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Diagnostics for Capacitive Sensor.

(57)

A capacitance measurement circuit (100) for determining a complex electric current of at least one capacitive sense-guard sensor comprises a periodic signal voltage source (12), wherein each guard electrode is electrically connectable to the signal voltage source (12), a current measurement circuit (10) comprising at least one measurement channel (26) to determine a measurement current through a sense electrode, and at least one diagnostics channel (34) to determine, with reference to an AC ground potential (16), a diagnostic current flowing through a guard electrode and a sense electrode of a capacitive sensor, and a remotely controllable switching unit (42), which in a measurement switching state is configured to electrically connect the sense electrode of the capacitive sensor to the measurement channel (26), and in a diagnostic switching state is configured to electrically connect the sense electrode to the diagnostics channel (34).

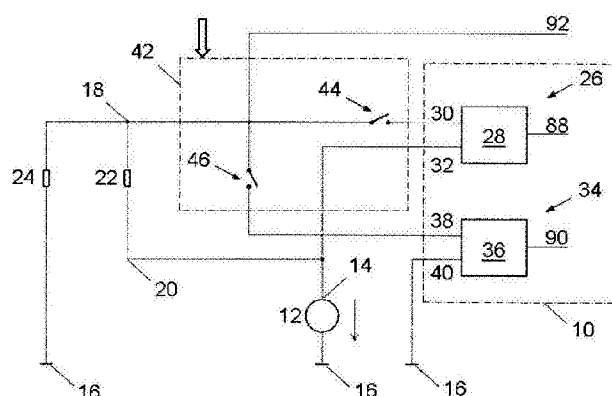
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Fig. 1

Diagnostics for Capacitive Sensor

Technical field

[0001] The invention relates to a capacitance measurement circuit for determining a complex electric current of at least one capacitive sensor, to a capacitive sensing system comprising such capacitance measurement circuit, to a method of operating such capacitive sensing systems with regard to capacitive sensor diagnosis, and to a software module for controlling automatic execution of such method.

Background of the Invention

[0002] Capacitive measurement and/or detection systems have a wide range of applications, and are among others widely used for the detection of the presence and/or the position of a conductive body in the vicinity of an electrode of the system. A capacitive sensor, called by some electric field sensor or proximity sensor, designates a sensor, which generates a signal responsive to the influence of what is being sensed (a person, a part of a person's body, a pet, an object, etc.) upon an electric field. A capacitive sensor generally comprises at least one antenna electrode, to which is applied an oscillating electric signal and which thereupon establishes an electric field into a region of space proximate to the antenna electrode, while the sensor is operating. The sensor comprises at least one sensing electrode – which could comprise the one or more antenna electrodes themselves – at which the influence of an object or living being on the electric field is detected.

[0003] The different capacitive sensing mechanisms are, for instance, explained in the technical paper entitled "Electric Field Sensing for Graphical Interfaces" by J. R. Smith et al., published in IEEE Computer Graphics and Applications, 18(3): 54-60, 1998. The paper describes the concept of electric field sensing as used for making non-contact three-dimensional position measurements, and more particularly for sensing the position of a human hand for purposes of providing three-dimensional positional inputs to a computer. Within the general concept of capacitive sensing, the author distinguishes between distinct mechanisms he refers to as "loading mode", "shunt mode", and "transmit mode", which correspond

to various possible electric current pathways. In the "loading mode", an oscillating voltage signal is applied to a transmit electrode, which builds up an oscillating electric field to ground. The object to be sensed modifies the capacitance between the transmit electrode and ground. In the "shunt mode", which is alternatively referred to as "coupling mode", an oscillating voltage signal is applied to the transmit electrode, building up an electric field to a receive electrode, and the displacement current induced at the receive electrode is measured, whereby the displacement current may be modified by the body being sensed. In the "transmit mode", the transmit electrode is put in contact with the user's body, which then becomes a transmitter relative to a receiver, either by direct electrical connection or via capacitive coupling.

[0004] The capacitive coupling is generally determined by applying an alternating voltage signal to a capacitive antenna electrode and by measuring the current flowing from the antenna electrode either towards ground (in the loading mode) or into the second electrode (receiving electrode) in case of the coupling mode. This current is usually measured by means of a transimpedance amplifier, which is connected to the sensing electrode and which converts a current flowing into said sensing electrode into a voltage, which is proportional to the current flowing into the antenna electrode.

[0005] Some capacitive sensors are designed as sense-only capacitive sensors having a single sense electrode. Also, quite often capacitive sensors are used that comprise a sense electrode and a guard electrode that are arranged close to each other and are mutually insulated from each other. This technique of "guarding" is well known in the art and is frequently used for intentionally masking, and thus shaping, a sensitivity regime of a capacitive sensor. To this end, the guard electrode is kept at the same electric AC potential as the sense electrode. As a result, a space between the sense electrode and the guard electrode is free of an electric field, and the guard-sense capacitive sensor is insensitive in a direction between the sense electrode and the guard electrode.

[0006] By way of example, patent document US 8,354,936 B2 describes a capacitive passenger detector for a vehicle. The capacitive passenger detector includes a main electrode, a sub-electrode and a guard electrode. The main electrode and the sub-electrode are separated apart from each other, and

disposed in a seat of a vehicle. The guard electrode is disposed between the main electrode and a body of the vehicle, and separated apart from the main electrode. A sensitive characteristic measurement unit is configured for applying an alternating voltage signal to the main electrode, the sub-electrode and the guard electrode selectively or totally and for converting a current generated in the main electrode, the sub-electrode and the guard electrode to a voltage, respectively. The capacitive passenger detector further comprises a controller that defines a current flowing through the guard electrode to be a reference current when a voltage of the main electrode and a voltage of the guard electrode have the same potential. The controller defines a current flowing direction of the current flowing through the guard electrode to be a negative direction when the voltage of the main electrode is higher than the voltage of the guard electrode. The controller defines the current flowing direction of the current flowing through the guard electrode to be a positive direction when the voltage of the main electrode is lower than the voltage of the guard electrode. The controller corrects the voltage of the main electrode based on the current flowing through the guard electrode so that a corrected voltage of the main electrode is set to be a passenger determination data. Even when a potential difference is generated between the main electrode and the guard electrode, the controller detects the capacitance of the passenger correctly.

[0007] Capacitive sensing systems which are used in the control of airbag systems or other safety-related applications may be considered as safety-relevant system components. It may thus be necessary to monitor the good functioning of the different components of the sensor (sensing electrode and/or guard electrode) in order to rule out a false reading by the capacitive occupancy or proximity detection system.

[0008] It has been proposed in the prior art to furnish capacitive measurement circuits with diagnostic means for detecting a capacitive sensor interruption, in particular a guard electrode interruption.

[0009] For instance, international application WO 2017/129552 A1 describes a capacitance measurement circuit for determining a sense current of a capacitive sensor with a sense electrode and a guard electrode. The capacitance measurement circuit comprises a periodic signal voltage source, a sense current

measurement circuit configured for determining the sense current with reference to a reference voltage and at least one remotely controllable switch member. The configuration is such that in the first switching state, the at least one switch member electrically connects the sense current measurement circuit to the periodic measurement voltage for providing a first reference voltage, and in the second switching state, the at least one switch member electrically connects the sense current measurement circuit to a second reference voltage that is different from the first reference voltage. By intentionally changing the reference voltage used for determining the sense current by connecting the sense current measurement circuit to the second reference voltage that is different from the first reference voltage, a signal can be generated by the sense current measurement circuit that can be indicative of an electrical interruption, wherein the interruption may include any interruption of electrical connections between the respective sense and guard cabling and connecting members.

Object of the invention

[0010] It is therefore an object of the present invention to provide an improved and as comprehensive as possible diagnostic concept for a capacitive sensing system, in particular for use in automotive applications, that is particularly suitable for multichannel capacitive sensing systems and that can be realized with low hardware effort and at moderate costs.

General Description of the Invention

[0011] In one aspect of the present invention, the object is achieved by a capacitance measurement circuit for determining a complex electric current of at least one capacitive sensor including at least one electrically conductive sense electrode and at least one electrically conductive guard electrode that are arranged close to each other. The at least one electrically conductive sense electrode and at least one electrically conductive guard electrode may e.g. be mutually galvanically separated from each other. However this is not a requirement. For example, a resistive connection between sense and guard electrodes can be used for diagnostics purpose.

[0012] The capacitance measurement circuit comprises at least one periodic signal voltage source, a current measurement circuit and a remotely controllable switching unit.

[0013] The at least one periodic signal voltage source is configured for providing an alternating measurement voltage at an output port, wherein each guard electrode is electrically connectable to the output port for receiving the periodic measurement voltage.

[0014] The current measurement circuit comprises at least one measurement channel and at least one diagnostics channel. The at least one measurement channel includes a measurement current-to-voltage converter that is configured to determine, with reference to the measurement voltage, a measurement current through a sense electrode that is indicative of a position of an object relative to the capacitive sensor. The at least one diagnostics channel includes a diagnostics current-to-voltage converter that is configured to determine, with reference to an AC ground potential, a diagnostic current flowing through a guard electrode and a sense electrode of a capacitive sensor that is connected to the diagnostics current-to-voltage converter.

[0015] The remotely controllable switching unit comprises, for each capacitive sensor, a plurality of operatively coupled switching members. In a measurement switching state with regard to the capacitive sensor, the switching unit is configured to electrically connect the sense electrode of the capacitive sensor to a signal input port of a measurement current-to-voltage converter. In a diagnostic switching state with regard to the capacitive sensor, the switching unit is configured to electrically connect the sense electrode to a signal input port of a diagnostics current-to-voltage converter. In the diagnostic switching state, the sense electrode is unconnected to the measurement current-to-voltage converter. In the measurement switching state, the sense electrode is unconnected to the diagnostics current-to-voltage converter.

[0016] One advantage of the proposed capacitance measurement circuit is that means are provided to diagnose the capacitive sensor and sensor wiring by measuring the complex sense-to-guard impedance of the capacitive sensor.

[0017] Another advantage is that an AC ground connection of the capacitive sensor can be diagnosed by the proposed capacitance measurement circuit when the sense electrode is connected to the signal input port of a diagnostics current-to-voltage converter.

[0018] When a capacitive sensor is not used for determining a measurement current through its sense electrode that is indicative of a position of an object relative to the capacitive sensor, an AC potential can be kept at or close to AC ground potential, which can be advantageous under certain circumstances.

[0019] The phrase "being configured to", as used in this application, shall in particular be understood as being specifically programmed, laid out, furnished or arranged. The phrase "operatively coupled switching members", as used in this application, shall in particular be understood as switching members that are configured to essentially change their switching states simultaneously.

[0020] Preferably, the at least one capacitive sensor is configured for being operated in loading mode.

[0021] The proposed capacitance measurement circuit is advantageously applicable particularly in vehicles. The term "vehicle", as used in this application, shall particularly be understood to encompass passenger cars, trucks, tractor units and buses.

[0022] Preferably, the measurement current-to-voltage converter and/or the diagnostics current-to-voltage converter comprise a transimpedance amplifier (TIA) whose function is to convert a current provided at a signal input port into an output voltage that is proportional to the determined current. A TIA is configured to convert the input current with reference to a reference voltage that is provided to a reference input port. Preferably, the transimpedance amplifier is based on one or more operational amplifiers.

[0023] In preferred embodiments, the capacitance measurement circuit is configured to generate an output signal that is indicative of a sensor interruption if the magnitude of a determined diagnostic current flowing through a sense electrode and a guard electrode of a capacitive sensor that is connected to the diagnostics current-to-voltage converter is less than a predefined threshold value.

The output signal can beneficially be transferred, for instance to a higher-ranking control unit of a vehicle, for initiating further action.

[0024] Preferably, for each capacitive sensor, a demultiplexer member is provided in the switching unit that is configured, in a measurement switching state with regard to a respective capacitive sensor, to keep a terminal of a switching member for electrically connecting the sense electrode to a signal input port of a diagnostics current-to-voltage converter at the converter end to guard potential of the respective capacitive sensor. By that, terminals of the switching member, which is in an open switching position when the capacitive sensor is in a measurement switching state, can be kept at the electric potential of the guard electrode. Thus, a parasitic capacitance of the switching member can virtually be reduced to zero, and a measurement error due to parasitic capacitance of the switching member can be minimized.

[0025] In preferred embodiments of the capacitance measurement circuit, for each capacitive sensor, a demultiplexer member is provided in the switching unit that is configured to, in a measurement switching state with regard to a respective capacitive sensor, keep a terminal of a switching member for electrically connecting the sense electrode to a signal input port of the diagnostics current-to-voltage converter at the converter end at guard potential of the respective capacitive sensor.

[0026] Further, the demultiplexer member provided in the switching unit is configured, for each capacitive sensor whose sense electrode is unconnected to a measurement current-to-voltage converter, to either connect a terminal of a switching member for electrically connecting the sense electrode to an input port of a diagnostics current-to-voltage converter at the converter end to guard potential of the capacitive sensor, or to connect the terminal of the switching member for electrically connecting the sense electrode to the signal input port of the diagnostics current-to-voltage converter at the converter end to AC ground potential.

