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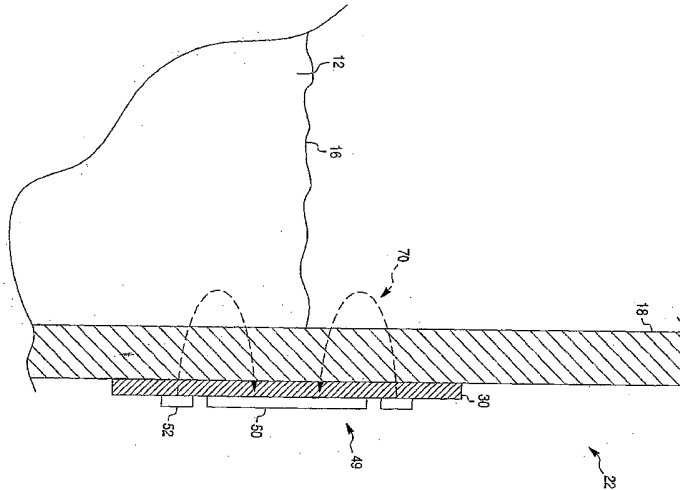
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(54) Title: PROXIMITY SENSOR FOR LEVEL SENSING IN A BILGE



(57) Abstract: A sensor system for sensing liquid level in a bilge, for use in automatic bilge pump actuators. First and second field effect sensors are potted or sealed within a container or the bilge wall and are aligned in a vertical array and each comprise a substantially planar pattern of "electrodes" or conductive traces disposed on a printed circuit board (PCB) along with integrated circuits used to create a loop or arc-shaped electric field. As bilge liquid rises to the proximity or level of the field effect sensors, a change in the arc-shaped electric field is sensed and, in response, a bilge pump is automatically actuated to pump liquid out of the bilge. Optionally, the pump control can be programmed by use of a microprocessor to permit control of on-off timing and prevent undesirable effects of "sloshing."

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## PROXIMITY SENSOR FOR LEVEL SENSING IN A BILGE

**BACKGROUND OF THE INVENTION**

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**Field of the Invention:**

The present invention relates to sensors for detecting the presence of a fluid, automatic systems for actuating pumps in response to detecting a fluid level and sensors mounted in the bottom of a boat bilge tank activating a bilge pump when the bilge fluid level reaches a preset distance above the bottom of the bilge tank.

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**Discussion of the Prior Art:**

In the past, bilge pumps have been activated manually or by mechanical float type switches with mercury or point contacts to complete an electrical circuit activating a pump. Pressure switches have also been used. These prior art switches worked adequately when initially installed. Over time, however, bilge debris and other sources of contamination often prevented the mechanical components from moving as intended, causing switch failure. In addition, prior art bilge pump activation switches typically wore out several times during the life of a boat and, being located in a boat's nether regions, were difficult to access for repair and replacement.

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Many fluid level or fluid proximity detectors of the prior art employed electrical switches actuated when a conductor, such as a body of water, moved into close proximity to the detector or sensor. U.S. Pat. Numbers 3,588,859; 3,665,300; 4,800,755 and 4,875,497 disclose such detectors. U.S. Pat. No. 5,017,909, discloses a proximity detector used as a liquid level detector for receptacles in vehicles.

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Other applications for liquid level detectors included bilge-pumping systems for ships. A bilge pumping system must be activated before the accumulated water reaches an

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excessive level. Prior art mechanisms for detection of an excessive bilge water level employed mechanical floatation systems, causing a switch to be actuated whenever the water reached such an undesired level. Bilge fluid or water eventually renders mechanical level sensing systems inoperative in part because bilge fluid can contain many forms of corrosive waste. Replacing failed parts a bilge level sensing system can be very expensive and  
5 troublesome, since a skilled technician must enter the bilge to perform the work.

Many electronic proximity detection systems have been proposed in searching for a solution to this messy, expensive problem. By way of example, Smith et al (U.S. Patent No. 4,881,873) discloses a capacitive level sensor for a bilge pump including a sensor plate 40  
10 positioned in a bilge at a position selected for pump actuation. The bilge water is sensed as a dielectric, in a manner of speaking, and so the sensor is susceptible to false alarms or missed detections once the contamination accompanying bilge inflow has accumulated in the bilge and contaminated the area around the sensor, and sloshing bilge water is likely to cause the bilge control to actuate when the bilge level does not require pumping.

15 Gibb (U.S. Patent No. 5,287,086) also discloses a capacitive level sensor for a bilge pump including a capacitive sensor plate 79 positioned in a bilge at a position selected for pump actuation. The sensor is contained within a sealed housing 32 to keep bilge water away from the sensor and other circuitry. Here again, bilge water is sensed as a dielectric, in a manner of speaking, and so the sensor is susceptible to false alarms or missed detections once  
20 the contamination accompanying bilge inflow has accumulated in the bilge and contaminated the area around the sensor, and sloshing bilge water is likely to cause the bilge control to actuate when the bilge level does not require pumping.

Santiago (U.S. Patent No. 4,766,329) discloses a solid-state two level sensor for a bilge pump including a high water level probe and a low water level probe, both positioned in

a bilge at positions selected for pump actuation. The probes are in contact with the bilge water, and so the probe sensors are susceptible to false alarms or missed detections once the contamination accompanying bilge inflow has accumulated in the bilge and contaminated the probes.

5           Farr (U.S. Patent No. 5,238,369) discloses a system for liquid level control including upper and lower capacitive level sensors 10, 18 having positions selected for pump actuation. This reference is silent on the need to keep bilge water away from the sensors, but the bilge water is sensed as a dielectric, in a manner of speaking, and so the sensor is susceptible to false alarms or missed detections once the contamination accompanying bilge inflow has  
10 accumulated in the bilge and contaminated the area around the sensors.

          The applicant has licensed a Field Effect sensor patent to Caldwell (U.S. Patent No. 5,594,222) on a “touch sensor” used to detect whether a user presses a virtual button; this sensor is referred to as a “touch sensor.” While the patent discloses the electromagnetic properties of Field Effect “touch” sensing, it is silent on how such technology might be  
15 employed in a sensor system for detecting a fluid/air interface or for automated bilge pump actuation.

          There is a need, therefore, for a system for sensing liquid level and liquid level control that overcomes the problems with prior art sensors and systems, permitting installation of a reliable, inexpensive fluid level sensing system which is unlikely to require maintenance or  
20 cleaning in the bilge. It would be highly desirable to have a new and improved proximity detection system which is highly reliable and relatively inexpensive to manufacture. Such a proximity detection system should be highly sensitive and possess a wide range of applications.

### SUMMARY OF THE INVENTION

The fluid level control and sensor system of the present invention comprises a fluid tight housing or container and a circuit board with electrodes and interconnect patterns assembled with components to create an electric field having arc shaped patterns and sense  
5 changes using the field effect principle.

The housing or container holds first and second electrode patterns in a vertical orientation and has ribs on the housing's sides to allow debris found in a bilge to slough off. By careful selection of materials, the container can resist biological attack (e.g., fungus or algae) and prevent fouling from other materials that might stick to the container otherwise. In  
10 the vertical position, gravity also helps to allow the anticipated contamination to slough off.

The field effect is described elsewhere in U.S. Patent No. 5,594,222 and others assigned to TouchSensor, LLC, which are typically used in large appliance applications for operator input. A similar principle is adapted to detect liquids in close proximity to the sensor, even when isolated from the liquid by a physical barrier, such as a tank wall or  
15 molded container. This technique rejects common mode contamination to the sensor and, through proper tuning of the device, allows the presence or absence of a liquid to be detected. Since this is a solid state device in close proximity to the detector and it is also low impedance, it is also very tolerant of electrical noise in the marine environment.

The electrode design can have geometries ranging from parallel plates to concentric  
20 rings of various sizes and geometric shapes. The design of the electrodes is determined by the materials of construction, thickness, composition of the liquid and other considerations.

Since the fluid level control and sensor system is submerged when active and passing current, an internal current switching device (e.g. a Field Effect Transistor (FET)) adapted to pass twenty amps is easily cooled.

