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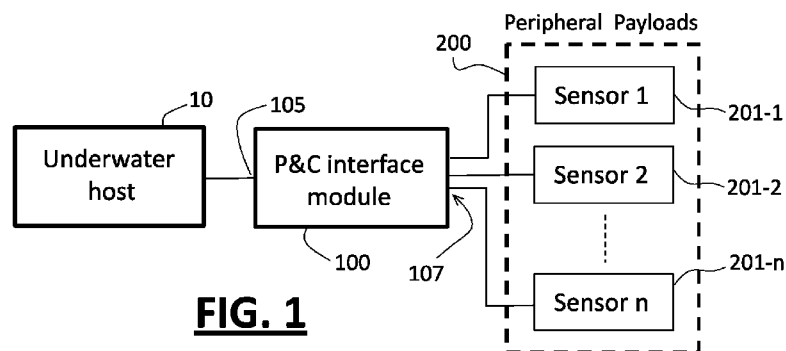
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(54) Title: INTERFACE MODULE FOR AN UNDERWATER HOST AND METHOD OF OPERATING SUCH INTERFACE
MODULE**FIG. 1**

(57) Abstract: A power and communications interface module for connecting multiple payloads to an underwater host has a primary power and communications connector capable of transferring electric power from the underwater host to the interface module and communicating data between the interface module and the underwater host and a plurality of secondary power and communications connectors for connecting to a plurality of payloads. An interface computing system is electrically powered with power from the primary power and communications connector. A data-communication interface is configured between the interface computing system and the primary power and communications connector. Multiple software interface drivers are available in the interface computing system. Operating of the power and communications interface module includes selecting one software interface driver from the multiple software interface drivers and activating the selected software interface driver to communicate with the selected underwater host through the primary power and communications connector.

INTERFACE MODULE FOR AN UNDERWATER HOST AND METHOD OF OPERATING SUCH INTERFACE MODULE

Field of the invention

The present invention relates to a power and communications interface module for connecting multiple payloads to an underwater host. The present invention further relates to a method of operating such a power and communications interface module.

5 Background of the invention

In the off-shore industry, particularly in the off-shore oil and gas industry, various kinds of sensors are deployed under water to survey an underwater environment or inspect underwater conditions. Such sensors, generally referred to as payloads, are usually carried on an underwater host. Such underwater hosts can be stationary (such as on a permanent or
10 semi-permanent underwater construction) or mobile.

Mobile hosts are usually deployed in the form of unmanned underwater vehicles (UUV) to perform various tasks under water including surveying and/or inspection. There are two distinguished kinds of unmanned underwater vehicles: remotely operated vehicles (ROV) and autonomous underwater vehicles (AUV). ROVs typically are controlled by a
15 remote human operator, while an AUV is a kind of robot that operates independently of direct human input. Such UUVs typically carry various kinds of sensors, generally referred to as payloads. Some sensors are primarily provided for obtain navigation status data (position, motion, depth, etc.) which can be used to control the navigation of the UUV. Other sensors are primarily provided to obtain survey data or inspection data. Examples
20 include sampling equipment, acoustic and non-acoustic sensors (such as CTD sensors and magnetometers).

One type of AUV that is commercially available from Kongsberg Maritime A. S., Norway, is the so-called HUGIN. A flexible payload system that has been developed for this type of AUV is described in a paper by Per Espen Hagen and Jon Kristensen,
25 published in Oceans 2002 MTS/IEEE conference proceedings, Volume 1, pp. 156-161, titled: "The HUGIN AUV 'Plug and Play' Payload System". An important feature of the described system is that it allows development of interface software for each payload. The software is integrated in such a way that the vehicle operators can then mix and match payloads integrated by different parties.

A drawback of this payload system is that it can only be employed in an AUV of the HUGIN type.

Summary of the invention

In accordance with a first aspect of the present invention, there is provided a power and communications interface module for connecting multiple payloads to an underwater host, said interface module comprising:

- a primary power and communications connector capable of transferring electric power from the underwater host to the interface module and communicating data between the interface module and the underwater host;
- 10 - a plurality of secondary power and communications connectors for connecting to a plurality of payloads; and
- an interface computing system powered with the electric power from the primary power and communications connector;
- a data-communication interface configured between the interface computing system and the primary power and communications connector for communicating the data to and from the interface computing system;

15 wherein multiple software interface drivers are available in the interface computing system, configured to communicate with multiple types of underwater hosts.