[0027] This embodiment is particularly beneficial in multichannel applications, which include more than two capacitive sensors and may comprise only one diagnostics current-to-voltage converter and one measurement current-to-voltage converter for cost reasons. In this case, time of operational availability can be

increased, as the capacitance measurement circuit can enable to set an AC potential of the sense electrodes of the capacitive sensors to AC ground potential even if a respective capacitive sensor is not connected to either the measurement current-to-voltage converter or to the diagnostics current-to-voltage converter.

[0028] Preferably, the current measurement circuit comprises, for each capacitive sensor, a diagnostics output port that is electrically connected to a sense electrode of the capacitive sensor. With a capacitive sensor in the diagnostic switching state, the diagnostics output port can provide a complex electrical signal for further diagnosis.

[0029] In such embodiments, the current measurement circuit may further comprise means, for each capacitive sensor, to keep the diagnostics output port at guard potential of the respective capacitive sensor, which can beneficially eliminate a systematic error of measurement due to the diagnostics output port being connected to the sense electrode of the capacitive sensor.

[0030] In preferred embodiments of the capacitance measurement circuit, the remotely controllable switching unit forms part of a microcontroller, by which a reliable and simple remote control of the remotely controllable switching unit and, in this way, a reliable diagnosis of a capacitive sensor can be enabled. Microcontrollers that are suitably equipped and include, for instance, a processor unit, a digital memory unit, a microcontroller system clock, a demultiplexer unit and analog-to-digital converters are nowadays readily available in many variations.

[0031] Preferably, the remotely controllable switching unit is configured to periodically switch, for each capacitive sensor and in a manner that is coordinated among the capacitive sensors, between a measurement switching state and a diagnostic switching state. In this way, reliable operation of the capacitance measurement circuit can be accomplished.

[0032] In another aspect of the invention, a capacitive sensing system is provided. The capacitive sensing system includes an embodiment of the capacitance measurement circuit disclosed herein, a switch remote control unit and a plurality of capacitive sensors.

[0033] The switch remote control unit is configured for remotely controlling the remotely controllable switching unit. Each capacitive sensor of the plurality of

capacitive sensors includes at least one electrically conductive sense electrode and at least one electrically conductive guard electrode that are arranged close to each other. As stated above, the at least one electrically conductive sense electrode and at least one electrically conductive guard electrode may be mutually galvanically separated from each other, but this is not a requirement. For example, a resistive connection between sense and guard electrodes can be used for diagnostics purpose.

[0034] The capacitance measurement circuit comprises one periodic signal voltage source that is configured for providing an alternating measurement voltage at an output port, wherein each guard electrode is electrically connected to the output port for receiving the periodic measurement voltage.

[0035] The current measurement circuit includes one measurement channel with one measurement current-to-voltage converter that is configured to determine, one at a time and with reference to the measurement voltage, a measurement current through a sense electrode of one of the plurality of capacitive sensors that is indicative of a position of an object relative to the respective capacitive sensor.

[0036] The current measurement circuit further comprises a plurality of diagnostics channels, each one being configured to determine, with reference to an AC ground potential, a diagnostic current flowing through a guard electrode and a sense electrode of a different one of the plurality of capacitive sensors.

[0037] In this way, a capacitive sensing system with reliable operation and a high percentage of operational availability can be accomplished, including the benefits that have been described beforehand in context with the disclosed capacitance measurement circuit.

[0038] Preferably, the switch remote control unit forms part of a microcontroller, by which a reliable and simple remote control of the remotely controllable switching unit and, in this way, a reliable diagnosis of a capacitive sensor can be enabled. Most preferred, both the switch remote control unit and the remotely controllable switching unit form part of the same microcontroller. In that way, short control paths between the switch remote control unit and the remotely controllable switching unit can be achieved, which are less susceptible to electromagnetic interference.

[0039] In the preferred embodiments, the capacitive sensing system further includes a signal processing unit that is configured for processing at least one out of an output signal of the measurement current-to-voltage converter with reference to the periodic measurement voltage and an output signal of the diagnostics current-to-voltage converter with reference to the periodic measurement voltage. In this way, an improved signal-to-noise ratio (SNR) can be achieved for the output signal of the measurement current-to-voltage converter and/or the output signal of the diagnostics current-to-voltage converter.

[0040] Further improvement of the SNR can be achieved if the capacitive sensing system includes a demodulation circuit that is configured for demodulating at least one out of an input signal of the measurement current-to-voltage converter with reference to the periodic measurement voltage and an input signal of the diagnostics current-to-voltage converter with reference to the periodic measurement voltage.

[0041] In case that the demodulation circuit is configured for demodulating the input signal of the measurement current-to-voltage converter, the demodulation circuit is preferably connected to the signal input port of the measurement current-to-voltage converter and the remotely controllable switching unit is accordingly configured to electrically connect the sense electrode of the capacitive sensor to the demodulation circuit.

[0042] In yet another aspect of the invention, a method of operating the capacitive sensing system disclosed herein with regard to capacitive sensor diagnosis is provided.

[0043] The method at least comprises steps of

- controlling the remotely controllable switching unit to electrically disconnect the sense electrode of a capacitive sensor to be diagnosed from the signal input port of the measurement current-to-voltage converter,
- controlling the remotely controllable switching unit to electrically connect the sense electrode of the capacitive sensor to be diagnosed to the signal input port of the diagnostics current-to-voltage converter,
- controlling the remotely controllable switching unit to electrically connect the sense electrode of another capacitive sensor to the signal input port of the

- measurement current-to-voltage converter and to disconnect the sense electrode of this capacitive sensor from guard potential or from AC ground potential,
- controlling the remotely controllable switching unit to electrically connect the sense electrodes of the remainder of the plurality of capacitive sensors to AC ground potential,
 - determining a sense current value through the sense electrode of the capacitive sensor to be diagnosed by the diagnostics current-to-voltage converter,
 - comparing the determined sense current value with at least one predetermined threshold value,
 - generating an output signal that is indicative of a sensor interruption if the determined sense current value is smaller than the predetermined threshold value.

[0044] In preferred embodiments of the method, the steps are executed and repeated in a periodic manner after swapping to a next capacitive sensor of the plurality of capacitive sensors to be diagnosed for each cycle of steps until all capacitive sensors of the plurality of capacitive sensors are diagnosed.

[0045] In yet another aspect of the invention, a software module for controlling automatic execution of steps of an embodiment of the method disclosed herein is provided.

[0046] The method steps to be conducted are converted into a program code of the software module, wherein the program code is implementable in a digital memory unit of the capacitive sensing system or of a separate control unit and is executable by a processor unit of the capacitive sensing system or of a separate control unit.

[0047] The software module can enable a robust and reliable execution of the method and can allow for a fast modification of method steps.

[0048] These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

[0049] It shall be pointed out that the features and measures detailed *individually* in the preceding description can be combined with one another in any technically

meaningful manner and show further embodiments of the invention. The description characterizes and specifies the invention in particular in connection with the figures.

Brief Description of the Drawings

[0050] Further details and advantages of the present invention will be apparent from the following detailed description of not limiting embodiments with reference to the attached drawing, wherein:

- Fig. 1 illustrates an electric equivalent circuit diagram of a possible embodiment of a single-channel capacitance measurement circuit in accordance with the invention,
- Fig. 2 illustrates an electric equivalent circuit diagram of an alternative embodiment of a single-channel capacitance measurement circuit in accordance with the invention,
- Fig. 3 illustrates an electric equivalent circuit diagram of a possible embodiment of a multichannel capacitive sensing system in accordance with the invention,
- Figs. 4-6 illustrate electric equivalent circuit diagrams of alternative possible embodiments of a multichannel capacitive sensing system in accordance with the invention, and
- Fig. 7 is a flow chart of a method of operating the capacitive sensing system pursuant to Fig. 6.

Description of Preferred Embodiments

[0051] In the different figures, the same parts are always provided with the same reference numerals. Therefore, these parts are usually described only once.

[0052] Fig. 1 schematically illustrates an electric equivalent circuit diagram of a possible embodiment of a single-channel capacitance measurement circuit 100 in accordance with the invention. The capacitance measurement circuit 100 serves for determining a complex electric current of a single capacitive sensor configured in loading mode that includes an electrically conductive sense electrode and an electrically conductive guard electrode that are arranged close to each other, and

that are mutually galvanically separated from each other. The sense electrode and a respective sense wiring resistance are represented in Fig. 1 by a sense node 18, and the guard electrode and a respective guard wiring resistance are represented by a guard node 20. A sense-to-guard impedance 22, which is substantially of capacitive nature, is electrically connected between the sense node 18 and the guard node 20. In this specific embodiment, the sense-to-guard impedance 22 may have a capacitance of about 1 nF, but capacitive sensors with a higher or lower sense-to-guard capacitance are also contemplated.

[0053] The single-channel capacitance measurement circuit 100 includes a periodic, namely sinusoidal, signal voltage source 12 that is configured for providing an alternating measurement voltage at an output port 14 with respect to an AC ground potential 16. The guard electrode is electrically connected to the periodic signal voltage source 12 for receiving the periodic measurement voltage, from where it is transferred to the guard node 20.

[0054] The single-channel capacitance measurement circuit 100 includes a current measurement circuit 10 that comprises a measurement channel 26 including a measurement current-to-voltage converter 28 and a diagnostics channel 34 including a diagnostics current-to-voltage converter 36. Both the measurement current-to-voltage converter 28 and the diagnostics current-to-voltage converter 36 comprise a transimpedance amplifier (TIA), whose function is to convert a complex electric current provided at a signal input port 30, 38 into an output voltage that is proportional to the determined sense current. Both the TIAs are configured to convert the sense current with reference to a reference voltage that is provided to a reference input port 32, 40. The reference input port 32 of the measurement current-to-voltage converter 28 is electrically connected to the output port 14 of the signal voltage source 12. The reference input port 40 of the diagnostics current-to-voltage converter 36 is electrically connected to AC ground potential 16.

[0055] Thus, the measurement current-to-voltage converter 28 is configured to determine, with reference to the measurement voltage, a measurement current through the sense electrode that is indicative of a position of an object relative to the capacitive sensor. An object approaching the sense electrode is represented in the electric equivalent circuit diagram of Fig. 1 by an unknown impedance 24 that

is connected to AC ground potential 16, which for instance may be a vehicle ground potential. If the grounded object approaches the sense electrode, the unknown impedance 24 changes in that at least its capacitive portion increases, and the measurement current flowing between the sense electrode and ground potential and, by that, an amplitude of the TIA output voltage signal is increased, indicating a closer proximity of the object to the capacitive sensor.

[0056] The diagnostics current-to-voltage converter 36 is configured to determine, with reference to AC ground potential 16, a diagnostic current flowing through the guard electrode and the sense electrode of a capacitive sensor when connected to the diagnostics current-to-voltage converter 36.

[0057] Furthermore, the capacitance measurement circuit 100 includes a switching unit 42 that is remotely controllable by a switch remote control unit (not shown). The switching unit 42 comprises a plurality of two operatively coupled switching members 44, 46. The switching members 44, 46 are operatively coupled in that the one switching member 44 changes a switching position from open to closed while the other switching member 46 changes the switching position from closed to open and *vice versa*.

[0058] A first one 44 of the switching members 44, 46 is positioned between the sense node 18 and the signal input port 30 of the measurement current-to-voltage converter 28. A second one 46 of the switching members 44, 46 is positioned between the sense node 18 and the signal input port 38 of the diagnostics current-to-voltage converter 36.

[0059] In a measurement switching state with regard to the capacitive sensor, the switching unit 42 is configured to electrically connect the sense electrode of the capacitive sensor to the signal input port 30 of the measurement current-to-voltage converter 28 by controlling the first switching member 44 into a closed switching state. At the same time, the second switching member 46 is controlled into an open switching state. The measurement current-to-voltage converter 28 measures the unknown current flowing through the unknown impedance 24. The voltage at an output port 88 of the measurement current-to-voltage converter 28 is indicative of the unknown impedance 24 and can be measured, recorded and evaluated. If necessary, a signal processing circuit, for example a synchronous rectifier and

lowpass filter, may be inserted between the output port 88 of the measurement current-to-voltage converter 28 and an evaluation unit (not shown).

[0060] It is noted that AC coupling capacitors or impedances for limiting electric currents during a potential sensor short circuit to any external nodes or in case of an ESD (electrostatic discharge) event can be inserted in series with most of the members of the capacitance measurement circuit 100.

[0061] In a diagnostic switching state with regard to the capacitive sensor, the switching unit 42 is configured to electrically connect the sense electrode to a signal input port 38 of the diagnostics current-to-voltage converter 36 by controlling the second switching member 46 into a closed switching state. At the same time, the first switching member 44 is controlled into an open switching state. In the diagnostic switching state, the sense electrode is kept at or close to AC ground potential, and, simultaneously, the sense node AC ground level and the sense-to-guard impedance 22 of the capacitive sensor can be diagnosed as follows.