Electronics to support the sensor optionally include components allowing control of devices demanding twenty amps of current without the addition of a separate relay. Through current scalping and other techniques, the bilge pump control system of the present invention operates through two wires or can have a separate third wire to provide power. The fluid  
5 level control and sensor system can be implemented with or without a microprocessor.

The bilge pump assembly consists of a housing, circuit board, components and wiring harness. In operation, the bilge pump sensor is installed in-line between the pump and a power supply. The circuit draws its own power from the power mains supply without activating the pump. Without bilge liquid present near the sensor electrodes, a sensing IC is  
10 at a first state, "off." With a liquid present near the sensor electrodes, the IC changes state to "on" and the circuitry allows connection of power to the bilge pump. The pump is activated until the liquid level goes below the sensor electrodes. The sensing IC changes state to "off" and the power to the pump is interrupted, causing the pump to stop. The sequence is repeated whenever liquid comes in proximity to the sensor. An optional microprocessor allows  
15 control of on-off timing and other time management operations provide a stable pump operation without rapid changes from the "on" to the "off" state (e.g., due to an instability referred to as "sloshing"). Sloshing may vary in amplitude depending on the length of craft and bilge tank and the rocking motion of the craft.

The bilge pump controller of the present invention includes a field effect sensor  
20 comprising an active, low impedance sensor on a dielectric substrate. The sensor has a first conductive electrode pad and a second conductive electrode which substantially surrounds the first electrode in a spaced apart relationship. The first electrode pad has a closed, continuous geometric shape and both electrodes are attached to the same surface of the substrate. An active electrical component is placed in close proximity to the electrodes.

The sensor is used to replace conventional switches and is activated when bilge fluid or water contacts or comes into close proximity with the substrate. The sensor is used to turn an electric pump motor on or off. The field effect sensor design operates properly with liquids present on the substrate and in the presence of static electricity, and is well-suited for use in  
5 an environment where water, grease and other liquids are common, such as boat bilges or other sea-going applications.

Electrodes are attached to the back surface of a substrate, opposite the front or "wet" surface, thereby preventing contact between the electrodes and the controlled fluid (e.g., bilge water). Since the sensor electrodes are not located on the wet surface of the substrate, the  
10 sensor is not damaged by scratching, cleaning solvents or any other contaminants which contact the substrate.

The cost and complexity of the sensor is reduced since a relay or switch is not required.

In the preferred form, an oscillator is electrically connected to the inner and outer  
15 electrodes through gain tuning resistors and delivers a square-wave like signal having a very steep slope on the trailing edge. The oscillator signal creates an arc shaped transverse electric field between the outer electrode and the center electrode. The electric field path is arc-shaped and extends through the substrate and past the front surface, projecting transversely to the plane of the substrate. The inner and outer electrode signals are applied  
20 as common mode signals to the inputs of a differential sensing circuit and when the difference in response between the inner and outer electrodes is great enough, the sensing circuit changes state (e.g., from high to low). The sensing circuit state is altered when the substrate is touched by the controlled fluid.

In the preferred form, an active electrical component preferably configured as a surface mount application specific integrated circuit (ASIC), is located at each sensor. Preferably, the ASIC is connected to the center pad electrode and to the outer electrode of each sensor. The ASIC acts to amplify and buffer the detection signal at the sensor, thereby  
5 reducing the difference in signal level between individual sensors due to different lead lengths and lead routing paths. A plurality of sensors may be arranged on the substrate.

The above and still further features and advantages of the present invention will become apparent upon consideration of the following detailed description of a specific embodiment thereof, particularly when taken in conjunction with the accompanying  
10 drawings, wherein like reference numerals in the various figures are utilized to designate like components.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

Fig. 1 is a side view, in elevation, of a bilge fluid level control and sensor system, in  
15 accordance with the present invention.

Fig. 2 is a partial cross section, in elevation, of the fluid level control and sensor system of Fig. 1, in accordance with the present invention.

Fig. 3 is a back side view, in elevation, of the primary, back or dry surface of a printed wiring board assembly for the fluid level control and sensor system of Figs. 1 and 2, in  
20 accordance with the present invention.

Fig. 4 is a schematic diagram of the printed wiring board assembly for the fluid level control and sensor system of Figs. 1, 2 and 3, in accordance with the present invention.

Fig. 5 is a diagram illustrating a field effect fluid level sensor system showing the arc-shaped field passing through the fluid, in accordance with the present invention.



Fig. 6 is a diagram drawn to scale and illustrating the component side layout of conductive traces on a printed circuit board including a balanced pad sensor electrode pattern.

Fig. 7 is an edge view, in elevation, illustrating the conductive traces on the printed circuit board of Fig. 6 including the balanced pad sensor electrode pattern, as seen from the  
5 side.

Fig. 8 is an edge view, in elevation, of an alternative two-sided embodiment illustrating the conductive traces on a printed circuit board including the balanced pad sensor electrode pattern, as seen from the side.

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#### **DESCRIPTION OF THE PREFERRED EMBODIMENT**

Referring to the exemplary embodiment illustrated in Figs 1-5, a bilge or fluid containment vessel 10 is bounded by a fluid tight wall or surface 18 and at times contains bilge water or some other fluid 12. The fluid level in the bilge rises and falls and the fluid level 14 is measurable over a selected dimension such as that shown by the vertical scale in  
15 Fig. 1. As the fluid level rises or falls, a fluid/air interface 16 can be sighted or measured along the fluid level scale 14. In the typical marine application, bilge 10 contains fluid 12 such as waste water or seawater that leaks through the hull or deck, and when the bilge fluid level 16 is excessively high (e.g., at a selected upper or trigger level 16H), fluid 12 must be pumped out, usually with an electrically powered pump (not shown) that is selectively  
20 energized when the excessively high fluid level 16H is detected. The fluid level is sensed while pumping progresses and the pump is turned off when the level of fluid 12 is low enough (e.g., at a selected lower or turn-off level 16L).

As shown in Figs 1, 2 and 3, fluid level control and sensor system 20 of the present invention comprises a fluid tight housing or container 24 and a printed wiring board assembly

22 with electrodes 50, 52, 60 and 62 and interconnect patterns assembled with components to create an electric field having arc shaped patterns and sense changes using the "field effect" principle.

Referring to Figs. 4 and 5, the field effect is generated and changes in the field are sensed using patterns of conductive traces or electrodes 50, 52 which create arc shaped electric fields 70 projecting transversely and passing through substrate 30. When a rising fluid/air interface 16 is sensed, the arc shaped electric fields 70 pass through the fluid 12 rather than the air above the fluid/air interface. The operation of the sensor system 20 will be described in greater detail below.

10 In the embodiment of Fig. 1, printed wiring board assembly 22 is disposed within a cavity 26 of housing or container 22 and, during assembly, is sealed inside to provide a fluid proof barrier of substantially uniform thickness. Printed wiring board or circuit board 30 is a dielectric planar substrate of substantially uniform thickness having a back side (shown in Figs 2 and 3) carrying the components and opposite a front side. The sensor system 20 is  
15 connected to a mains supply and an electric pump (not shown) via a two cable wire assembly 32 preferably comprising at least first and second sixteen gauge (16AWG) wire segments.

The electrical components in the sensor embodiment illustrated in Figs 2, 3 and 4 include a pre-programmed integrated circuit (IC) eight bit micro-controller also identified as U4, which is connected to and responsive to first and second touch switch ICs, 36, 37 also  
20 identified as U2 and U3, respectively. A sensor system power supply includes voltage regulator 38, also identified as U1, and the mains supply voltage is also controlled by a pair of diodes including series connected diode 46 and shunt connected zener diode 44 providing power to a voltage regulator 38.

In the illustrated embodiment, the bilge water pump actuation and supply comes from a large switching N channel Field Effect Transistor (NFET) 42, the mains supply voltage (e.g., 12 VDC) is connected through connector J1 to the drain and the current, when switched on to actuate the pump, passes through the source and through connector J2 to the pump.