In accordance with a second aspect of the invention, there is provided a method of operating a power and communications interface module for connecting multiple payloads to an underwater host, wherein:

- selecting an underwater host from multiple types of underwater hosts;
- connecting the power and communications interface module to the underwater host via a primary power and communications connector capable of transferring electric power from the underwater host to the interface module and of communicating data between the interface module and the underwater host;
- 25 - connecting the power and communications interface module to a plurality of payloads via a plurality of secondary power and communications connectors;
- selecting one software interface driver from multiple software interface drivers are available in an interface computing system within the power and communications interface to communicate with multiple types of underwater hosts, wherein the interface computing system is powered with the electric power provided through the primary power and communications connector; and

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- activating the selected software interface driver to communicate with the selected underwater host through the primary power and communications connector.

Brief description of the drawing

Fig. 1 shows a high level schematic of a power and communications interface module connected multiple payloads and an underwater host;

Fig. 2 shows a schematic of internals of the power and communications interface module of Fig. 1;

Fig. 3 shows a schematic view of a pressure resistant container in which the power and communications interface module of Fig. 1 can be packaged;

Fig. 4 shows a schematic view of the power and communications module incorporated in an example AUV; and

Fig. 5 shows a schematic view of the power and communications module incorporated in an example ROV.

These figures are not to scale. Identical reference numbers used in different figures refer to similar components.

Detailed description of the invention

The invention will be further illustrated hereinafter by way of example only, and with reference to the non-limiting drawing. The person skilled in the art will readily understand that, while the invention is illustrated making reference to one or more a specific combinations of features and measures, many of those features and measures are functionally independent from other features and measures such that they can be equally or similarly applied independently in other embodiments or combinations.

Proposed herein is a power and communication interface for connecting multiple payloads to an underwater host that is host-agnostic. Figure 1 illustrates a power and communications interface module 100 connected to multiple payloads and to an underwater host 10. The interface module 100 comprises a primary power and communications connector 105. The primary power and communications connector 105 is capable of transferring electric power from the underwater host 10 to the interface module 100, and of communicating data between the interface module 100 and the underwater host 10. The interface module 100 further has a plurality of secondary power and communications connectors 107, connected to peripheral payloads 200. The payloads 200 in this case are represented by multiple sensors (201-1, 201-2, ... , 201-n).

The underwater host 10 can be a mobile host, such as an unmanned underwater vehicle, but it can also be stationary. Within these classes, multiple types exist. For instance, various types of unmanned underwater vehicles exist, including remotely operated vehicles (ROV) and autonomous underwater vehicles (AUV), and they can come
5 from a variety of manufactures and providers. Each manufacturer or provider tends to adhere to their own specific power and communications specifications. Various modifications are proposed herein, each contributing to the power and communications interface module 100 to be host-agnostic and suitable to be deployed with multiple sets of host-specific specifications. A number of these modifications are illustrated with reference
10 to Fig. 2.

Figure 2 schematically illustrates internals of an embodiment of the power and communications interface 100. The primary power and communications connector 105 is configured with multiple electrically conducting lines, which are represented in the Figure by solid lines, dashed lines, and dot-dashed lines. Solid lines schematically represent
15 power, dashed lines represent serial data and dot-dashed lines represent Ethernet data.

The power and communications interface comprises an interface computing system 110. The interface computing system 110 is powered with electric power from the primary power and communications connector 105. This is electric power from the power supply by which the underwater host 10 is powered. A data-communication interface 120 is
20 configured between the interface computing system 110 and the primary power and communications connector 105, for communicating data between the interface computing system 110 and the underwater host 10. The data-communication interface 120 is suitably also connected to the payloads via a plurality of secondary power and communications connectors 107-1, 107-2, ... , 107-n. The payloads are represented in the Figure by sensors
25 201-1, 201-2, ... , 201-n.

The power and communications interface is intended to connect, monitor, and control various payloads. It also connects to the host's systems to receive power and data. In addition, it may transmit data to the host's systems.

