元并执行电信号处理的电子电路单元和传热构件而获得。它由传热系数高于电子电路单元的材料制成，并将电子电路单元的热量传递到壳体表面。冷却单元可拆卸地安装在探头单元的壳体上，并且通过使冷却剂通过形成在冷却单元内部的通道中来冷却传热构件。