5 As best seen in Fig. 3, a first sensor electrode pattern 49 includes a substantially rectangular upper center electrode pad 50 including a plurality of vertical conductive traces separated by approximately equal width sections of non-conductive PCB surface, where each conductive trace is connected at its upper and lower ends by a surrounding conductive trace, all connected to resistor R5. Upper center electrode pad 50 is not quite completely encircled  
10 by upper outer electrode 52 which is connected to upper touch sensor ASIC 36. Both inner pad 50 and outer electrode 52 are at least partly encircled by a perimeter of solid conductive trace material to provide a ground ring (not shown). The ground ring can be configured to influence sensitivity and directionality of outer electrode 52; if the ground ring is situated too closely to outer electrode 52, however, the sensor's differential mode is lost and the sensor  
15 behaves in a single ended fashion.

A second sensor electrode pattern 59 is disposed in a vertically aligned orientation below the first sensor electrode pattern 49 and includes a substantially rectangular lower center electrode pad 60 including a plurality of vertical conductive traces separated by approximately equal width sections of non-conductive PCB surface, where each conductive  
20 trace is connected at its upper and lower ends by a surrounding conductive trace, all connected to resistor R7. Lower center electrode pad 60 is not quite completely encircled by lower outer electrode 62 which is connected to lower touch sensor ASIC 37. Both pad 60 and outer electrode 62 are also at least partially encircled by a second perimeter of solid conductive trace material to provide a second ground ring (not shown).

In accordance with the present invention, the field effect principle is adapted to detect liquid 12 when in close proximity to sensor 20, even when isolated from the liquid by a physical barrier such as a tank wall or molded container (e.g., 24). This technique rejects common mode contamination to the sensor and, through proper tuning of the device, allows the presence or absence of liquid or fluid (e.g., bilge water 12) to be detected. Since the touch sensors ASICs 36, 37 are solid state devices in close proximity to the electrode pads and also of low impedance, they are also very tolerant of electrical noise in the marine environment.

The electrode design can have geometries ranging from parallel plates to concentric rings of various sizes and geometric shapes. The design of the electrodes (e.g., 50, 52, 60 and 62) is determined by the materials of construction, thickness, composition of liquid 12 and other considerations, as will be appreciated by those with skill in the art.

In the illustrated embodiment, the electronics supporting the sensor include components allowing control of devices (e.g., a pump) demanding 20 amps of current without the addition of a separate relay. Since fluid level control and sensor system 20 is submerged when active and passing current, heat sinking to the bilge fluid 12 allows an internal current switching device (e.g. NFET 42) and a twenty amp supply circuit to be easily cooled.

Through current scalping and other techniques, the bilge pump control system 20 operates through two wires or can have a separate third wire (not shown) to provide power. Current scalping or scavenging utilizes the error output of Voltage regulator 38 as an input to microprocessor 34 which is programmed to turn off FET switch 42 for a short interval during which shunt storage capacitor C1 charges back to 12 volts. This current scalping method permits an "on-time" for FET switch 42 of at least 97%.

Fluid level control and sensor system 20 can be implemented with or without a microprocessor (not shown).

Housing or container 24 supports and protects first and second electrode patterns 49 and 59, in a vertical orientation and optionally has one or more external ribs transversely projecting vertically aligned elongated features 27 on the housing's sides to allow bilge debris to slough off or away from housing 24 as the fluid level falls during pumping. Housing 24 is preferably made of inert materials such as ABS, polypropylene or epoxy to resist biological attack (e.g., fungus or algae) and prevent fouling from other substances that might otherwise tend to stick to the housing or container sidewalls. In the vertical orientation or position shown in Fig. 1, gravity also helps to allow the anticipated contamination to slough off.

In operation, the bilge pump sensor 20 is installed in-line between the pump and a power mains supply using wire assembly 32. The circuit draws its own power from the power mains supply through connector J1 without activating the pump. Without bilge liquid present near the sensor electrodes, each of the sensing ICs 36, 37 is at a first state, "off." With liquid 12 present near the sensor electrodes, the sensing ICs 36, 37 change state to a second state, "on", and the circuitry connects power through FET 42 to the bilge pump. The pump remains activated until the sensed liquid level 16 goes below the sensor electrodes 49 and 59. The sensing ICs 36, 37 then change state to "off" and the power to the pump is interrupted, causing the pump to stop. This sequence is repeated whenever the fluid surface 16 comes into proximity with the sensor system 20. An optional microprocessor allows control of on-off timing and other time management operations to provide a stable pump operation without rapid changes from the "on" to the "off" state (e.g., due to an instability

referred to as "sloshing"). Sloshing may vary in amplitude depending on the length of craft and bilge tank and the rocking motion of the craft.

The bilge pump controller or sensor system 20 of the present invention includes at least one field effect sensor comprising an active, low impedance sensor attached to only one side of dielectric substrate 30 and is used to replace conventional switches. The field effect sensor design operates properly with liquids present on the substrate and in the presence of static electricity, and is well-suited for use in a marine environment where water, grease and other liquids are common, such as boat bilges or other sea-going applications.

As shown in Fig. 5, the sensor's printed wiring board assembly 22 may be molded or fabricated into the bilge sidewall 18 rather than being separately encapsulated in housing 24, with the front or "wet" side of the PC board 30 facing the interior of the bilge 10.

Preferably, sensor electrode patterns 49, and 59 are attached to the back surface of PCB substrate 30. The back surface of the substrate is opposite the front or "wet" surface, thereby preventing contact of the electrodes by the controlled fluid (e.g., bilge water). Since the sensor electrodes are not located on the front surface of the substrate, the sensor is not damaged by scratching, cleaning solvents or any other contaminants which contact the front surface of the substrate. Furthermore, the cost and complexity of the sensor is reduced since a switch is not required.

Preferably, an active electrical component, such as a surface ASIC (e.g., 36) is located at each sensor and connected between the center electrode (e.g., 50) and the outer electrode (e.g., 52) of each sensor. The ASIC acts to amplify and buffer the detection signal at the sensor, thereby reducing the difference in signal level between individual sensors due to different lead lengths and lead routing paths.

The Integrated circuit connected to the field effect sensor electrodes is an active device and, in the illustrated embodiment, is preferably configured as ASIC operating in the manner described in U.S. Patent 6,320,282, to Caldwell, the entire disclosure of which is incorporated herein by reference. As described above, a simple field effect cell has two electrodes (e.g., 50, 52), an ASIC (e.g., 36) and two gain tuning resistors (e.g., R5 and R6).  
5 The pin-out for the TS-100 ASIC of the invention is similar to that illustrated in Fig. 4 of the '282 patent, but the pin-outs vary slightly. The TS-100 ASIC is available from Touch Sensor, LLC. Specifically, for the TS-100 ASIC shown in this application, the input power (Vdd) connection is on pin 1, the ground connection is on Pin 2, the sensor signal output  
10 connection is on pin 3, the outer electrode resistor (e.g., R6) is connected to pin 4, the "oscillator out" connection is at pin 5 and the inner pad electrode resistor (e.g., R5) is connected to pin 6. Optionally, an ASIC can be configured to eliminate the need for gain tuning resistors R5 and R6 by making the gain tuning adjustments internal to the ASIC.

15 The sensitivity of the field effect sensor or cell is adjusted by adjusting the values of gain tuning resistors R5 and R6. The sensor of the present invention can be adapted for use in a variety of applications and the gain resistors R5 and R6 can be changed to cause a desired voltage response. The sensor of the present invention is like other sensors in that the sensor's response to measured stimulus must be tuned or calibrated to avoid saturation  
20 (i.e., from gain/sensitivity set too high) and to avoid missed detections (i.e., from gain/sensitivity set too low). For most applications, a gain tuning resistor value which yields a sensor response in a linear region is preferred. The tuning or calibration method typically places the sensor assembly in the intended sensing environment and the circuit test points at the inputs to the decision circuit (e.g., points 90 and 91 as seen in Fig 4 of Caldwell's '282

patent) are monitored as a function of resistance. The resistance value of the gain tuning resistors R5 and R6 are adjusted to provide an output in the mid-range of the sensor's linear response.