The interface computing system 110 suitably comprises a computing processor 112
30 and a computer readable storage medium 114. The computer readable storage medium 114 may comprise a solid state hard disk. Multiple software interface drivers are available in the interface computing system 110. The multiple software interface drivers are configured to communicate with multiple types of underwater hosts. The multiple software interface

drivers are interchangeably selectively loadable in the computing processor 110. When deploying the power and communications interface module 100, one software interface driver is selected from the multiple software interface drivers that are available in the interface computing system 110 within the power and communications interface 100. The
5 selected software interface driver is then activated to communicate with the selected underwater host 10.

This way the power and communications interface module 100 is not only capable of only working in one type of underwater host, but it is capable of being deployed in any type of underwater host without a need to physically change any hardware on the interface
10 module itself. Additional software interface drivers can be added to the multiple software interface drivers that are already stored on the computer readable storage medium. This provides extra versatility.

The data-communication interface 120 suitably comprises a serial data card 112 as well as an Ethernet card 124. Suitable standards for serial data transmission include RS-
15 232, RS-422, RS-485, and others. The Ethernet card 124 preferably supports at least 10/100 Ethernet. With both the serial data card 112 and the Ethernet card 124 available a large variety of underwater hosts 10 can be communicated with. The interface computing system 110 is electrically connected with the primary power and communications connector 105 through the serial data card 122 and/or the Ethernet card 124. The primary
20 power and communications connector 105 preferably comprises an Ethernet connection as well as a serial data connection.

The interface module may further comprise a power conditioning unit 130. The power conditioning unit 130 is electrically connected to the primary power and communications connector 105, and arranged to convert power from the underwater host
25 10 to secondary power output within predetermined specifications.

The power conditioning unit 130 may for instance comprise one or more filters, to eliminate or reduce disruptive noise from the electric power. Some underwater hosts are powered using DC batteries, but particularly ROVs are sometimes powered with AC power. The use of filtering widens the envelope of suitable external power supplies that
30 can power the power and communications interface module 100. The relevance of the filters is not only protect the internals of the power and communications interface module 100, such as the interface computing system 110, but also to protect the payloads, which are powered via the power and communications interface module 100.

The power conditioning unit 130 may also comprise rectifiers and/or one or more voltage transformers. Suitably, at least two power outputs are available, wherein a first predetermined specification of one of the at least two power outputs is different from a second predetermined specification of another one of the at least two power outputs. This is schematically indicated in Fig. 2, where the power in line 131 has a different specification (for instance a different voltage) than the power in line 132. This widens the ability to receive and control more different types of payloads.

Suitably, the interface module of claim 2, further comprising a power distributor 140, which is electrically connected with the power conditioning unit 130. The power distributor 140 is configured to selectively distribute power between the plurality of secondary power and communications connectors 107-1, 107-2, ... , 107-n. Preferably, the power distributor 140 comprises a plurality of power switches (142-1, 142-2, ... , 142-n) configured to selectively connect or disconnect power to any one of the plurality of secondary power and communications connectors 107-1, 107-2, ... , 107-n. The ability to independently switch individually selected payloads on or off provides flexibility. For illustrative purpose, these switches have been represented by mechanical switches. However, these may be embodied in the form of electronic switching circuits. The switching circuits may further be arranged to switch between different secondary power lines. This also offers flexibility in selecting which power specifications are used for each payload.

Optionally, an uninterruptable power supply (UPS) unit 150 is provided within the power and communications interface module 100, to temporarily supply power if for some reason the power supply from the underwater host 10 is not available or disconnected. This ensures continued operation of the power and communications interface module 100 in case of minor disruptions of power from the underwater host 10. The UPS unit 150 may be connected functionally in parallel with the primary power and communications connector 105.

Each of the secondary power and communications connectors 107-1, 107-2, ... , 107-n preferably comprise a secondary serial data connector and a secondary Ethernet connector in addition to a secondary power connector. The secondary serial data connectors and secondary Ethernet connectors are preferably in communication with the data communication interface 120. Suitably, the secondary serial data connectors and

secondary Ethernet connectors may be in communication with the serial card 122 and the Ethernet card 124 in the data communication interface 120.

Some sensor information coming in via the data communication interface 120 may be communicated directly to the underwater host 10 as controlled by the interface
5 computing system 110. Typically, this could include position and/or motion data relevant for the navigation and/or operation of the underwater host 10. Optionally, the interface computing unit 110 may comprise an autonomy computer 116, capable of running high level autonomy software which can be fed back to the host platform to command the underwater host in response to sensor data.