[0062] The diagnostics current-to-voltage converter 36 is measuring a current flowing from the signal voltage source 12 through the guard node 20, the sense-to-guard impedance 22, the sense node 18 and the second switching member 46, and into the signal input port 38 of the diagnostics current-to-voltage converter 36. The output voltage at an output port 90 of the diagnostics current-to-voltage converter 36 can be measured, recorded and evaluated. If necessary, a signal processing circuit, for example a synchronous rectifier and lowpass filter, may be inserted between the output port 90 of the diagnostics current-to-voltage converter 36 and an evaluation unit (not shown). Furnished with an evaluation unit, the capacitance measurement circuit 100 is configured to generate an output signal that is indicative of a sensor interruption if the magnitude of a determined diagnostic current flowing through the sense electrode and the guard electrode of the capacitive sensor is less than a predefined threshold value.

[0063] As the voltage of the signal voltage source 12 is known *a priori*, the sense-to-guard impedance 22 can be calculated. As the reference input port 40 of the diagnostics current-to-voltage converter 36 is grounded, the sense node 18 is also grounded. As the diagnostics current-to-voltage converter 36 measures the current into its signal input port 38, a quantitative statement can also be made with regard

to sense electrode AC ground level diagnostics: If no electric current is detected, there is an issue within the measurement path, which may lead to the sense electrode not being properly connected to AC ground potential 16. The current measurement circuit 100 comprises a diagnostics output port 92 that is electrically connected to the sense electrode of the capacitive sensor. If desired, a more precise diagnostic can be applied by measuring the voltage at the diagnostics output port 92, which is equal to the voltage at the sense node 18.

[0064] In the following, other embodiments of capacitance measurement circuits in accordance with the invention and of capacitive sensing systems comprising such capacitance measurement circuit will be described with reference to Figs. 2 to 6. In order to avoid unnecessary repetition, only differences to a respective preceding embodiment will be described.

[0065] Fig. 2 illustrates an electric equivalent circuit diagram of an alternative embodiment of a single-channel capacitance measurement circuit 200 in accordance with the invention. The single-channel capacitance measurement circuit 200 comprises two modifications compared to the embodiment as shown in Fig. 1.

[0066] For the connected capacitive sensor, a demultiplexer member 48 is provided in the remotely controllable switching unit 42. The remotely controllable switching unit 42 is configured, by controlling the demultiplexer member 48 and in the measurement switching state with regard to the capacitive sensor, to keep a terminal of the switching member 46 for electrically connecting the sense electrode to the signal input port 38 of the diagnostics current-to-voltage converter 36 at the converter end to guard potential of the capacitive sensor. This prevents introducing a measurement error by a parasitic capacitance of the switching member 46, as a voltage difference across terminals of the switching member 46 is virtually reduced to 0 V.

[0067] In a diagnostic switching state with regard to the capacitive sensor, the remotely controllable switching unit 42 is configured, by controlling the demultiplexer member 48, to connect the terminal of the switching member 46 at the converter end to the signal input port 38 of the diagnostics current-to-voltage converter 36.

[0068] Moreover, the current measurement circuit 200 comprises means, for each capacitive sensor, to keep the diagnostics output port 92 at guard potential of the respective capacitive sensor, which can beneficially eliminate a systematic error of measurement due to the diagnostics output port 92 being connected to the sense electrode of the capacitive sensor. In this particular embodiment, the means comprise two resistors 54, 56 and a capacitor 58 arranged in a T configuration.

[0069] Fig. 3 illustrates an electric equivalent circuit diagram of a possible embodiment of a multichannel capacitive sensing system 300 in accordance with the invention, comprising a plurality of two capacitive sensors. The multichannel capacitive sensing system 300 includes a capacitance measurement circuit 200 pursuant to Fig. 2, and a duplicated version 200' of this capacitance measurement circuit 200, wherein the periodic signal voltage source 12 is common to both capacitance measurement circuits 200, 200'. In other embodiments, each of the capacitance measurement circuits may include a periodic signal voltage source of its own. Each capacitance measurement circuit 200, 200' includes one measurement channel 26, 26' and one diagnostics channel 34, 34' for each one of the two capacitive sensors.

[0070] The multichannel capacitive sensing system 300 includes a microcontroller 60, and the remotely controllable switching unit 42 forms part of the microcontroller. In turn, the microcontroller 60 comprises a switch remote control unit 62 that is configured for remotely controlling the remotely controllable switching unit 42.

[0071] The microcontroller 60 comprises a processor unit 64, a digital data memory unit 66 to which the processor unit 64 has data access, and a plurality of analog-to-digital converters (ADCs, not shown), and is also employed to serve as an evaluation unit 70.

[0072] The remotely controllable switching unit 42 is configured, by control of the switch remote control unit 62, to control the switching members 44, 44', 46, 46' such that each capacitive sensor is connected either in the measurement switching state or in the diagnostic switching state.

[0073] The remotely controllable switching unit 42 is further configured, by control of the switch remote control unit 62, to periodically switch, for each capacitive

sensor and in a manner that is coordinated among the capacitive sensors, between the measurement switching state and the diagnostic switching state.

[0074] Although in this particular embodiment the multichannel capacitive sensing system 300 includes a plurality of two capacitive sensors, it is also contemplated that the multichannel capacitive sensing system 300 may include a plurality of more than two capacitive sensors.

[0075] Fig. 4 illustrates an electric equivalent circuit diagram of an alternative possible embodiments of a multichannel capacitive sensing system 400 in accordance with the invention. The difference of the multichannel capacitive sensing system 400 compared to the multichannel capacitive sensing system 300 pursuant to Fig. 3 is that there is only one measurement current-to-voltage converter 28.

[0076] In multichannel multiplexed measurement applications, time is neither lost by the sense-to-guard diagnostics nor by the sense electrode AC ground level diagnostics. Usually, the measurement current-to-voltage converter 28 and associated processing circuit is more expensive than the diagnostics current-to-voltage converter 36 due to the required measurement accuracy, which is lower for the diagnostics current-to-voltage converter 36. Therefore, only one measurement current-to-voltage converter 28 is used in the multichannel capacitive sensing system 400 pursuant to Fig. 4, while there is one diagnostics current-to-voltage converter 36, 36' per capacitive sensor. The switching configuration is the same as for the multichannel capacitive sensing system 300 pursuant to Fig. 3, except that the remotely controllable switching unit 42 is configured, controlled by the switch remote control unit 62, to only put one capacitive sensor into a measurement switching state at the same time. As the diagnostics can be executed for each capacitive sensor which is currently not measuring, in parallel to the measurement, the diagnostics does not add time to a required total measurement time.

[0077] Fig. 5 illustrates an electric equivalent circuit diagram of another alternative possible embodiments of a multichannel capacitive sensing system 500 in accordance with the invention. The difference of the multichannel capacitive sensing system 500 compared to the multichannel capacitive sensing system 400

pursuant to Fig. 4 is that there is only one measurement current-to-voltage converter 28 and only one diagnostics current-to-voltage converter 36.

[0078] This embodiment is cost-efficient, however, for more than two capacitive sensors, a case that is contemplated as well, the remotely controllable switching unit 42 has to be configured, controlled by the switch remote control unit 62, to only put one capacitive sensor into a diagnostic switching state at the same time, leaving the sense nodes 18, 18' of the other capacitive sensors at guard potential. Consequently, time is lost by not being able to perform measurements and diagnostics at the same time.

[0079] Fig. 6 illustrates an electric equivalent circuit diagram of another alternative possible embodiments of a multichannel capacitive sensing system 600 in accordance with the invention. The difference of the multichannel capacitive sensing system 600 compared to the multichannel capacitive sensing system 500 pursuant to Fig. 5 is that a demultiplexer member 50, 50' that is provided in the remotely controllable switching unit 42 for each capacitive sensor comprises an additional terminal.

[0080] In a measurement switching state with regard to a respective capacitive sensor, each one of the demultiplexer members 50, 50' having an additional terminal is configured to keep the terminal of the switching member 46, 46' for electrically connecting the sense electrode to a signal input port 38 of the diagnostics current-to-voltage converter 36 at the converter end at guard potential of the respective capacitive sensor.

[0081] Further, for each capacitive sensor whose sense electrode is unconnected to the signal input port 30 of the measurement current-to-voltage converter 28, the demultiplexer members 50, 50' are configured to either connect the terminal of the switching member 46, 46' for electrically connecting the sense electrode to a signal input port 38 of the diagnostics current-to-voltage converter 36 at the converter end to guard potential of the capacitive sensor, or to connect the terminal of the switching member 46, 46' for electrically connecting the sense electrode to the signal input port 38 of the diagnostics current-to-voltage converter 36 at the converter end to AC ground potential 16.

[0082] By that, a remedy is provided for a loss in operational availability existing for the capacitive sensing system 500 pursuant to Fig. 5 in a case of more than two capacitive sensors, and high operational availability can be achieved despite the hardware saving.

[0083] In the following, an embodiment of a method of operating the capacitive sensing system 600 pursuant to Fig. 6 with regard to capacitive sensor diagnosis will be described. A flowchart of the method is given in Fig. 7. In preparation of using the capacitive sensing system 600, it shall be understood that all involved units and devices are in an operational state and configured as illustrated in Fig. 6.

[0084] The microcontroller 60 is furnished with a software module 68 for controlling automatic execution of steps of the method. Steps to be conducted are converted into a program code of the software module, wherein the program code is implementable in the digital data memory unit 66 of the microcontroller 60 and is executable by the processor unit 64 of the microcontroller 60.

[0085] In a first step 72 of the method, the remotely controllable switching unit 42 is controlled by the switch remote control unit 62 to electrically disconnect the sense electrode of a capacitive sensor to be diagnosed from the signal input port 30 of the measurement current-to-voltage converter 28. At substantially the same time and in an immediately following step 74, the remotely controllable switching unit 42 is controlled by the switch remote control unit 62 to electrically connect the sense electrode of the capacitive sensor to be diagnosed to the signal input port 38 of the diagnostics current-to-voltage converter 36.

[0086] Then, in another step 76, the remotely controllable switching unit 42 is controlled by the switch remote control unit 62 to electrically connect the sense electrode of another capacitive sensor to the signal input port 30 of the measurement current-to-voltage converter 28 and, in an immediately following step 78, to disconnect the sense electrode of this capacitive sensor from guard potential or from AC ground potential 16.

[0087] The remotely controllable switching unit 42 is controlled by the switch remote control unit 62 to electrically connect the sense electrodes of the remainder of the plurality of capacitive sensors to AC ground potential 16 in a further step 80. Then, in a further step 82, a complex sense current value through the sense

electrode of the capacitive sensor to be diagnosed is determined by the diagnostics current-to-voltage converter 36. After that, the determined sense current value is compared with a predetermined threshold value by the microcontroller 60 serving as the evaluation unit 70 in a next step 84. An output signal that is indicative of a sensor interruption is generated in another step 86 if the magnitude of the determined sense current value is smaller than the predetermined threshold value.

[0088] After a step of swapping, for each cycle of steps, to a next capacitive sensor of the plurality of capacitive sensors that is to be diagnosed, the above-described steps are executed and repeated in a periodic manner until all capacitive sensors are diagnosed.

[0089] While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive; the invention is not limited to the disclosed embodiments.

[0090] Other variations to be disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality, which is meant to express a quantity of at least two. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. Any reference signs in the claims should not be construed as limiting scope.

List of Reference Symbols

10	current measurement circuit	54	resistor
12	signal voltage source	56	resistor
14	output port	58	capacitor
16	AC ground potential	60	microcontroller
18	sense node	62	switch remote control unit
20	guard node	64	processor unit
22	sense-to-guard impedance	66	digital data memory unit
24	unknown impedance	68	software module
26	measurement channel	70	evaluation unit
28	measurement current-to-voltage converter (MCVC)	88	output port MCVC 28
30	signal input port	90	output port DCVC 36
32	reference input port	92	diagnostic output port
34	diagnostics channel	100	single-channel capacitance measurement circuit
36	diagnostics current-to-voltage converter (DCVC)	200	single-channel capacitance measurement circuit
38	signal input port	300	multichannel capacitive sensing system
40	reference input port	400	multichannel capacitive sensing system
42	remotely controllable switching unit	500	multichannel capacitive sensing system
44	switching member	600	multichannel capacitive sensing system
46	switching member		
48	demultiplexer member		
50	demultiplexer member		

Method steps

72	disconnect sense electrode of capacitive sensor to be diagnosed from MCVC signal input port
74	connect sense electrode of capacitive sensor to be diagnosed to DCVC signal input port
76	connect sense electrode of another capacitive sensor to MCVC signal input port
78	disconnect sense electrode of this capacitive sensor from guard or AC ground potential
80	connect sense electrodes of remainder of capacitive sensors to AC ground potential

- 82 determine sense current value of sensor to be diagnosed
- 84 compare determined sense current value with threshold
- 86 generate output signal

P-IEE-492/LU

PATENTANSPRÜCHE

1. Kapazitätsmessschaltung (100) zum Bestimmen eines komplexen elektrischen Stroms von mindestens einem kapazitiven Sensor mit mindestens einer elektrisch leitfähigen Erfassungselektrode und mindestens einer elektrisch leitfähigen Schutzelektrode, die nahe beieinander angeordnet sind, wobei die Kapazitätsmessschaltung (100) aufweist:
- mindestens eine periodische Signalspannungsquelle (12), die dazu ausgelegt ist, eine Wechselmessspannung an einem Ausgangsport (14) bereitzustellen, wobei jede Schutzelektrode mit dem Ausgangsport (14) elektrisch verbunden werden kann, um die periodische Messspannung zu empfangen,
 - eine Strommessschaltung (10), die mindestens einen Messkanal (26) mit einem Messstrom/Spannungs-Wandler (28) aufweist, der dazu ausgelegt ist, mit Bezug auf die Messspannung einen Messstrom durch eine Erfassungselektrode zu bestimmen, der eine Position eines Gegenstands relativ zum kapazitiven Sensor angibt, und mindestens einen Diagnosekanal (34) mit einem Diagnosestrom/Spannungs-Wandler (36), der dazu ausgelegt ist, mit Bezug auf ein Wechselstrom-Massepotential (16) einen Diagnosestrom zu bestimmen, der durch eine Schutzelektrode und eine Erfassungselektrode eines kapazitiven Sensors fließt, der an den Diagnosestrom/Spannungs-Wandler (36) angeschlossen ist, und
 - eine fernsteuerbare Schalteinheit (42), die für jeden kapazitiven Sensor mehrere funktionsmäßig gekoppelte Schaltelemente (44, 46) aufweist, wobei in einem Messschaltungszustand im Hinblick auf den kapazitiven Sensor die Schalteinheit (42) dazu ausgelegt ist, die Erfassungselektrode des kapazitiven Sensors mit einem Signaleingangsport (30) eines Messstrom/Spannungs-Wandlers (28) elektrisch zu verbinden, und wobei in einem Diagnoseschaltungszustand im Hinblick auf den kapazitiven Sensor die Schalteinheit (42) dazu ausgelegt ist, die Erfassungselektrode mit

einem Signaleingangsport (38) eines Diagnosestrom/Spannungs-Wandlers (36) elektrisch zu verbinden.