5           While other electrode patterns are suitable for this bilge pump control application, the illustrated electrode patterns 49 and 59, as shown in 3, are each balanced. "Balanced" as used here, means that the conductive trace area of the inner electrode (e.g., center pad 50) is equal (or as equal as possible within PCB manufacturing tolerances) to the area of its corresponding outer electrode ring (e.g., outer electrode 52).

10           The applicants have discovered that the illustrated balanced pad electrode design provides improved noise or electromagnetic interference (EMI) immunity and works exceptionally well for sensing the presence of a fluid such as water.

          The EMI immunity appears to stem from a common mode rejection of spurious noise or interference signals. This "common mode" rejection is attributable to the equal area of the  
15   center pad and the outer ring electrode, which appear to be affected by spurious noise or interference signals substantially equally, and so when one electrode's signal is subtracted from the other electrode's signal, the common noise/interference signals cancel one another.

          In the embodiment illustrated in Fig. 3, each balanced center pad is substantially rectangular having a horizontal extent of approximately twelve millimeters (mm) and a  
20   vertical extent of nine mm. As can be seen from Fig. 3, each center electrode pad (e.g., 50 and 60) include a plurality of vertical conductive traces (each approx. one mm in width) separated by approximately equal width sections of non-conductive PCB surface, where each conductive trace is connected at its upper and lower ends by a surrounding conductive trace



material, all connected to a resistor (e.g., R5 for upper pad 50). Each center electrode pad (e.g., 50) is not quite completely encircled by upper outer electrode 52 which is approximately 1.5 mm in width and is connected to an ASIC (e.g., 36).

An alternative electrode pattern embodiment is illustrated in Figs. 6 and 7; Fig 6 is a  
5 diagram drawn to scale and illustrating the component side layout of conductive traces on a printed circuit board including a balanced pad sensor electrode pattern 69, and Fig. 7 is an edge view, in elevation, illustrating the conductive traces of balanced pad sensor electrode pattern 69, as seen from the side of the PCB (e.g., such as PCB 30). As noted above, a balanced pad or electrode pattern has a conductive trace area for the inner electrode (e.g.,  
10 center pad 70) that is equal (or as equal as possible within PCB manufacturing tolerances) to the area of its corresponding outer electrode ring (e.g., outer electrode 72). Both pad 70 and outer electrode 72 are also optionally encircled by a perimeter of solid conductive trace material to provide a ground ring 76.

The optional ground ring 76 is useful for reducing the effects of the boat or bilge  
15 material on the operation of the sensor 20. When a ground ring 76 is included, sensor 20 may be installed in either a conductive (e.g. aluminum or steel) bilge or a dielectric (e.g., fiberglass) bilge with negligible effects on sensor performance.

An alternative electrode pattern embodiment is illustrated in Fig. 8, a diagram  
illustrating an edge view of a two-sided layout of conductive traces on a printed circuit board  
20 including a balanced pad sensor electrode pattern 79, as seen from the side of the PCB (e.g., such as PCB 30). As above, a balanced pad or electrode pattern has a conductive trace area for the inner electrode (e.g., center pad 80) carried on one side of the PCB that is equal (or as equal as possible within PCB manufacturing tolerances) to the area of its corresponding outer

electrode ring (e.g., outer electrode 82) on the opposite side of PCB 30. Both pad 80 and outer electrode 82 are at least partially encircled by a perimeter of solid conductive trace material to provide a ground ring 86 which is spaced apart from outer electrode 82.

An alternative embodiment with microprocessor control can be programmed to  
5 provide delays for pump turn-on and turn-off. The micro-controller has been programmed to read the lower level pad 60 and the upper level pad 50. Both pads must be activated for at least 256 consecutive reads before the bilge pump is turned on. The interval between reads is 0.0011 seconds, resulting in 0.286 seconds of total time of continuous reads with both pads active before turning on the pump. If at any time, either sensor is not active, the read is  
10 canceled and no pump enabling action is taken. During periods when the pump is not active, the controller puts itself to sleep for 2.5 seconds and then wakes up and reads both upper and lower pads 50, 60. Thus, the time between water level readings is about 2.78 seconds. This pre-programmed algorithm would have a high probability of not turning on the pump if the water is merely sloshing around in bilge 10, but gives fairly quick response. This pre-  
15 programmed algorithm is preferably stored in a memory and operates in a manner similar to the principals of fuzzy logic.

Other methods may be used to overcome "sloshing" Various electronic methods include using simple timing circuits like "one shots" , "pulse switching and timing circuits", and "low pass filtering". None of these would be as economical as using the single chip  
20 micro-computer incorporating the entire control function in simple circuit using a micro, however.

A mechanical anti-sloshing control method includes configuring a plastic chamber or shield around the sensing area and allowing water to slowly flow in and out of the chamber

and sensing area thereby preventing water level from changing very rapidly in the area of the sensor. This damped flow method would not prevent sensors from switching on/off rapidly when the water level was at the very edge of activation, where slight movements of water or electrical noise would cause sensor oscillation. The mechanical anti-slosh chamber could be  
5 coupled with a simple electronic filter circuit such as a low pass and comparator, but this would require more plastic than the illustrated design. The mechanical method of slosh proofing could also be used in conjunction with our current micro-controller design. The anti-sloshing chamber may create problems if the water entry points were to get clogged due to dirt and/or debris.

10 The illustrated micro controller solution results in the simplest, smallest, cheapest, lowest energy consumption result with maximum flexibility and reliability, and so is preferable to non-micro solutions or mechanical methods.

Having described preferred embodiments of a new and improved method, it is believed that other modifications, variations and changes will be suggested to those skilled in  
15 the art in view of the teachings set forth herein. It is therefore to be understood that all such variations, modifications and changes are believed to fall within the scope of the present invention as defined by the appended claims.

**WHAT IS CLAIMED IS:**

1. A fluid level sensor apparatus for detecting a moving fluid level and capable of activating a controlled device, said fluid level sensor apparatus comprising:

a fluid-proof barrier of substantially uniform thickness having first and second opposite surfaces, wherein said first barrier surface is exposed to the fluid;

a dielectric substrate of substantially uniform thickness having first and second opposite surfaces, wherein said substrate is proximate said barrier second surface;

a first thin, conductive electrode pad disposed on said substrate in a closed, continuous geometric form having an area which affords substantial coverage by fluid contact with said barrier;

a second thin, conductive electrode disposed on said substrate in a spaced, coplanar and substantially surrounding relationship to said first electrode pad; and

an active electrical component disposed on said substrate proximate said first and second electrodes and electrically coupled to said first and second electrodes, such that fluid contact with said barrier activates the controlled device.

2. The fluid level sensor apparatus of claim 1, further comprising:

a fluid-proof housing enclosing a cavity proximate said fluid proof barrier; and wherein said substrate is sealed within said cavity.

3. The fluid level sensor apparatus of claim 2 wherein said substrate is overmolded within said housing cavity.

4. The fluid level sensor apparatus of claim 3 wherein said electric field has an arc-shaped path originating at said second electrode and terminating at said first electrode.

5. The fluid level sensor apparatus of claim 4, wherein said fluid level sensor generates a detection signal indicating the status of said fluid level sensor.
6. The fluid level sensor apparatus of claim 5, wherein the level of said detection signal is altered when said fluid level contacts said barrier first surface and approaches said substrate.
7. The fluid level sensor apparatus of claim 1 wherein said substrate is glass.
8. The fluid level sensor apparatus of claim 1 wherein said substrate is plastic.
9. The fluid level sensor apparatus of claim 1 wherein said substrate is made from a fiberglass reinforced epoxy resin.
10. The fluid level sensor apparatus of claim 1 wherein a channel is located between said first and second electrodes, said channel having a generally uniform width.
11. The fluid level sensor apparatus of claim 1 wherein a plurality of said fluid level sensor electrodes are disposed on said first surface of said substrate.
12. The fluid level sensor apparatus of claim 1 wherein a plurality of said fluid level sensor electrodes are disposed on said substrate and arranged in a vertical array.