10 The interface computing system 110 may also support in-module data processing for automatic target recognition.

Some sensor data is not needed for the operation of the underwater host 10. This sensor data may be stored within the power and communications module 100 for later retrieval. For this purpose a data logging unit may suitably be provided on the power and
15 communications interface module 100. Suitably, data logged by the data logging unit is stored on the same computer readable storage medium 114 on which also the software interface drivers are stored. However, an independent data logging storage capability may be provided if desired, which may be preferred to store the logged data independently from the software interface drivers. The data logging storage capability may be removable, but
20 this is not necessary as the stored data may be outputted via the data communication interface 120 (e. g. by using the Ethernet card 124).

Advantageously, the power and communications interface module 100 is packaged in a pressure resistant container, suitably filled with air. By packaging the power and communications interface module 100, various connections and points of failure are
25 eliminated which is particularly valuable for underwater performance. The container is preferably pressure resistant, so that the power and communications interface module 100 can be used under water regardless of whether the underwater host has a pressure-regulated space available in it.

A perspective view of a possible example embodiment of such a container is
30 presented in Fig. 3. The pressure resistant container shown in Fig. 3 comprises a cylindrical body 101 provided with end caps 102,104. The end caps 102,104 are spaced apart from each other in a longitudinal direction. Primary and secondary power and communication connectors (105 and 107-1, 107-2, ... , 107-n) are arranged in one or both of the end caps

102,104. In the presented view, all power and communication connectors are configured in one of the end caps (104), which makes it easier to assemble the power and communications interface module 100. There are industry-standard connectors suitable for use under water.

5 The embodiment of Fig. 3 is only one of the possible designs. However, if such a cylindrical design is selected, it is recommended that the cylindrical body 101 has an outer diameter of less than 27 cm. This way the integration of the power and communications interface module into a 12.75 inch diameter AUV is facilitated. Preferably, the outer diameter is kept to less than 24 cm, in which case it would also be possible to
10 accommodate the module into an 21 inch diameter AUV next to another similarly sized (pressure) vessel. For similar reasons, it is recommended that the pressure resistant container measured in the longitudinal direction between extremities of the end caps 102,104 (e. g. the optional rims) does not exceed 61 cm. Preferably, this length does not exceed 31 cm.

15 The pressure resistant container, including the connectors, is suitably rated for a water depth of at least 500 m. However, in further support of a wide window of applicability, a pressure rating of at least 4500 m is preferred. With a depth rating of 4500 m, the power and communications module can be used at essentially any depth encountered in the offshore oil and gas industry. The (air) pressure within the pressure
20 resistant container is preferably about atmospheric, for instance between 0.7 and 1.0 bar absolute. This is expected to not impose any restriction on the internal components that can be used for the power and communications interface module, despite the fact that the power and communications interface module can be used in deep water. Preferably, the interface module packaged in the pressure resistant container is neutrally or positively
25 buoyant in seawater at a temperature of 0 °C and a Knudsen salinity of 25 ppt. Herewith the impact on the underwater stability of the underwater host is marginal.

A vacuum port is suitably available on the pressure resistant container to allow pulling a partial vacuum in the container and/or to apply a purge with an inert gas (e. g. nitrogen).

30 Figure 4 presents a schematic impression of the power and communications module 100 packaged as illustrated in Fig. 3 and incorporated in an example AUV. An AUV typically has an outer shell 40 and a propeller 42 and a host platform 44. As illustrated schematically in Fig. 4, the power and communications module 100 is connected to the

host platform 44 via the primary power and communications connector 105. Various sensors (201-1, 201-2, 201-3, 201-n) are schematically illustrated in the payload section 200.

Figure 5 presents a schematic impression of the power and communications module 100 packaged as illustrated in Fig. 3 and incorporated in an example ROV. In this case, the primary power and communications connector 105 may be connected to an umbilical 52. Also the ROV power supply may go through the umbilical 52.

The power and communications interface module may also be applied in different types of underwater hosts, including stationary structures.

Example sensors that can be used as peripheral payload include:

- underwater mass spectrometer;
- CTD instrument (for seawater conductivity, temperature and depth);
- (multi-beam) echo sounder;
- camera.