2. Kapazitätsmessschaltung (100) nach Anspruch 1, wobei die Kapazitäts-
messschaltung (100) dazu ausgelegt ist, ein Ausgangssignal zu erzeugen,
das eine Sensorstörung angibt, wenn die Größe eines ermittelten Diagno-
sestroms, der durch eine Erfassungselektrode und eine Schutzelektrode ei-
nes kapazitiven Sensors fließt, der an den Diagnosestrom/Spannungs-
Wandler (36) angeschlossen ist, kleiner als ein vorbestimmter Schwellen-
wert ist.
3. Kapazitätsmessschaltung (100) nach Anspruch 1 oder 2, wobei für jeden
kapazitiven Sensor ein Demultiplexer-Element in der Schalteinheit vorgese-
hen ist, das dazu ausgelegt ist, in einem Messschaltungszustand im Hinblick
auf einen jeweiligen kapazitiven Sensor, einen Anschluss eines Schaltele-
ments zur elektrischen Verbindung der Erfassungselektrode mit einem Sig-
naleingangsport eines Diagnosestrom/Spannungs-Wandlers am Wandler-
ende auf dem Schutzpotential des jeweiligen kapazitiven Sensors zu halten.
4. Kapazitätsmessschaltung (200) nach Anspruch 1 oder 2, wobei für jeden
kapazitiven Sensor ein Demultiplexer-Element (48) in der Schalteinheit (42)
vorgesehen ist, das dazu ausgelegt ist,
 - in einem Messschaltungszustand im Hinblick auf einen jeweiligen kapazi-
tiven Sensor einen Anschluss eines Schaltelements (46) zur elektrischen
Verbindung der Erfassungselektrode mit einem Signaleingangsport (38)
des Diagnosestrom/Spannungs-Wandlers (36) am Wandlerende auf dem
Schutzpotential des jeweiligen kapazitiven Sensors zu halten,
und
 - für jeden kapazitiven Sensor, dessen Erfassungselektrode keine Verbin-
dung zu einem Messstrom/Spannungs-Wandler (28) hat, einen An-
schluss eines Schaltelements (46) zur elektrischen Verbindung der Er-
fassungselektrode mit einem Signaleingangsport (38) eines Diagno-

5 sestrom/Spannungs-Wandlers (36) am Wandlerende auf das Schutzpotential des kapazitiven Sensors aufzuschalten oder den Anschluss des Schaltelements (46) zur elektrischen Verbindung der Erfassungselektrode mit dem Signaleingangsport (38) des Diagnosestrom/Spannungs-Wandlers (36) am Wandlerende auf das Wechselstrom-Massepotential (16) aufzuschalten.

10 5. Kapazitätsmessschaltung (200) nach einem der vorhergehenden Ansprüche, wobei die Strommessschaltung (10) für jeden kapazitiven Sensor einen Diagnose-Ausgangsport (92) aufweist, der mit einer Erfassungselektrode des kapazitiven Sensors elektrisch verbunden ist.

15 6. Kapazitätsmessschaltung (200) nach Anspruch 5, wobei die Strommessschaltung (10) eine Einrichtung (54, 56, 58) für jeden kapazitiven Sensor aufweist, um den Diagnose-Ausgangsport (92) auf dem Schutzpotential des jeweiligen kapazitiven Sensors zu halten.

20 7. Kapazitätsmessschaltung (200) nach einem der vorhergehenden Ansprüche, wobei die fernsteuerbare Schalteinheit (42) einen Teil eines Mikrocontrollers (60) bildet.

25 8. Kapazitätsmessschaltung (100) nach einem der vorhergehenden Ansprüche, wobei die fernsteuerbare Schalteinheit (42) dazu ausgelegt ist, für jeden kapazitiven Sensor auf eine zwischen den kapazitiven Sensoren koordinierte Art und Weise zwischen einem Messschaltungszustand und einem Diagnoseschaltungszustand periodisch umzuschalten.

30 9. Kapazitives Erfassungssystem (300), aufweisend:
– eine Kapazitätsmessschaltung (200) nach einem der vorhergehenden Ansprüche,
– eine Fernschaltungs-Steuereinheit (62), die dazu ausgelegt ist, die fernsteuerbare Schalteinheit (42) aus der Ferne zu bedienen, und

- mehrere kapazitive Sensoren, wobei jeder kapazitive Sensor mindestens eine elektrisch leitfähige Erfassungselektrode und mindestens eine elektrisch leitfähige Schutzelektrode aufweist, die nahe beieinander angeordnet und gegenseitig galvanisch voneinander getrennt sind,
5 und die Kapazitätsmessschaltung (200) aufweist:
 - eine periodische Signalspannungsquelle (12), die dazu ausgelegt ist, eine Wechselmessspannung an einem Ausgangsport (14) bereitzustellen, wobei jede Schutzelektrode mit dem Ausgangsport (14) elektrisch verbunden ist, um die periodische Messspannung zu empfangen,
10 und wobei
 - die Strommessschaltung (10) aufweist:
 - einen Messkanal (26) mit einem Messstrom/Spannungs-Wandler (28), der dazu ausgelegt ist, einzeln und mit Bezug auf die Messspannung einen Messstrom durch eine Erfassungselektrode eines der mehreren
15 kapazitiven Sensoren zu bestimmen, der eine Position eines Gegenstands relativ zum jeweiligen kapazitiven Sensor angibt, und
 - einen Diagnosekanal (34) mit einem Diagnosestrom/Spannungs-Wandler (36), der dazu ausgelegt ist, mit Bezug auf ein Wechselstrom-Massepotential (16) einen Diagnosestrom zu bestimmen, der durch eine
20 Schutzelektrode und eine Erfassungselektrode eines jeden kapazitiven Sensors der mehreren kapazitiven Sensoren fließt.

10. Kapazitives Erfassungssystem (300) nach Anspruch 9, wobei die Strommessschaltung (10) mehrere Diagnosekanäle (34, 34') aufweist, wobei jeder
25 Diagnosekanal (34, 34') einen Diagnosestrom/Spannungs-Wandler (36, 36') enthält, der dazu ausgelegt ist, mit Bezug auf ein Wechselstrom-Massepotential (16) einen Diagnosestrom zu bestimmen, der durch eine Schutzelektrode und eine Erfassungselektrode eines anderen Sensors der mehreren kapazitiven Sensoren fließt.

30

11. Kapazitives Erfassungssystem (300) nach Anspruch 9 oder 10, wobei die Fernschaltungs-Steuereinheit (62) einen Teil eines Mikrocontrollers (60) bildet.
- 5 12. Kapazitives Erfassungssystem (300) nach einem der Ansprüche 9 bis 11, darüber hinaus eine Signalverarbeitungseinheit aufweisend, die dazu ausgelegt ist, mindestens ein Ausgangssignal des Messstrom/Spannungswandlers (28) mit Bezug auf die periodische Messspannung und mindestens ein Ausgangssignal des Diagnosestrom/Spannungswandlers (36) mit
10 Bezug auf die periodische Messspannung zu verarbeiten.
13. Kapazitives Erfassungssystem (300) nach einem der Ansprüche 9 bis 12, darüber hinaus eine Demodulationsschaltung aufweisend, die dazu ausgelegt ist, mindestens eines von einem Eingangssignal des Messstrom/Spannungswandlers (28) mit Bezug auf die periodische Messspannung und einem Eingangssignal des Diagnosestrom/Spannungswandlers (36) mit Bezug auf die periodische Messspannung zu demodulieren.
15
14. Verfahren zum Betreiben des kapazitiven Erfassungssystems (600) nach einem der Ansprüche 9 bis 13 im Hinblick auf die Diagnose eines kapazitiven Sensors, wobei das Verfahren zumindest folgende Schritte aufweist:
20
- Steuern der fernsteuerbaren Schalteinheit (42) auf solche Weise, dass die Erfassungselektrode eines kapazitiven Sensors, an dem eine Diagnose durchzuführen ist, vom Signaleingangsport (30) des Messstrom/Spannungswandlers (28) elektrisch getrennt (72) wird,
25
 - Steuern der fernsteuerbaren Schalteinheit (42) auf solche Weise, dass die Erfassungselektrode des kapazitiven Sensors, an dem eine Diagnose durchzuführen ist, mit dem Signaleingangsport (38) des Diagnosestrom/Spannungswandlers (36) elektrisch verbunden (74) wird,
 - 30 – Steuern der fernsteuerbaren Schalteinheit (42) auf solche Weise, dass die Erfassungselektrode eines anderen kapazitiven Sensors mit dem Signaleingangsport (30) des Messstrom/Spannungswandlers (28)

elektrisch verbunden (76) und die Erfassungselektrode dieses kapazitiven Sensors vom Schutzpotential oder Wechselstrom-Massepotential (16) getrennt (78) wird,

- 5 – Steuern der fernsteuerbaren Schalteinheit (42) auf solche Weise, dass die Erfassungselektroden aller verbleibenden der mehreren kapazitiven Sensoren mit dem Wechselstrom-Massepotential (16) elektrisch verbunden (80) werden,
- 10 – Bestimmen (82), durch den Diagnosestrom/Spannungs-Wandler (36), eines Erfassungsstromwerts durch die Erfassungselektrode des kapazitiven Sensors, an dem eine Diagnose durchzuführen ist,
- 15 – Vergleichen (84) des ermittelten Erfassungsstromwerts mit mindestens einem vorbestimmten Schwellenwert, und
- 15 – Erzeugen (86) eines Ausgangssignals, das eine Sensorstörung anzeigt, wenn der ermittelte Erfassungsstromwert kleiner als der vorbestimmte Schwellenwert ist.

15. Verfahren nach Anspruch 14, wobei die Schritte (72) bis (86) auf sich wiederholende und in periodischer Weise durchgeführt werden, nachdem für jeden Zyklus der Schritte (72) bis (86) auf den nächsten kapazitiven Sensor der mehreren kapazitiven Sensoren, an denen eine Diagnose durchzuführen ist, übergegangen wurde, und zwar solange, bis an allen kapazitiven Sensoren die Diagnose durchgeführt ist.

25 16. Softwaremodule (68) zum Steuern der automatischen Ausführung der Schritte des Verfahrens nach Anspruch 14 oder 15, wobei die auszuführenden Verfahrensschritte in einen Programmcode des Softwaremoduls (68) umgesetzt sind, wobei der Programmcode in einer digitalen Datenspeichereinheit (66) des kapazitiven Erfassungssystems (600) oder einer separaten Steuereinheit implementierbar ist und von einer Prozessoreinheit (64) des kapazitiven Erfassungssystems (600) oder einer separaten Steuereinheit

30 ausgeführt werden kann.