13. A low impedance fluid level sensor apparatus for detecting contact by a fluid and capable of activating a controlled device, said fluid level sensor apparatus comprising:

a dielectric carrier;

a first thin, conductive electrode pad disposed on said carrier in a closed, continuous geometric form having an area which affords substantial coverage by a region of fluid contact;

a second thin, conductive electrode disposed on said carrier in a spaced and substantially surrounding relationship to said first electrode;

an active electrical component disposed on said carrier proximate said first and second electrodes and electrically coupled to said first and second electrodes; and

a dielectric substrate having first and second opposite surfaces, said dielectric carrier disposed on said first surface of said dielectric substrate, such that fluid contact of said substrate activates the controlled device.

14. The apparatus of claim 13 wherein said first surface of said substrate is a non-fluid touching surface and said second surface of said substrate is a fluid touching surface.

15. A low impedance fluid proximity sensor apparatus for detecting fluid contact and capable of activating a controlled device, said fluid proximity sensor apparatus comprising:

a dielectric substrate having first and second opposite surfaces;

a first thin, conductive electrode pad disposed on said substrate in a closed, continuous geometric form having an area which affords substantial coverage by an area of fluid contact;

a second thin, conductive electrode disposed on said substrate in a spaced, coplanar and substantially surrounding relationship to said first electrode pad; and

an active device disposed on said first surface of said substrate proximate said first and second electrodes and electrically coupled to said first and second electrodes, such that fluid contact with said substrate activates the controlled device.

16. The fluid proximity sensor apparatus of claim 15 wherein said active device is an ASIC configured to energize said electrodes with an oscillator signal.

17. The fluid proximity sensor apparatus of claim 16 further including at least one gain tuning resistor disposed on said substrate and electrically coupled between said ASIC and one of first and second electrodes.

18. The fluid proximity sensor apparatus of claim 17, wherein a plurality of said fluid proximity sensors are disposed on said substrate.

19. The fluid proximity sensor apparatus of claim 17 wherein said fluid proximity sensor ASIC generates a detection signal in response to a rising fluid level.

20. A plurality of fluid sensing pads for detecting fluid contact and capable of activating a controlled device, each fluid sensing pad comprising:

a dielectric carrier;

a first thin, conductive electrode pad having a peripheral edge and disposed on said carrier in a closed, continuous geometric form having an area which affords substantial coverage by a fluid contact area;

a second thin, conductive electrode disposed on said carrier in a spaced relationship to said first electrode, said second electrode surrounding said first electrode on peripheral edges

having an adjacent fluid sensing pad; and

a dielectric substrate having first and second opposite surfaces, said carrier disposed on said first surface of said substrate, such that fluid contact with said substrate activates the controlled device.

21. A fluid proximity sensor for detecting a moving fluid and capable of generating a fluid presence detected signal or activating a controlled device, said fluid proximity sensor apparatus comprising:

a fluid-proof dielectric substrate of substantially uniform thickness having first and second opposite surfaces;

a first thin, conductive electrode pad disposed on said first surface of said substrate in a closed, continuous geometric form having an area which affords substantial coverage by fluid contact with said substrate second surface;

a second thin, conductive electrode disposed on said first surface of said substrate in a spaced, coplanar and substantially surrounding relationship to said first electrode pad; and

an active electrical component disposed on said substrate proximate said first and second electrodes and electrically coupled to said first and second electrodes, such that fluid contact with said substrate second surface activates the controlled device.

22. The fluid proximity sensor of claim 21, wherein said first thin, conductive electrode pad disposed on said first surface of said substrate comprises a balanced pad electrode having an area that is substantially equal in area with the area of said second conductive electrode.



23. The fluid proximity sensor of claim 22, wherein said balanced pad electrode comprises a substantially planar electrode having a plurality of conductive traces connected at an end to other conductive traces and separated by segments of non-conductive dielectric material.

24. The fluid proximity sensor of claim 23, wherein said balanced pad electrode has a substantially rectangular conductive perimeter.

25. The fluid proximity sensor of claim 23, further comprising a substantially planar conductive ground ring disposed on said substrate and encircling said second electrode.

26. A method of operating a bilge pump, comprising the steps of:

a) positioning within a bilge a sealed housing having therein at least a first field effect sensor;

b) generating an electromagnetic field with the sensor; and

c) sensing the presence of fluid proximate the sensor by detecting variations in the electromagnetic field.

27. The method of claim 26, further including the step of:

d) operating the bilge pump when a fluid is detected.

28. The method of claim 27, further including the step of:

e) stopping operation of the bilge pump when the fluid is no longer detected.

29. The method of claim 27, further including the step of:

e) stopping operation of the bilge pump when the fluid level is determined to be at a selected lower level.

30. The method of claim 26, further including the steps of:

d) starting a timer and measuring the duration of the interval for which fluid is present, and, if fluid is present for an interval indicating that the sensed condition is not a result of sloshing fluid; and

e) operating the bilge pump.