The drivers for the payloads in use are suitably available in the interface computing system 110. The secondary power requirements (voltage, peak current, etc.) are made available through the power conditioning unit 130. In exceptional cases, the UPS unit 150 (if provided) may be needed to supplement power that is sourced from the underwater host 10. Voltage and current supplied to each connected payload may be monitored. Voltage and current supplied from the underwater host 10 through the primary power and communications connector 105 may be monitored.

Referring, again, to Figure 2, the power and communications interface module 100 may comprise an environmental board 160 to monitor environmental data within the pressure resistant container. Suitably, the environmental board is configured to monitor one or more of:

- internal (air) pressure, preferably in a range of from 0. 3 to 1. 4 bar absolute;
- internal temperature, preferably in a range of from 0 to 60 °C;
- internal humidity, preferably in a range of from 0 to 100 % relative humidity.

The environmental board further preferably has a (binary) leak detection capability to detect water intrusion.

The person skilled in the art will understand that the present invention can be carried out in many various ways without departing from the scope of the appended claims.

CLAIMS

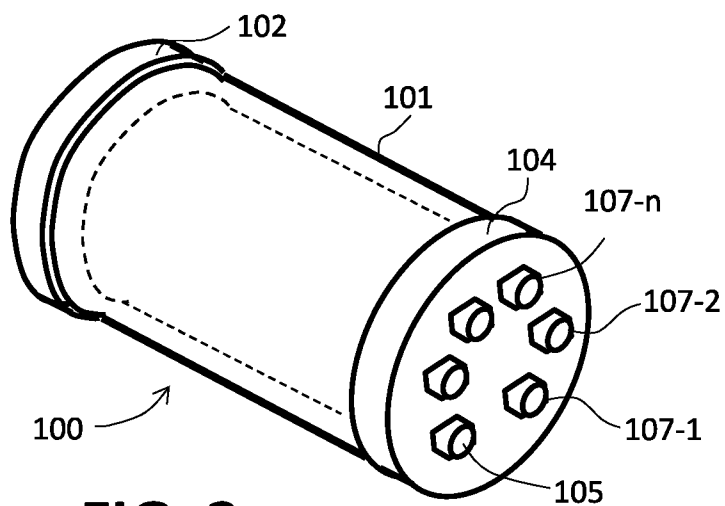
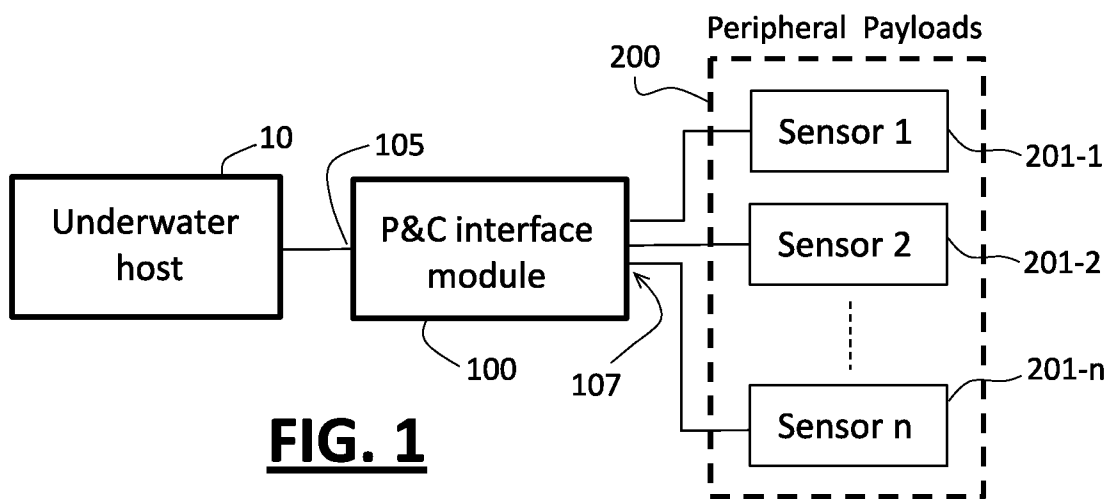
1. A power and communications interface module for connecting multiple payloads to an underwater host, said interface module comprising:
 - 5 - a primary power and communications connector capable of transferring electric power from the underwater host to the interface module and communicating data between the interface module and the underwater host;
 - a plurality of secondary power and communications connectors for connecting to a plurality of payloads; and
 - 10 - an interface computing system powered with the electric power from the primary power and communications connector;
 - a data-communication interface configured between the interface computing system and the primary power and communications connector for communicating the data to and from the interface computing system;
 - 15 wherein multiple software interface drivers are available in the interface computing system, configured to communicate with multiple types of underwater hosts.
2. The interface module of claim 1, wherein the interface computing system comprises a computing processor and a computer readable storage medium, wherein the computer readable storage medium has multiple software interface drivers stored on it and wherein
20 one of the multiple software interface drivers is selectively loadable in the computing processor.
3. The interface module of claim 1, further comprising a power conditioning unit electrically connected to the primary power and communications connector, arranged to convert power from the underwater host to secondary power output within predetermined
25 specification.
4. The interface module of claim 3, further comprising a power distributor electrically connected with the power conditioning unit, which power distributor is configured to selectively distribute secondary power between the plurality of secondary power and communications connectors.
- 30 5. The interface module of claim 4, wherein the power distributor comprises a plurality of power switches configured to selectively connect or disconnect secondary power to any one of the plurality of secondary power and communications connectors.