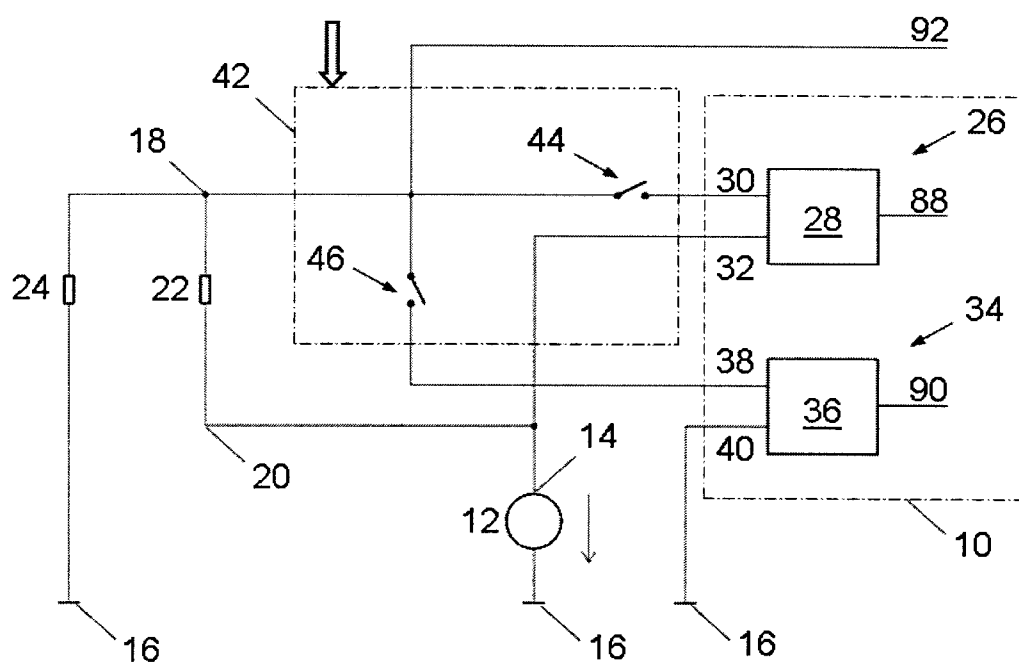
100

Fig. 1

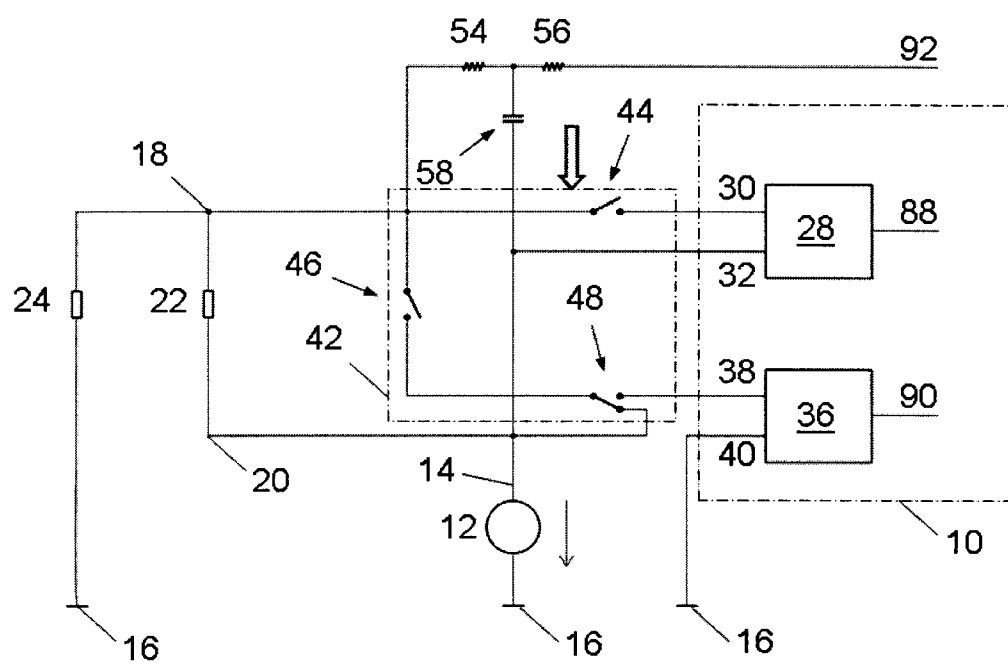
200

Fig. 2

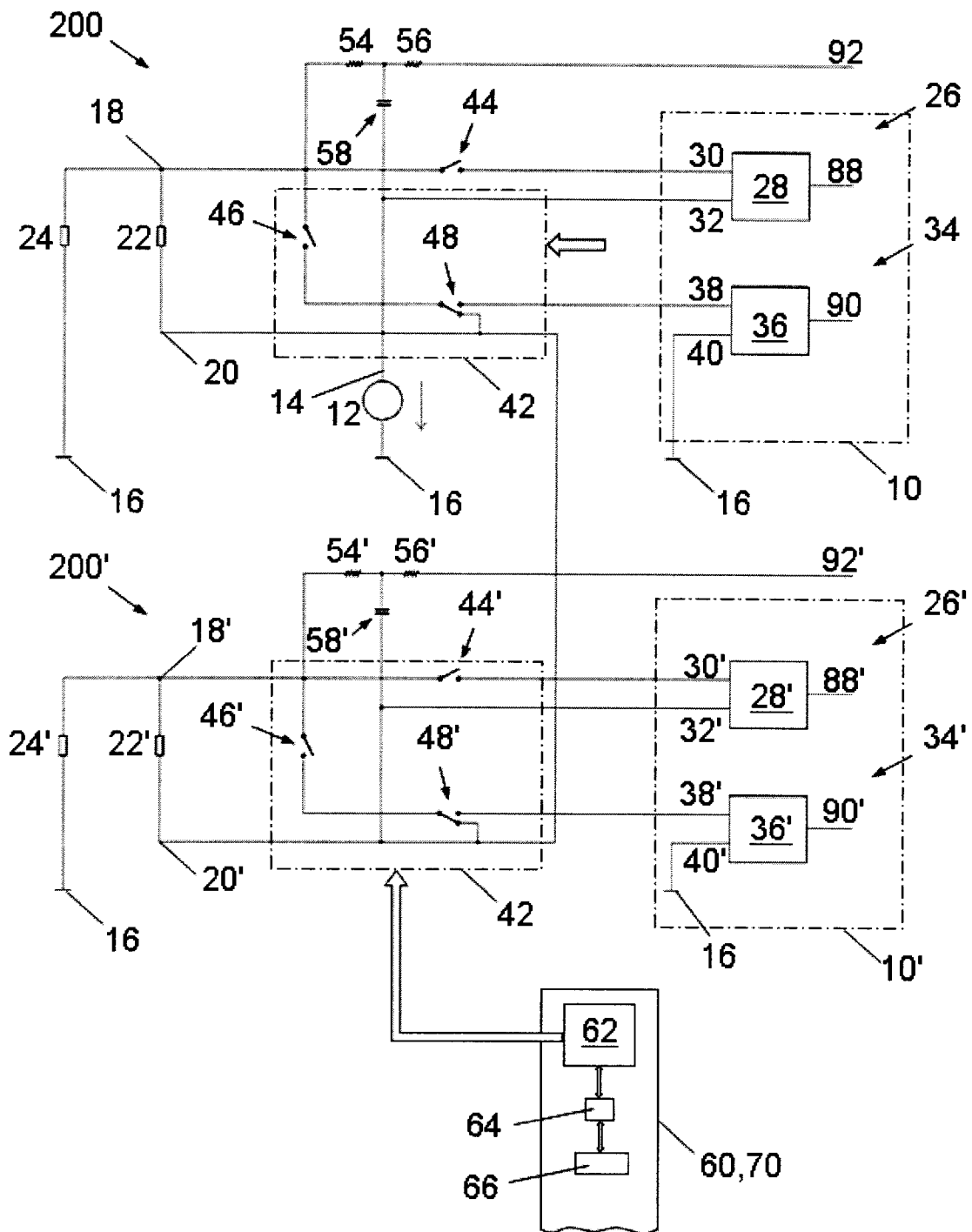
300

Fig. 3

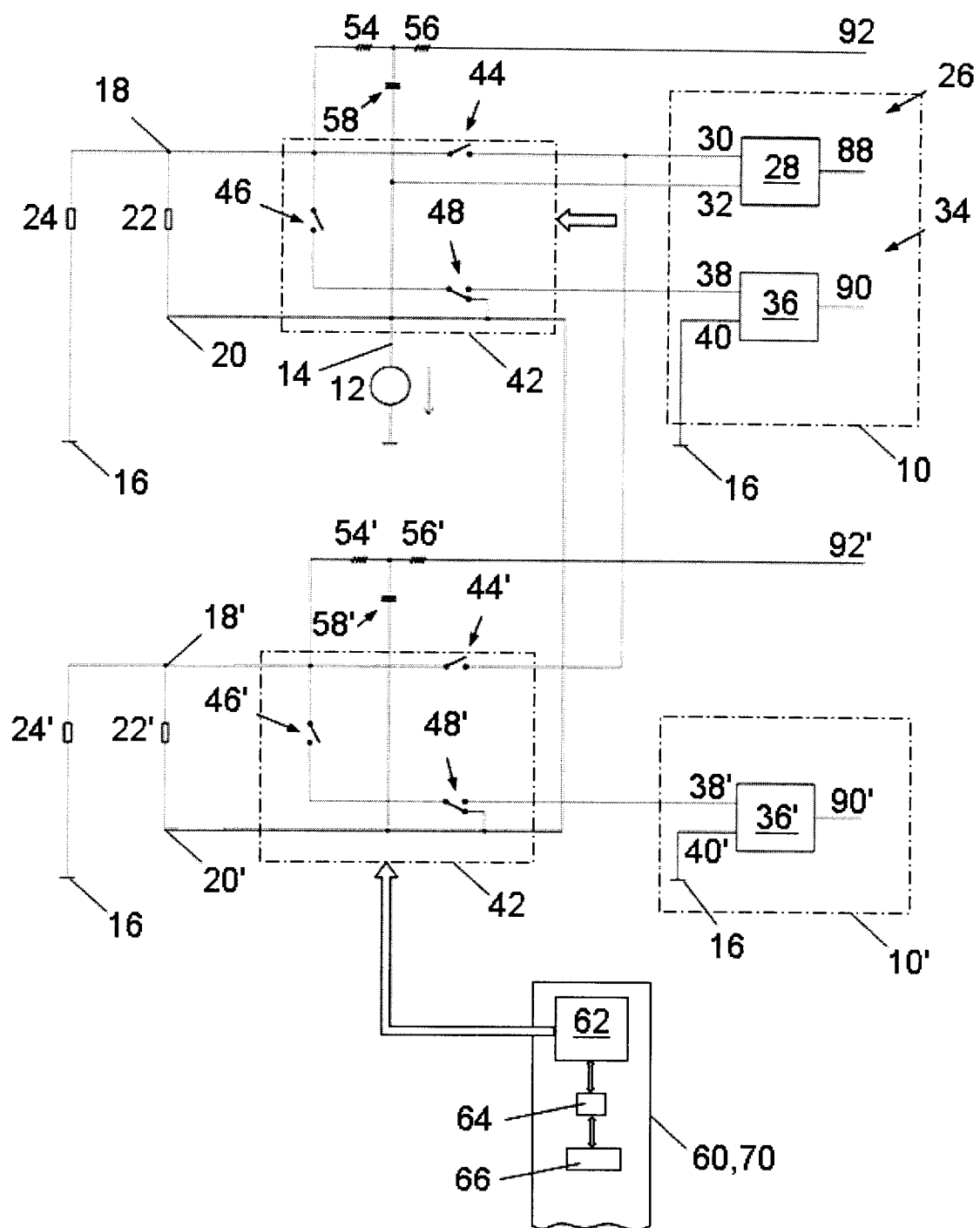
400

Fig. 4

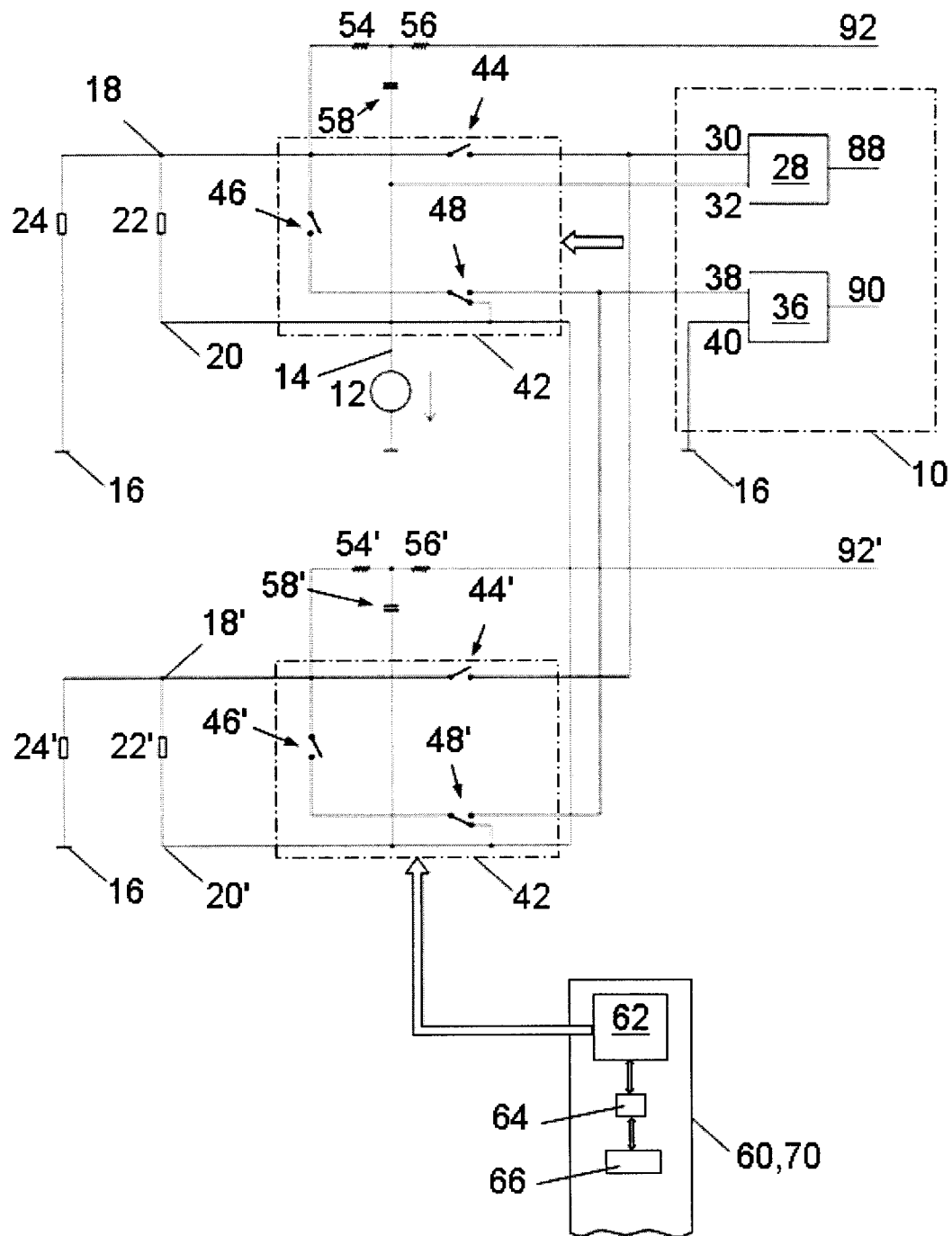
500

Fig. 5

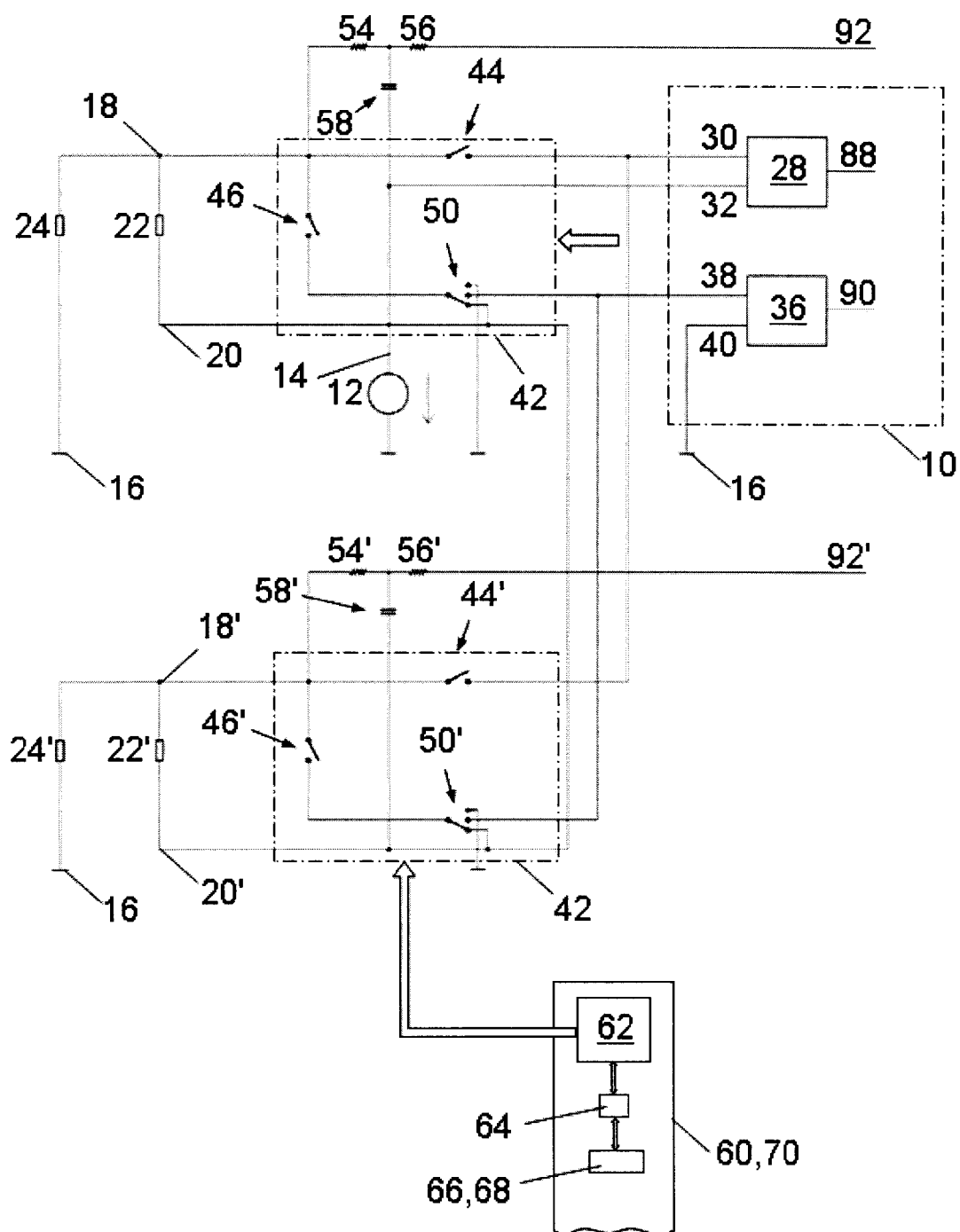
600

Fig. 6

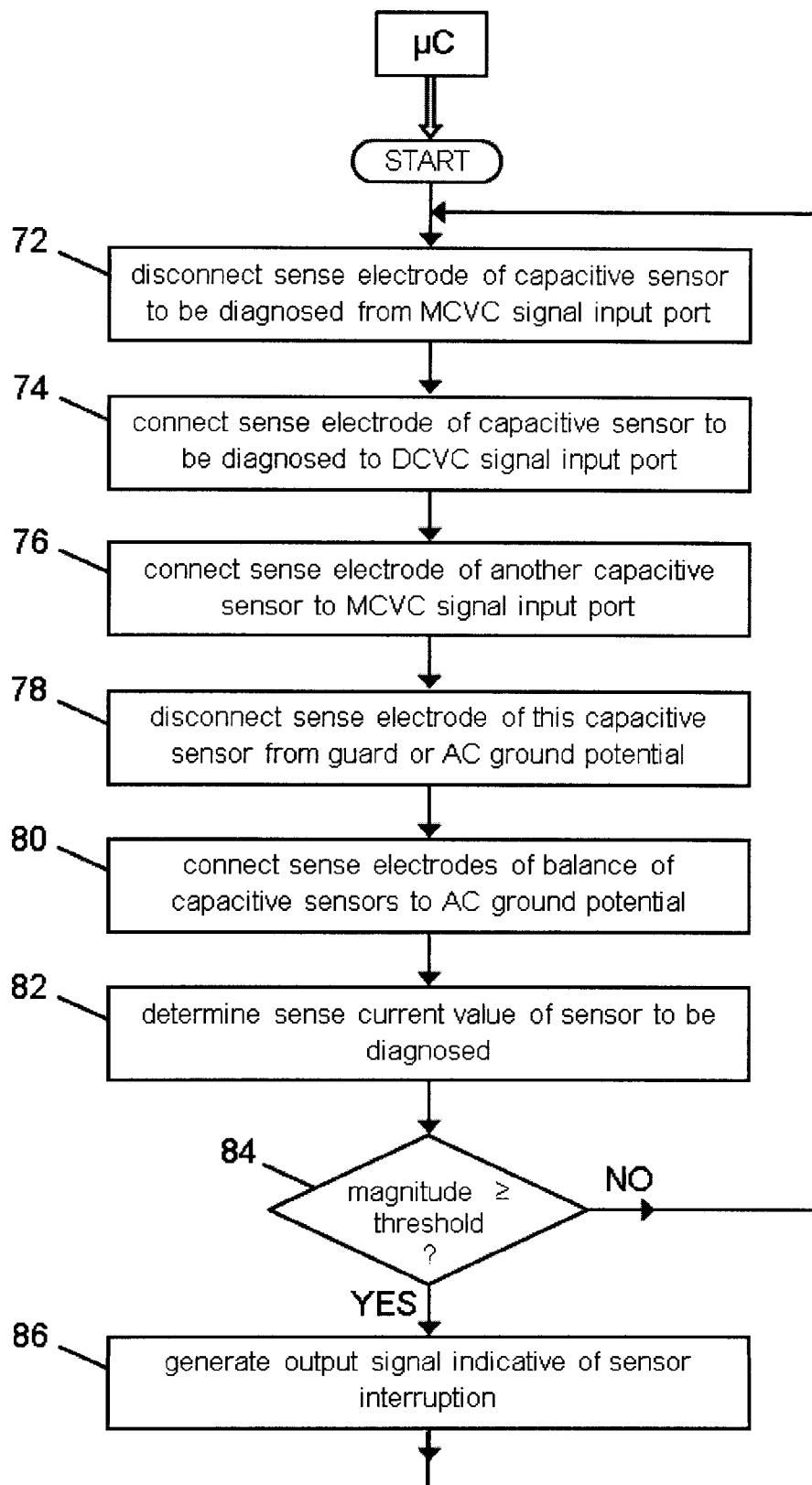


Fig. 7

Abstract

A capacitance measurement circuit (100) for determining a complex electric current of at least one capacitive sense-guard sensor comprises a periodic signal voltage source (12), wherein each guard electrode is electrically connectable to the signal voltage source (12), a current measurement circuit (10) comprising at least one measurement channel (26) to determine a measurement current through a sense electrode, and at least one diagnostics channel (34) to determine, with reference to an AC ground potential (16), a diagnostic current flowing through a guard electrode and a sense electrode of a capacitive sensor, and a remotely controllable switching unit (42), which in a measurement switching state is configured to electrically connect the sense electrode of the capacitive sensor to the measurement channel (26), and in a diagnostic switching state is configured to electrically connect the sense electrode to the diagnostics channel (34).

(Fig. 1)



SEARCH REPORT
in accordance with Article 35.1 a)
of the Luxembourg law on patents
dated 20 July 1992

LO 1893
LU 100737

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	WO 2017/129552 A1 (IEE INT ELECTRONICS & ENG SA [LU]) 3 August 2017 (2017-08-03) * paragraph [0032]; figures 1,2 * * paragraph [0053] - paragraph [0055] * -----	1-16	INV. H03K17/955
A	JP 2007 051930 A (MATSUSHITA ELECTRIC IND CO LTD) 1 March 2007 (2007-03-01) * paragraph [0047]; figure 1 * -----	1-16	
A	US 2013/207677 A1 (TOGURA TAKESHI [JP]) 15 August 2013 (2013-08-15) * figures 1,3,4 * -----	1-16	
A	WO 2016/055667 A1 (IEE SARL [LU]) 14 April 2016 (2016-04-14) * figures 1,2 * -----	1-16	
			TECHNICAL FIELDS SEARCHED (IPC)
			H03K B60R G01V G01D