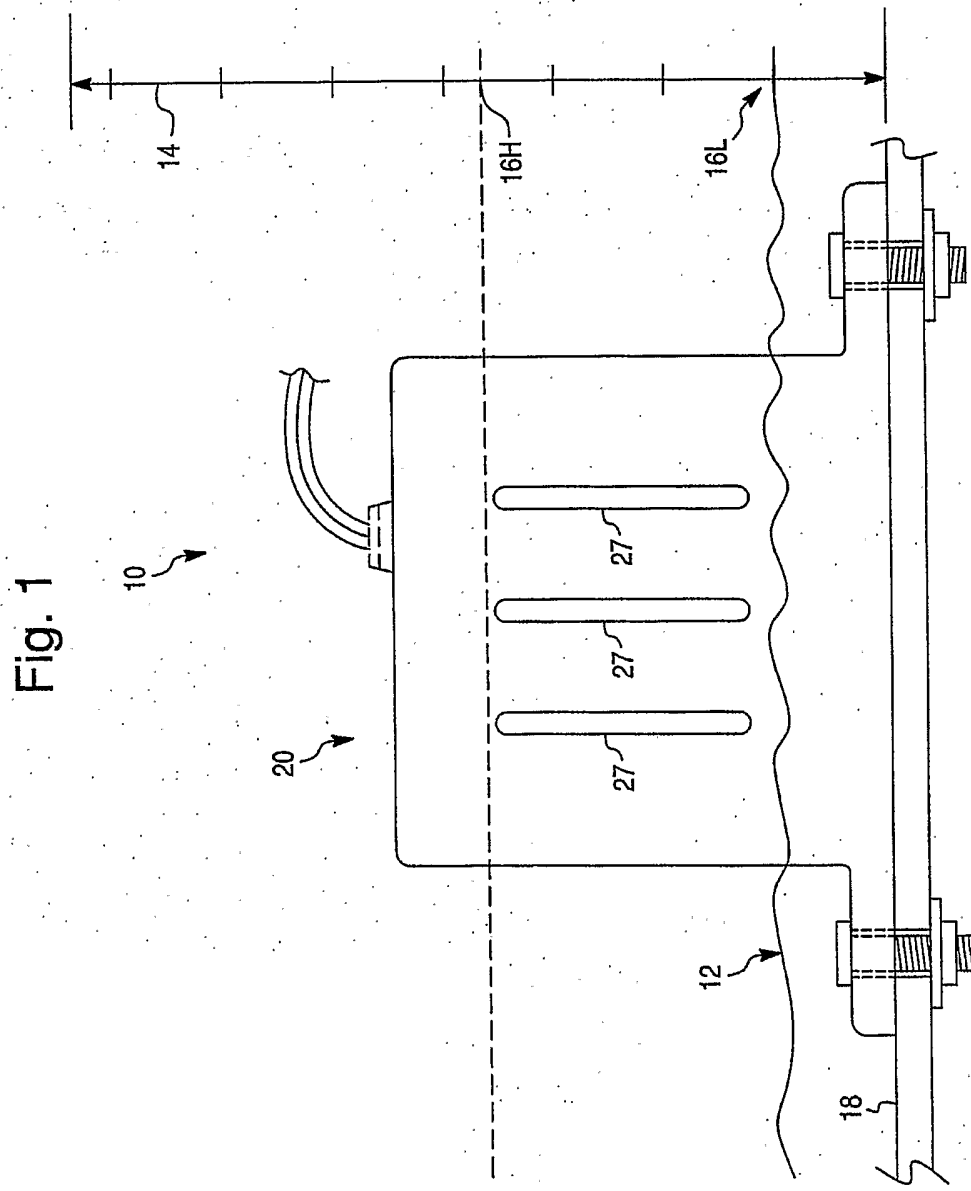


Fig. 2

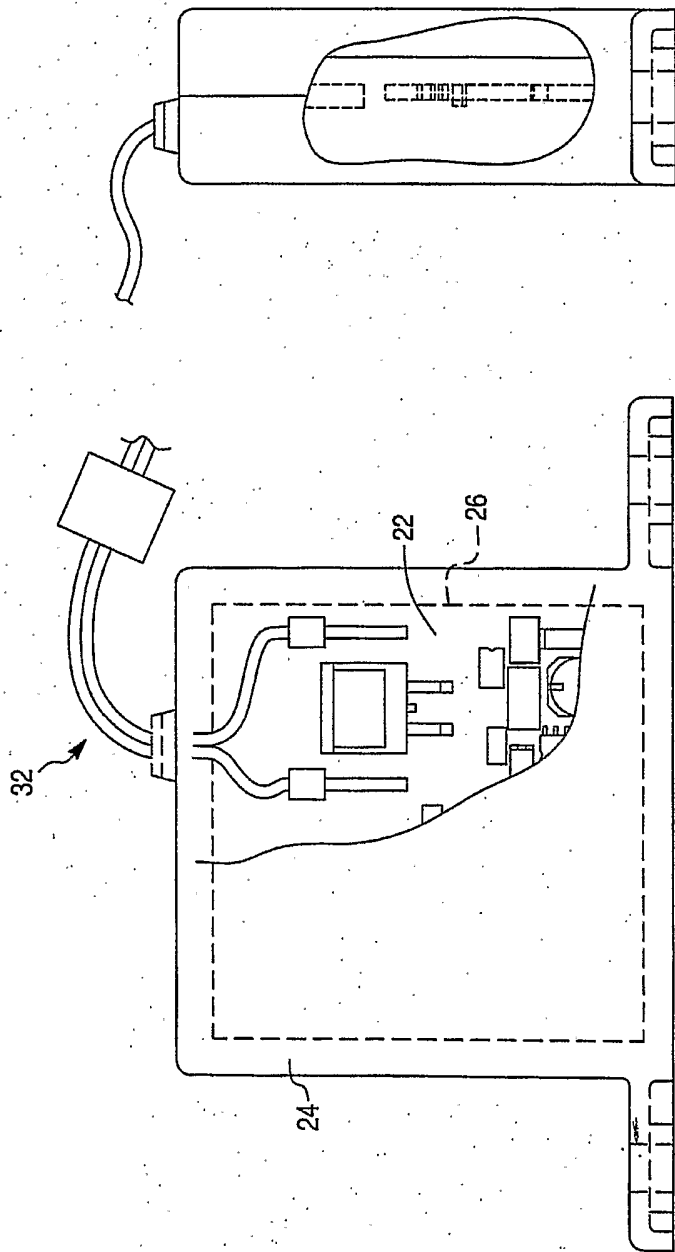


Fig. 3

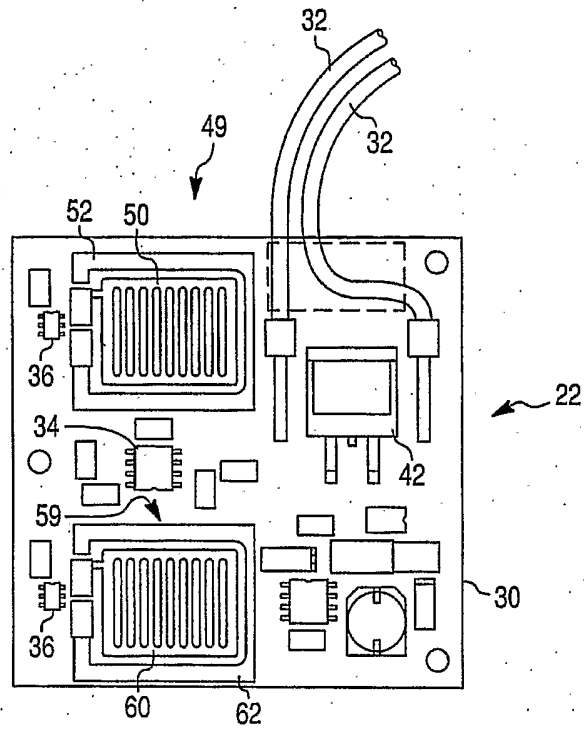


Fig. 4

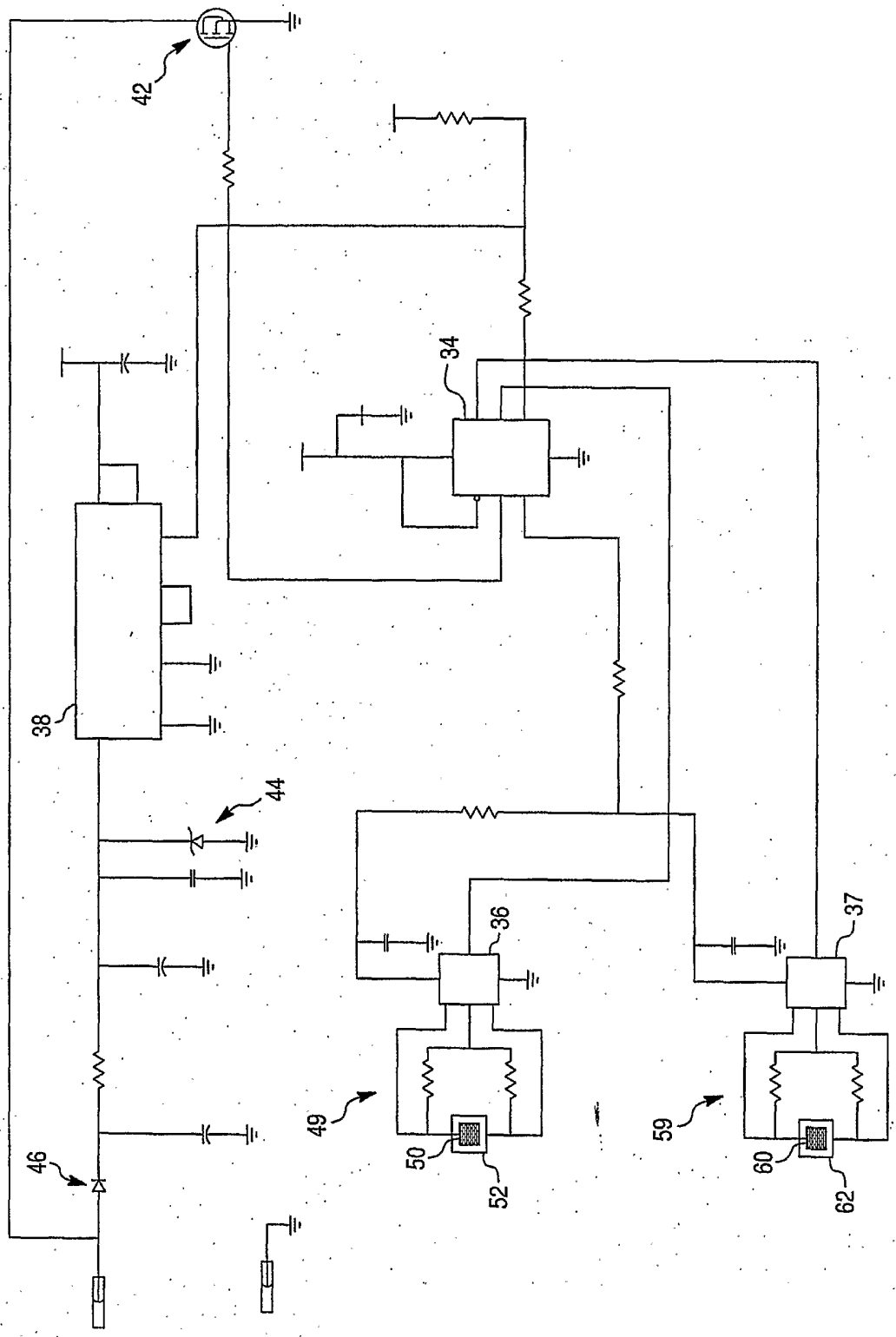


Fig. 5

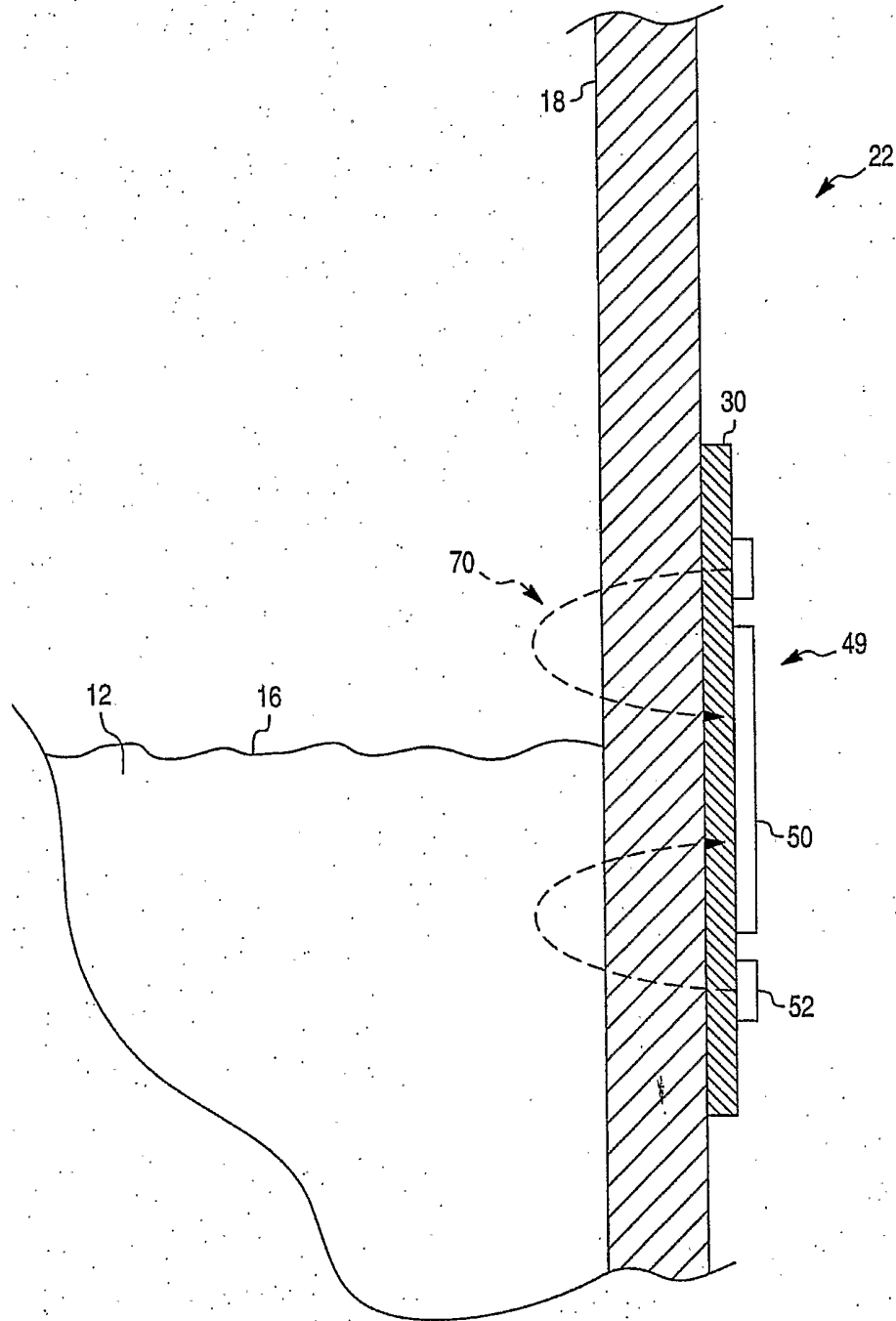


Fig. 6

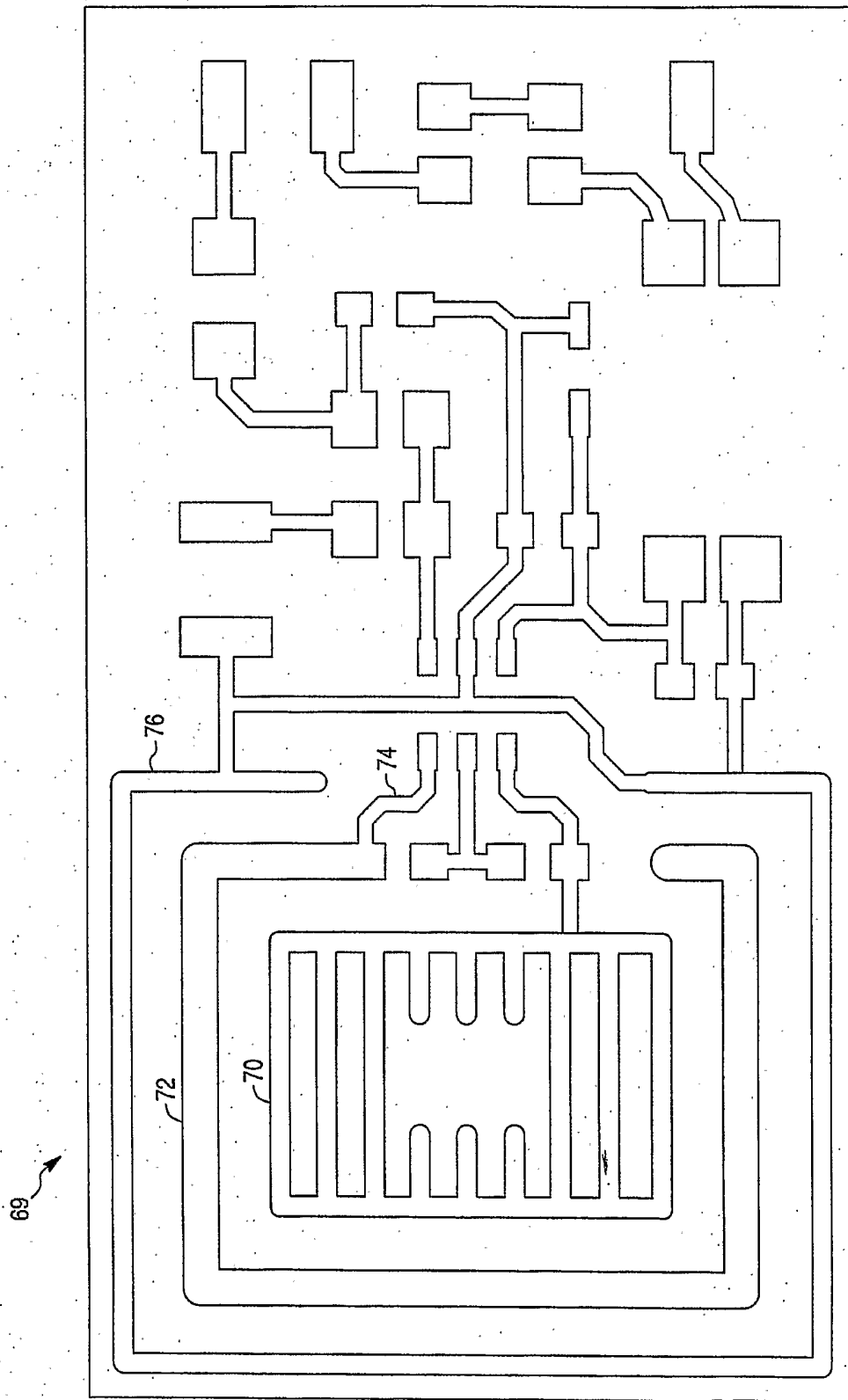




Fig. 7

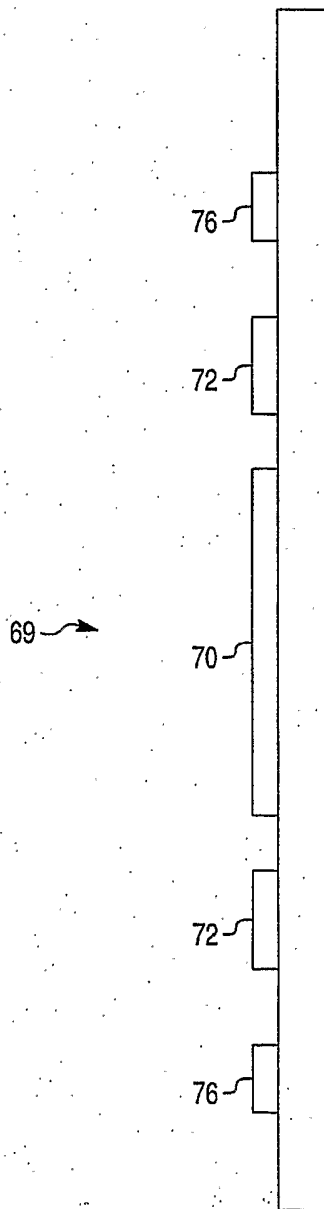
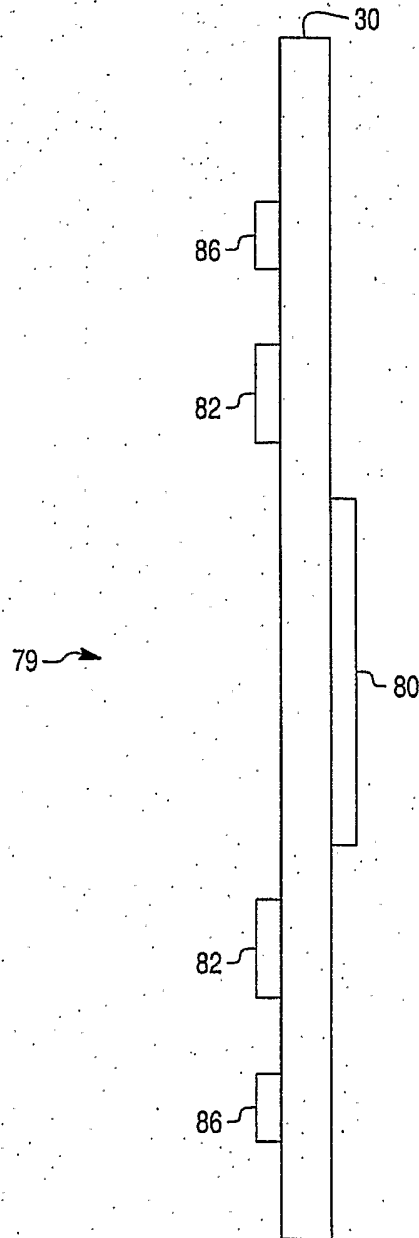


Fig. 8



# INTERNATIONAL SEARCH REPORT

Application No /US2005/024235
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**A. CLASSIFICATION OF SUBJECT MATTER**  
 IPC 7 G01F23/26 G01F23/284 F04D15/02

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)  
 IPC 7 G01F F04D H03K

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 practical, search terms used)  
 EPO-Internal, WPI Data, PAJ

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	ANONYMOUS: "Touchsensor - Technology" INTERNET ARTICLE, 'Online! 13 June 2004 (2004-06-13), XP002351984 Retrieved from the Internet: URL: <a href="http://web.archive.org/web/20040613100140/http://touchsensor.com/technology_apps_5.html">http://web.archive.org/web/20040613100140/http://touchsensor.com/technology_apps_5.html</a> > 'retrieved on 2005-10-31! the whole document	1-30
Y	US 5 594 222 A (CALDWELL) 14 January 1997 (1997-01-14) cited in the application the whole document	1-25
Y	EP 0 373 809 A (ALTUS TECHNOLOGY CORPORATION) 20 June 1990 (1990-06-20) cited in the application the whole document	26-30
A		2
----- -/--		

Further documents are listed in the continuation of box C.       Patent family members are listed in annex.