6. The interface module of claim 5, wherein the power conditioning unit comprises at least two secondary power outputs, wherein a first predetermined specification of one of the at least two secondary power outputs is different from a second predetermined specification of another one of the at least two secondary power outputs.
- 5 7. The interface module of claim 1, further comprising an uninterruptable power supply unit within the power and communications interface module connected functionally in parallel with the primary power and communications connector.
8. The interface module of claim 1, wherein the data-communication interface comprises a serial data card and an Ethernet card, wherein the interface computing system
10 is electrically connected with the primary power and communications connector through the Ethernet card and/or the serial data card.
9. The interface module of claim 1, further comprising a data logging unit for storing sensor information from one or more of the payloads.
10. The interface module of claim 1, wherein the interface module is packaged in a
15 pressure resistant container filled with air.
11. The interface module of claim 10, wherein the pressure resistant container comprises a cylindrical body provided with end caps, wherein the primary and secondary power and communication connectors are arranged in the end caps.
12. The interface module of claim 11, wherein the cylindrical body has an outer diameter
20 of less than 27 cm and/or wherein the pressure resistant container measured in a longitudinal direction between extremities of the end caps does not exceed 61 cm.
13. The interface module of claim 10, wherein the interface module packaged in the pressure resistant container is neutrally or positively buoyant in seawater at a temperature of 0 °C and a Knudsen salinity of 25 ppt.
- 25 14. The interface module of claim 1, wherein the underwater host is an unmanned underwater vehicle.
15. Method of operating a power and communications interface module for connecting multiple payloads to an underwater host, wherein:
- 30 - selecting an underwater host from multiple types of underwater hosts;
- connecting the power and communications interface module to the underwater host via a primary power and communications connector capable of transferring electric power from the underwater host to the interface module and of communicating data between the interface module and the underwater host;

- connecting the power and communications interface module to a plurality of payloads via a plurality of secondary power and communications connectors;
- selecting one software interface driver from multiple software interface drivers are available in an interface computing system within the power and communications interface
- 5 to communicate with multiple types of underwater hosts, wherein the interface computing system is powered with the electric power provided through the primary power and communications connector; and
- activating the selected software interface driver to communicate with the selected underwater host through the primary power and communications connector.