The present search report has been drawn up for all claims			
Date of completion of the search		Examiner	
12 November 2018		O'Reilly, Siobhan	
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

**ANNEX TO THE SEARCH REPORT
ON LUXEMBOURG PATENT APPLICATION NO.**

LO 1893
LU 100737

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

12-11-2018

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		US 2017305376 A1	26-10-2017
		WO 2016055667 A1	14-04-2016



WRITTEN OPINION

File No. LO1893	Filing date (day/month/year) 20.03.2018	Priority date (day/month/year)	Application No. LU100737
International Patent Classification (IPC) INV. H03K17/955			
Applicant IEE International Electronics & Engineering S.A.			

This report contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☐ Box No. VII Certain defects in the application
- ☒ Box No. VIII Certain observations on the application

Form LU237A (Cover Sheet) (January 2007)	Examiner O'Reilly, Siobhan
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WRITTEN OPINION

LU100737

Box No. I Basis of the opinion

1. This opinion has been established on the basis of the latest set of claims filed before the start of the search.
2. With regard to any **nucleotide and/or amino acid sequence** disclosed in the application and necessary to the claimed invention, this opinion has been established on the basis of:
 - a. type of material:
 - ☐ a sequence listing
 - ☐ table(s) related to the sequence listing
 - b. format of material:
 - ☐ on paper
 - ☐ in electronic form
 - c. time of filing/furnishing:
 - ☐ contained in the application as filed.
 - ☐ filed together with the application in electronic form.
 - ☐ furnished subsequently.
3. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.
4. Additional comments:

Box No. V Reasoned statement with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty	Yes: Claims	1-16
	No: Claims	
Inventive step	Yes: Claims	1-16
	No: Claims	
Industrial applicability	Yes: Claims	1-16
	No: Claims	

2. Citations and explanations

see separate sheet

WRITTEN OPINION

Application No.