° Special categories of cited documents :

<p>*A* document defining the general state of the art which is not considered to be of particular relevance</p> <p>*E* earlier document but published on or after the international filing date</p> <p>*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)</p> <p>*O* document referring to an oral disclosure, use, exhibition or other means</p> <p>*P* document published prior to the international filing date but later than the priority date claimed</p>	<p>*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</p> <p>*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</p> <p>*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.</p> <p>*Z* document member of the same patent family</p>
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Date of the actual completion of the international search  <b>4 November 2005</b>	Date of mailing of the international search report  <b>21/11/2005</b>
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Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer  <b>Barthélemy, M</b>
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## INTERNATIONAL SEARCH REPORT

Application No  
/US2005/024235

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 192 752 B1 (BLAINE) 27 February 2001 (2001-02-27) abstract; figures 1-3,7d,8a-8d,8h,8p,14 column 3 column 5 - column 10 column 13 - column 15 -----	1,7-25
X	US 2003/019291 A1 (PCHELNIKOV ET AL) 30 January 2003 (2003-01-30) abstract; figures 4,8,11,12,16,17,20-26,32-36 paragraphs '0001!, '0002!, '0009! - '0012!, '0055! - '0059!, '0070!, '0071!, '0090! - '0117! -----	1,10-17, 19,21-25