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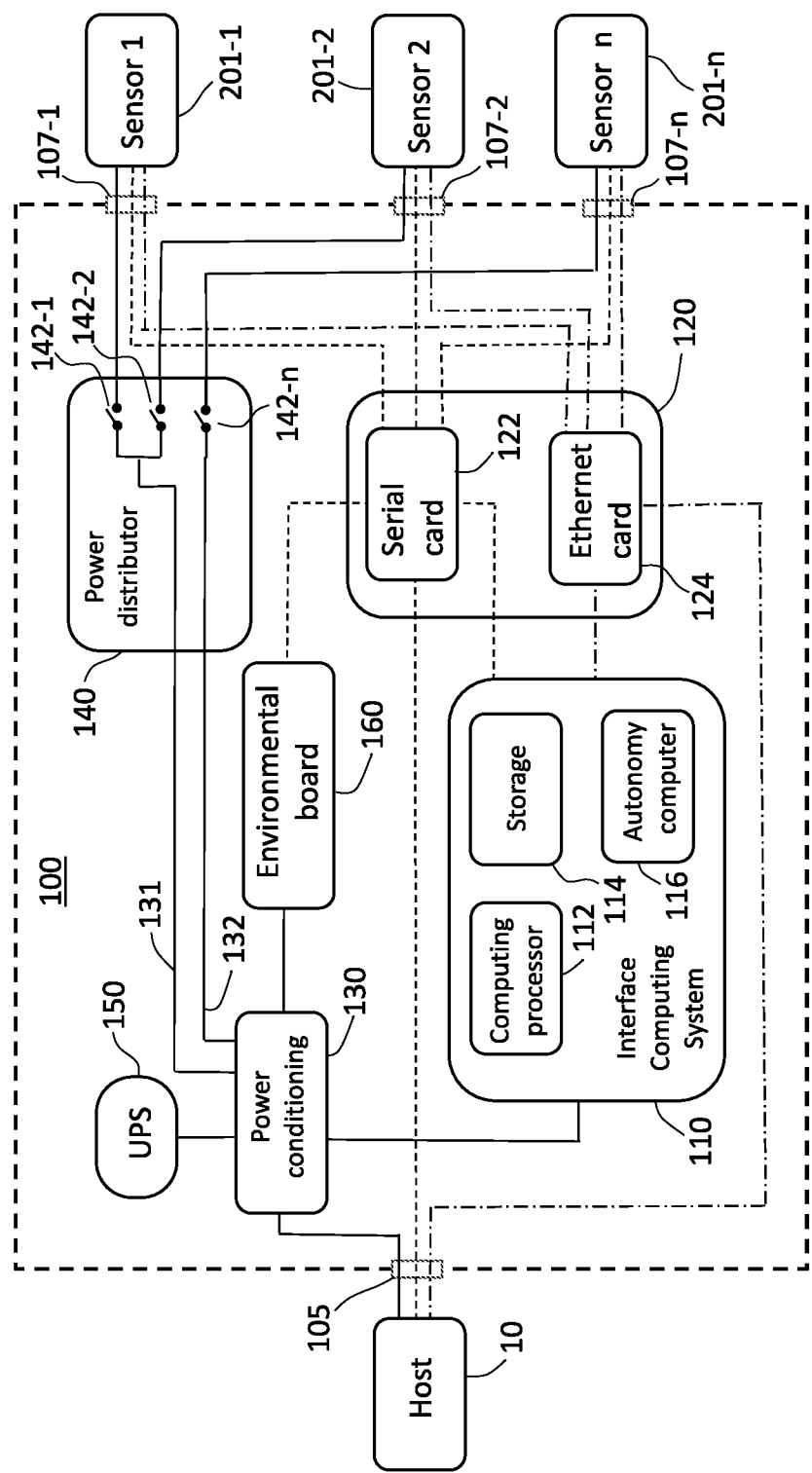
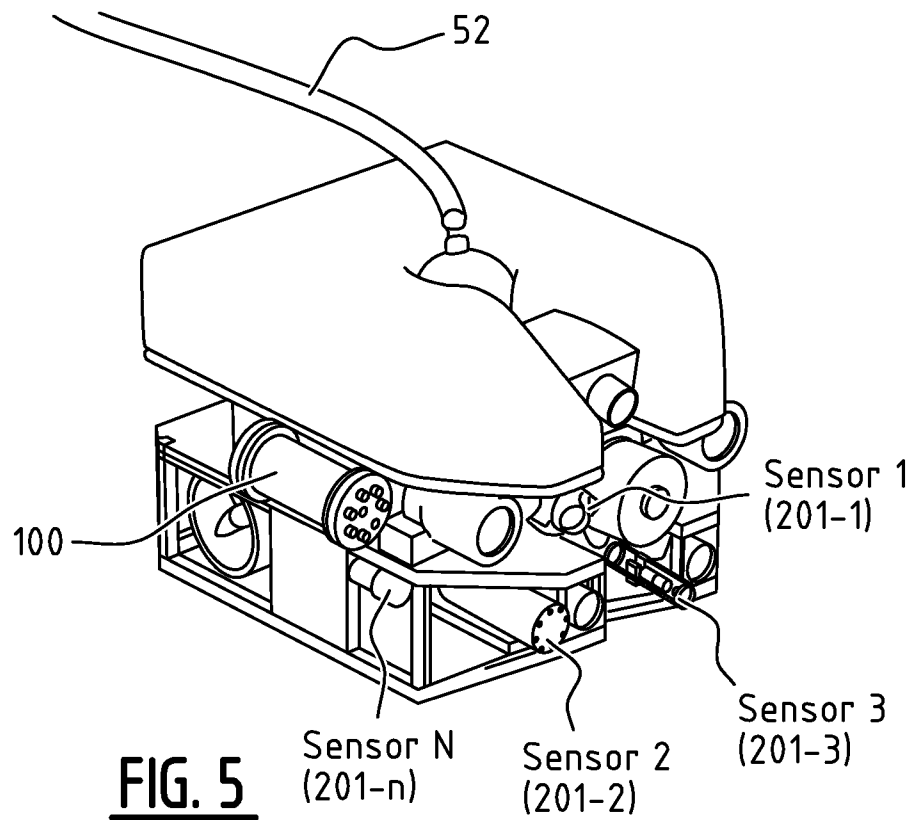
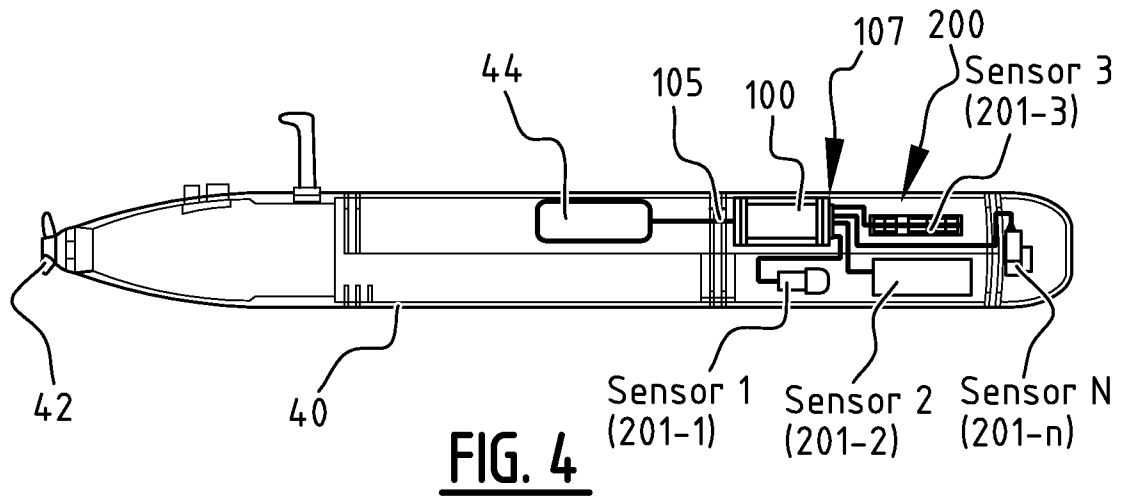


FIG. 2

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INTERNATIONAL SEARCH REPORT

International application No

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A. CLASSIFICATION OF SUBJECT MATTER
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 ADD.

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)
 G06F B63G

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	SANGEKAR M ET AL: "Hardware architecture for a modular autonomous underwater vehicle STARFISH", OCEANS 2008, IEEE, PISCATAWAY, NJ, USA, 15 September 2008 (2008-09-15), pages 1-8, XP031483044, ISBN: 978-1-4244-2619-5 paragraphs [00IV] - [000V]; figures 2,6 -----	1-15
A	US 5 875 415 A (LIEB ROBERT [US] ET AL) 23 February 1999 (1999-02-23) column 1, line 17 - column 2, line 56 column 6, line 24 - line 56 -----	1,2,8,15
A	WO 01/93185 A1 (PSC SCANNING INC [US]) 6 December 2001 (2001-12-06) abstract ----- -/--	1,2,8,15



Further documents are listed in the continuation of Box C.



See patent family annex.

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"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

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Date of the actual completion of the international search

15 August 2016

Date of mailing of the international search report

24/08/2016

Name and mailing address of the ISA/

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Cohen, Benjamin

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/035297

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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