LU100737

Box No. VIII Certain observations on the application

see separate sheet

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1 Reference is made to the following document:

D1 WO 2017/129552 A1 (IEE INT ELECTRONICS & ENG SA [LU]) 3
August 2017 (2017-08-03)

2 Independent claims:

2.1 Claim 1:

2.1.1 D1 is regarded as being the prior art closest to the subject-matter of claim 1, in so far as this claim is understood, and discloses (references in parentheses referring to Fig.1 of this document unless indicated otherwise):

A capacitance measurement circuit (28) for determining a complex electric current of at least one capacitive sensor (12; [0010]) including at least one electrically conductive sense electrode ([0010]) and at least one electrically conductive guard electrode ([0010]) that are arranged close to each other ([0010]), the capacitance measurement circuit (28) comprising

- at least one periodic signal voltage source (24) that is configured for providing an alternating measurement voltage at an output port (26), wherein each guard electrode is electrically connectable to the output port (26) for receiving the periodic measurement voltage ([0041]),

- a current measurement circuit (30) comprising at least one measurement channel (32) including a measurement current-to-voltage converter ([0042]) that is configured to determine, with reference to the measurement voltage ([0045]), a measurement current through a sense electrode that is indicative of a position of an object relative to the capacitive sensor ([0043]), and at least one diagnostics ~~state channel~~ ~~including a diagnostics current-to-voltage converter~~ that is configured to determine, with reference to an AC ground potential (Ground connected to 50), a diagnostic current flowing through a guard electrode and a sense electrode of a capacitive sensor (12; [0047]) that is connected to the ~~diagnostics~~ **measurement** current-to-voltage converter (30), and

- a remotely controllable switching unit (40) comprising, for each capacitive sensor, a plurality of operatively coupled switching members (40), wherein in a measurement switching state (42, connected to 44;

[0045]) with regard to the capacitive sensor (12), the switching unit (40) is configured to electrically connect the ~~sense electrode of the capacitive sensor~~ **periodic measurement voltage** (26) to a signal input port (34) of a measurement current-to-voltage converter (30), and wherein in a diagnostic switching state (42₂ connected to 44; [0047]) with regard to the capacitive sensor, the switching unit (40) is configured to electrically connect the ~~sense electrode~~ **AC ground potential** to a signal input port (34) of a diagnostics **measurement** current-to-voltage converter (30).

- 2.1.2 The subject-matter of claim 1 therefore differs from this known capacitance measurement circuit in that only one current to voltage converter is used and the reference voltage is switched between the measurement and diagnostic states and is therefore novel.
- 2.1.3 The problem to be solved by the present invention may be regarded as how to implement a diagnostic state for a capacitance measurement circuit.
- 2.1.4 The solution to this problem proposed in claim 1 of the present application is considered as involving an inventive step as while the other documents in the search report also address the problem to be solved they do not do so in the same way as the application. None of the prior art address the implementation of a diagnostic state for a capacitance measurement circuit using a separate channel with a dedicated current to voltage converter. Additionally the solution chosen by the present application is not obvious, so the skilled person would need to exercise an inventive step to arrive at the subject-matter of claim 1.
- 2.2 Claims 2-13 are dependent on claim 1 whose subject-matter is considered as being new and inventive, as discussed above, and as such said dependent claims also meet the requirements of novelty and inventive step.
- 2.3 Claim 14:
 - 2.3.1 The subject-matter of independent method claim 14 corresponds to a method for controlling the dependent system claim 9 which is considered to be new and inventive as it controls features included in the novelty and inventiveness reasoning for claim 1.
- 2.4 Claim 16:

- 2.4.1 The subject-matter of independent product claim 16 corresponds to a product for implementing the independent method claim 14. Hence the same reasoning of claim 14 applies, *mutatis mutandis*, to the subject-matter of the corresponding independent claim 16, which therefore is also considered new and inventive.
- 3 A new set of claims should be drafted to overcome the major objections with respect to the clarity mentioned below. At present it is not clear how the claims as written adequately reflects the claimed invention.
- 3.1 It is noted that this suggestion is only for assisting the applicant in his decision on how to proceed. It in no way precludes consideration of alternative solutions submitted by the applicant. The responsibility for determining the text of the application and in particular for defining the subject-matter for which protection is sought remains with the applicant.

Re Item VIII

Certain observations on the application

- 4 Claims 1, 3, 4, 9, 12 and 13 are not clear.
- 4.1 Claim 1:
- 4.1.1 In claim 1 the same feature is referred to in three different ways creating confusion as to whether or not the feature is indeed the same or not rendering the claim unclear. The objection refers to "an alternating measurement voltage" later referred to as "the periodic measurement voltage" and then as "the measurement voltage".
- Additionally it is unclear why the features is referred to as a "measurement" voltage, given that it acts as a biasing or reference voltage.
- 4.1.2 The abbreviation AC should be referred to as alternating current before the first instance of the use of the abbreviation.
- 4.1.3 The capacitive measurement circuit of claim 1 comprises "a current measurement circuit comprising at least one measuring channel including a measurement current-to-voltage converter" and "at least one diagnostics channel including a diagnostics current-to-voltage converter". Later in the claim when defining the switching unit reference is made to "a measurement current-to-voltage converter" and "a diagnostics current-to-voltage converter".
- 4.2 Claim 3:

- 4.2.1 The terminology used and lack of reference signs render the subject-matter of claim 3 unclear, particularly the phrase "to keep a terminal of a switching member for electrically connecting the sense electrode to a signal input port of a diagnostics current-to-voltage converter at the converter end". The phrasing could be clarified by defining the terminal and then defining that in the "measurement switching state with regard to a respective capacitive sensor", the switching unit is configured keep said terminal "to guard potential of the respective capacitive sensor". Note that "guard potential" has not yet been defined and is assumed to mean the potential of the guard electrode.
- 4.2.2 Additionally "a measurement switching state" has been defined in claim 1 so reference to the same switching stage should refer to "the measurement switching state" or alternatively a second measurement switching state should be defined.
- 4.2.3 The definition of the "demultiplexer member" is not clear. Specifically it is not clear that the switching member (46) is disconnected from the diagnostics current-to-voltage converter during the measurement switching state.

For the purpose of the present opinion, with support from the description and the drawings, it is assumed that the demultiplexer member should correspond to the feature denoted with the reference sign (48) in figures 2-5, i.e. that it is

- connected at the output terminal of the switching member (46) in series between the switching member (46) and the diagnostics current-to-voltage converter (36),

and operates as described in [0066] and [0067]:

- disconnecting said output terminal from the signal input port (38) of the diagnostics during the measurement switching state with regard to a respective capacitive unit and connecting said output terminal to the guard potential of the respective capacitive sensor.

4.3 Claim 4:

- 4.3.1 The subject matter of claim 4 is broader than that of claim 3 and claim 3 contains all the features of claim 4. For the purpose of the present opinion, it is assumed that claim 4 is dependent and should be directed to claim 3 rather than a repetition of features.
- 4.3.2 Additionally the reference to "a diagnostics current-to-voltage converter" is unclear and should be referred to with respect to the corresponding capacitive sensor.

- 4.4 Claim 9:
 - 4.4.1 The subject-matter of claim 9 is not concise as it repeats features of claim 1, e.g. one periodic signal voltage source.
- 4.5 Claims 12 and 13:
 - 4.5.1 Note that the objection in section 4.1.1 applies also to claims 12 and 13.

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JP2007051930 A 20070301

SUBJECT OF THE INVENTION

The drive circuit for generate|occur|producing the drive signal which vibrates an excitation piece (piezoelectric material) is required for the signal-processing apparatus of the conventional piezoelectric sensor,

The drive current for vibrating an excitation piece (piezoelectric material) is top where a structure is complicated needed,

The subject which the consumption current of the whole apparatus increases occurred. PROBLEM to be solved

Only the alternating-current component of the electric-charge variation produced in the piezoelectric sensor **1** by the 1st capacitor|condenser **3** is inputted into an operational amplifier **4**,

The direct-current|flow component of the voltage between the 1st resistor **2** and the 2nd resistor **7** is not inputted into an operational amplifier **4**,

For this reason, it becomes possible to determine abnormality, such as a disconnection of the electrode of the piezoelectric sensor **1**, and a short circuit, based on the voltage between the 1st resistor **2** and the 2nd resistor **7**,

It is simple and abnormality, such as a disconnection of a piezoelectric sensor and a short circuit, can be determined by few|small structure of a consumption current.

DETAILED DESCRIPTION of the INVENTION

[0001] TECHNICAL FIELD

This invention relates to the signal-processing apparatus of an electric-charge variation type|mold sensor.

Specifically,

It concerns on abnormality detection of the electric-charge variation type|mold sensor in the signal-processing apparatus of the electric-charge variation type|mold sensor which uses charge amplifier.

DESCRIPTION OF RELATED ART

[0002] As a system which derives|leads-out the output signal from a piezoelectric sensor, if the voltage-amplification type|mold amplifier (henceforth charge amplifier) is used

With electrostatic-capacitance C_s of a piezoelectric sensor, and the high-pass filter of the cutoff frequency $f_c (=1/(2\pi \cdot C_s \cdot R))$ formed by the resistance R connected in parallel with a piezoelectric sensor, a signal attenuation in a low-frequency region occurs.

Therefore, in order to avoid a signal attenuation in a low-frequency region, using charge amplifier is known.

[0003] And a drive signal is applied to the yaw rate sensor equipped with the excitation piece which consists both of a piezoelectric material, and the detection piece, for example as a structure which performs disconnection detection of the piezoelectric sensor in the signal-processing apparatus of the piezoelectric sensor which uses charge amplifier from a drive circuit, and said excitation piece is vibrated, The said detection piece detects the vibration, There exists structure (refer the patent documents 1) which inputs the output signal from said detection piece into charge amplifier. If the signal line from a yaw rate sensor to charge amplifier is disconnected by this structure, for example, A disconnection is detected based on the signal corresponding to said vibration not being output from charge amplifier.

Unexamined-Japanese-Patent No. **2000-146594**

DISCLOSURE OF THE INVENTION

PROBLEM TO BE SOLVED BY THE INVENTION

[0004] However, the drive circuit for generate|occur|producing the drive signal which vibrates an excitation piece (piezoelectric material) is required for the signal-processing apparatus of the above-mentioned conventional piezoelectric sensor, The drive current for vibrating an excitation piece (piezoelectric material) is top where a structure is complicated needed, The subject that the consumption current of the whole apparatus increased occurred.

[0005] In view of said conventional subject, PROBLEM ADDRESSED is a signal-processing apparatus of the electric-charge variation type|mold sensor which uses charge amplifier.

WHEREIN:

It is providing the signal-processing apparatus which detects the abnormality of the electric-charge variation type|mold sensor which is simple and has few|small consumption currents.

MEANS TO SOLVE THE PROBLEM

[0006] It is an electric-charge variation type|mold sensor by which the signal-processing apparatus of the electric-charge variation type|mold sensor based on this invention has several electrodes in order to solve said subject,

It has the non-inversion input terminal which connected at least one to the inverting-input terminal connected to one electrode of said electric-charge variation type|mold sensor via the 1st capacitor|condenser, and the other electrode of said electric-charge variation type|mold sensor, or a reference(standard) electric potential, The operational amplifier which connected the 2nd capacitor|condenser between said inverting-input terminal and the output terminal,
 The 1st resistor connected between the electrodes of said electric-charge variation type|mold sensor, and the 2nd resistor connected between the predetermined voltage source and said 1st resistor,
 An abnormality-determination means to determine the abnormality of the electrode of said electric-charge variation type|mold sensor based on the voltage between said 1st resistor and said 2nd resistor is provided.

[0007] And only the alternating-current component of the electric-charge variation produced in an electric-charge variation type|mold sensor by said 1st capacitor|condenser is inputted into said operational amplifier,
 Since the direct-current|flow component of the voltage between said 1st resistor and said 2nd resistor is not inputted into said operational amplifier, it becomes possible to determine abnormality, such as a disconnection of said electrode of said electric-charge variation type|mold sensor, and a short circuit, based on the voltage between said 1st resistor and said 2nd resistor,
 It is simple and abnormality, such as a disconnection of a piezoelectric sensor and a short circuit, can be determined by few|small structure of a consumption current.

[0008] ADVANTAGE OF THE INVENTION

The signal-processing apparatus of the electric-charge variation type|mold sensor of this invention

Since only the alternating-current component of the electric-charge variation produced in an electric-charge variation type|mold sensor by the 1st capacitor|condenser is inputted into an operational amplifier and the direct-current|flow component of the voltage between the 1st resistor and the 2nd resistor is not inputted into said operational amplifier

It becomes possible to determine the abnormality of said electric-charge variation type|mold sensor based on the voltage between said 1st resistor and said 2nd resistor,
 It is simple and the abnormality of an electric-charge variation type|mold sensor can be determined by few|small structure of a consumption current.

PREFERRED EMBODIMENT OF THE INVENTION

[0009] The signal-processing apparatus of the electric-charge variation type|mold sensor in 1st invention is an electric-charge variation type|mold sensor which has several electrodes,

It has the non-inversion input terminal which connected at least one to the inverting-input terminal connected to one electrode of said electric-charge variation type|mold sensor via the 1st capacitor|condenser, and the other electrode of said electric-charge variation type|mold sensor, or a reference(standard) electric potential, The operational amplifier which connected the 2nd capacitor|condenser between said inverting-input terminal and the output terminal,

The 1st resistor connected between the electrodes of said electric-charge variation type|mold sensor, and the 2nd resistor connected between the predetermined voltage source and said 1st resistor,

An abnormality-determination means to determine the abnormality of the electrode of said electric-charge variation type|mold sensor based on the voltage between said 1st resistor and said 2nd resistor is provided.