P,Y	WO 2004/095388 A (TOUCHSENSOR TECHNOLOGIES, LLC) 4 November 2004 (2004-11-04) the whole document -----	26-30
P,Y	WO 2004/104529 A (TOUCHSENSOR TECHNOLOGIES, LLC) 2 December 2004 (2004-12-02) the whole document -----	1-25
Y	GB 2 064 135 A (SCHMALL K-H) 10 June 1981 (1981-06-10) column 1, line 6 - line 83 column 1, line 51 - line 58 column 3, line 74 - line 77 figure 4 -----	1-25
A	US 6 218 948 B1 (DANA) 17 April 2001 (2001-04-17) the whole document -----	26-30

# INTERNATIONAL SEARCH REPORT

Information on patent family members

Application No US2005/024235
---------------------------------

Patent document cited in search report	Publication date	Publication date	Patent family member(s)	Publication date
US 5594222	A	14-01-1997	AT 276606 T	15-10-2004
			AT 221708 T	15-08-2002
			AU 706850 B2	24-06-1999
			AU 4134596 A	15-05-1996
			CA 2203695 A1	02-05-1996
			CN 1220786 A	23-06-1999
			DE 69527646 D1	05-09-2002
			DE 69527646 T2	20-02-2003
			DE 69533529 D1	21-10-2004
			DE 69533529 T2	29-09-2005
			DK 795233 T3	09-09-2002
			EP 0795233 A1	17-09-1997
			ES 2227330 T3	01-04-2005
			ES 2179890 T3	01-02-2003
			HK 1045224 A1	22-04-2005
			JP 2001503205 T	06-03-2001
			NZ 296672 A	29-09-2000
			WO 9613098 A1	02-05-1996
EP 0373809	A	20-06-1990	US 4881873 A	21-11-1989
US 6192752	B1	27-02-2001	NONE	
US 2003019291	A1	30-01-2003	NONE	
WO 2004095388	A	04-11-2004	US 2005068049 A1	31-03-2005
WO 2004104529	A	02-12-2004	US 2005081624 A1	21-04-2005
GB 2064135	A	10-06-1981	CH 656702 A5	15-07-1986
			DE 3042781 A1	27-08-1981
US 6218948	B1	17-04-2001	NONE	