[0010] And only the alternating-current component of the electric-charge variation produced in said piezoelectric sensor by said 1st capacitor|condenser is inputted into said operational amplifier,

Since the direct-current|flow component of the voltage between said 1st resistor and said 2nd resistor is not inputted into said operational amplifier, it becomes possible to determine abnormality, such as a disconnection of said electrode of said piezoelectric sensor, and a short circuit, based on the voltage between said 1st resistor and said 2nd resistor,

It is simple and abnormality, such as a disconnection of a piezoelectric sensor and a short circuit, can be determined by few|small structure of a consumption current.

[0011] 2nd invention comprises an electric-charge variation type|mold sensor by a piezoelectric sensor especially in 1st invention,

The said piezoelectric sensor is a center electrode connected to an inverting-input terminal via the 1st capacitor|condenser,

The piezoelectric material formed in the circumference|surroundings of said center electrode,

It forms in the circumference|surroundings of said piezoelectric material, and while shape|molding the ground electrode connected to at least one of a non-inversion input terminal or a reference(standard) electric potential in the shape of a coaxial cable, the connection side with an operational amplifier connects the 1st resistor between said center electrode and said ground electrode in the front-end|tip part of a reverse side.

[0012] And the structure which uses charge amplifier by connecting the 1st resistor between the electrodes in the front-end|tip part of a cable shaped piezoelectric sensor WHEREIN:

Abnormality, such as a disconnection of a piezoelectric sensor and a short circuit, can be determined.

[0013] 3rd invention comprises an electric-charge variation type|mold sensor by a piezoelectric sensor especially in 1st invention,

The said piezoelectric sensor is a center electrode connected to an inverting-input terminal via the **1st** capacitor|condenser,
 The piezoelectric material formed in the circumference|surroundings of said center electrode,
 While shape|molding the ground electrode which is formed in the circumference|surroundings of said piezoelectric material and is connected to at least one of a non-inversion input terminal or a reference(standard) electric potential in the shape of a coaxial cable
 The connection side with an operational amplifier is **1st** return electrode that is connected with said center electrode in the front-end|tip part of a reverse side, and is extended to the connection side to said operational amplifier,
 The **2nd** return electrode that is connected with said ground electrode in said front-end|tip part, and is extended to the connection side with said operational amplifier is provided,
 In the connection edge part to said operational amplifier, the **1st** resistor is connected between said **1st** return electrode and said **2nd** return electrode.

[0014] It is and like abnormality, such as a disconnection of a piezoelectric sensor and a short circuit, can be determined, and **2nd** invention by providing the **1st** return electrode and the **2nd** return electrode, and connecting the **1st** resistor between said **1st** return electrode and said **2nd** return electrode in the connection edge part to an operational amplifier.

There is nothing in the need of connecting the **1st** resistor, and a simpler structure is made in these between the electrodes of the front-end|tip part of a piezoelectric sensor.

[0015] **4th** invention is what the piezoelectric sensor was equipped with the connection part with a coaxial cable especially in **2nd** or **3rd** invention, and was connected with the operational amplifier via said coaxial cable.

For example, when a piezoelectric sensor is mounted in a product, even if there exists an area|region which receives the influence of unnecessary vibration noise, the structure which arranges a coaxial cable at the area|region and the noise signal by vibration noise does not generate|occur|produce is attained,

The degrees of freedom of the layout at the time of mounting in a product improves. Moreover, not only a piezoelectric sensor but a disconnection and short circuit of a coaxial cable are detectable,

Therefore

Reliability improves.

[0016] **5th** invention is what formed the polarization area|region and the non-polarization area|region in the piezoelectric material especially in **2nd** or **3rd** invention.

For example, when a piezoelectric sensor is mounted in a product, even if there exists an area|region which receives the influence of unnecessary vibration noise, the structure which arranges the non-polarization area|region of a piezoelectric sensor at the area|region, and the noise signal by vibration noise does not generate|occur|produce is attained,
Even if it does not use a coaxial cable like 4th invention, the degrees of freedom of the layout at the time of mounting in a product improves.

[0017] 6th invention is the signal-processing board|substrate part equipped with an operational amplifier, the 1st capacitor|condenser, the 2nd capacitor|condenser, the 2nd resistor, and at least one with an abnormality-determination means especially in any one 1st - 5th invention,
The shield means which shields said signal-processing board|substrate part electrically
It is the thing provided with these and the influence of electrical noise can be decreased by a shield means,
Therefore
Reliability improves.

[0018] 7th invention connects the inverting-input terminal of an operational amplifier to one electrode of the electric-charge variation type|mold sensor provided with several electrodes via the 1st capacitor|condenser,
The other electrode of said electric-charge variation type|mold sensor is connected to the non-inversion input terminal of said operational amplifier, or at least one of a reference(standard) electric potential,
While connecting the 2nd capacitor|condenser between the inverting-input terminal of said operational amplifier, and an output terminal, the 1st resistor is connected between the electrodes of said electric-charge variation type|mold sensor,
The 2nd resistor is connected between a predetermined voltage source and said 1st resistor,
It is the signal-processing method of an electric-charge variation type|mold sensor of determining the abnormality of said electrode based on the voltage between said 1st resistor and said 2nd resistor.

[0019] And only the alternating-current component of the electric-charge variation produced in an electric-charge variation type|mold sensor by said 1st capacitor|condenser is inputted into an operational amplifier,
Since the direct-current|flow component of the voltage between said 1st resistor and said 2nd resistor is not inputted into said operational amplifier, it becomes possible to determine abnormality, such as a disconnection of said electrode of said electric-charge variation type|mold sensor, and a short circuit, based on the voltage between said 1st resistor and said 2nd resistor,
The signal-processing method of the electric-charge variation type|mold sensor which is simple and has few|small consumption currents can be provided.

[0020] Hereafter, Embodiment of this invention is demonstrated, referring drawing. In addition, this invention is not limited by this Embodiment. Moreover, it is set as the thing which does not give explanation which attached the same code and overlapped at the place which has the same structure and an effect in description of this Embodiment.

[0021] (Embodiment 1)

1st Embodiment in the signal-processing apparatus of the electric-charge variation type|mold sensor of this invention is demonstrated with reference to FIGS. 1-5.

[0022] FIG. 1 is a block diagram of the signal-processing apparatus which uses a piezoelectric sensor as an electric-charge variation type|mold sensor in the 1st Embodiment of this invention,

FIG. 2 is sectional drawing of the piezoelectric sensor 1 in AA line|wire of FIG. 1.

The piezoelectric sensors 1 as an electric-charge variation type|mold sensor are the piezoelectric material 1b which is a cable shaped thing with flexibility and was formed in the circumference|surroundings of the center electrode 1a and the center electrode 1a as shown in FIG. 2, and a piezoelectric material.

The ground electrode 1c formed in the circumference|surroundings of 1b and 1d of coating layers are shape|molded in the shape of a coaxial cable.

In the front-end|tip part 1e of the piezoelectric sensor 1, the 1st resistor 2 is connected between the center electrode 1a and the ground electrode 1c.

[0023] Usual metal singlet conducting wire may be used for the center electrode 1a, However,

Here, the electrode which wound the metal coil is used for the circumference|surroundings of the insulating polymeric fiber.

The insulating polymeric fiber, the polyester fiber commercially used in the electric blanket as a metal coil, and the copper alloy containing 5 wt% of silver are preferable respectively.

[0024] The piezoelectric material 1b is what knead|mixed the polyethylene-type resin and the piezoelectric-ceramic (here lead zirconate titanate) powder, with the center electrode 1a, is extruded continuously and forms the flexible piezoelectric material 1b.

In addition, as a piezoelectric ceramic, it is preferable to use the material of a non-lead system, for example, the piezoelectric-ceramic material of a bismuth-titanate sodium type|system|group or a niobic-acid alkali type|system|group, from the consideration to an environmental viewpoint.

[0025] And the extruding processing of the piezoelectric material 1b was carried out to the circumference|surroundings of the center electrode 1a,

Then, a several kilovolts DC voltage is applied between the center electrode **1a** and the pseudo|simulation electrode made to contact the surface of the piezoelectric material **1b**, and the polarization of the piezoelectric material **1b** is performed.

Thereby, the piezoelectric material **1b** is equipped with a piezoelectric effect.

Using the band electrode which the metal film adhere|attached on the polymeric layer, as the ground electrode **1c** winds this around the circumference|surroundings of the piezoelectric material **1b**, it comprises it.

[0026] Using a polyethylene * terephthalate (PET) as a polymeric layer, also commercially, the electrode which adhere|attached the aluminum film|membrane on this is mass-produced while having high thermal stability at **120** degrees C, Therefore

It is preferable as a ground electrode **1c**.

In addition, in order to shield from the electrical noise of an external environment, it is preferable to wind around the circumference|surroundings of the piezoelectric material **1b**, as the ground electrode **1c** overlaps partly.

1d of coating layers are good to use a chloroethylene by a reliability surface, However,

It is preferable to use non-vinyl-chloride type-materials, such as thermoplastic elastomer, from the consideration to an environmental viewpoint.

[0027] FIG. **3** is sectional drawing of the vicinity of the front-end|tip part **1e** of the piezoelectric sensor **1**.

In the figure, the **1st** resistor **2** is equipped with the lead parts **2a** and **2b**, and the lead part **2a** return|folds a front-end|tip in the shape of a hairpin,

The front-end|tip is similarly engaged and soldered at the center electrode **1a** and B point which were return|folded in the shape of a hairpin.

A part of lead part **2b**, the **1st** resistor **2**, the vicinity of B point, and some piezoelectric materials **1b** are covered with **1f** of insulators, such as a heat contraction tube.

[0028] Moreover, a part of lead part **2b**, the whole of **1f** of insulators, and some ground electrodes **1c** are covered with **1g** of conductive materials, such as a braid sleeve and a metal tape,

In C point, the front-end|tip and **1g** of conductive materials of the lead part **2b** are soldered, and the ground electrode **1c** and **1g** of conductive materials are soldered in D point.

[0029] Furthermore, a part of whole of **1g** of conductive materials and **1d** of coating layers are covered by **1h** of heat contraction tubes.

In this case, the adhesive layer which consists of **1d** of coating layers, a hot melt which can be adhere|attached, etc. is formed in the inner surface side of **1h** of heat contraction tubes,

1h of heat contraction tubes and the gap between **1d** of coating layers are sealed by the thermal|heat process with an adhesive agent.

Moreover, while the opening of 1h of heat contraction tubes also shrink|contracts the other end (C point side) of 1h of heat contraction tubes by a thermal|heat process, an adhesive agent elutes and an opening is sealed.

[0030] In FIG. 1, the center electrode 1a is connected to the inverting-input terminal of an operational amplifier 4 via the 1st capacitor|condenser 3. The ground electrode 1c is connected to the reference(standard) electric potential 5 as the non-inversion input terminal and bias-voltage source of an operational amplifier 4. The 2nd capacitor|condenser 6 is connected between the inverting-input terminal of an operational amplifier 4, and the output terminal. Moreover, the 2nd resistor 7 is connected between the predetermined voltage source Vs and the 1st resistor 2.

[0031] In parallel, in order to prevent the output drift and saturation of an operational amplifier 4, the 3rd resistor 8 is connected to the 2nd capacitor|condenser 6.

Furthermore, while an abnormality-determination means 9 to determine abnormality, such as a disconnection of the center electrode 1a and the ground electrode 1c and a short circuit, is provided based on the voltage Vd between the 1st resistor 2 and the 2nd resistor 7

Based on the output Vo of an operational amplifier 4, an object contacts the piezoelectric sensor 1 directly or indirectly, or a determination means 10 to determine that the vibration was applied is provided.

[0032] An operational amplifier 4, the 1st capacitor|condenser 3, the 2nd capacitor|condenser 6, the 2nd resistor 7, the 3rd resistor 8, the abnormality-determination means 9, and the determination means 10 are arranged at the signal-processing board|substrate part 11 which consists of the same board|substrate.

The signal-processing board|substrate part 11 is incorporated in the shield means 12 which consists of metal casing, and is shielded electrically,

The gland|grand|ground and metal casing of the signal-processing board|substrate part 11 are conducted at at least one place.

The shield means 12 covered the one end part of the piezoelectric sensor 1, and has couple|bonded together.

[0033] In addition, in this Embodiment, the operational amplifier 4 is using the single power-supply type thing from practicability,

However,

It is sufficient to use a both power-supplies type thing as needed.

[0034] Next, the effect|action of said structure is demonstrated.

If an object contacts the piezoelectric sensor 1 directly or indirectly or a vibration is applied, the piezoelectric sensor 1 will deform|transform,

The electric charge according to the acceleration of the deformation|transformation generate|occur|produces.

A variation of the generate|occur|produced electric charge is inputted into the inverting-input terminal of an operational amplifier **4** via the **1st** capacitor|condenser **3**.

[0035] Under the present circumstances, since only the alternating-current component of the electric-charge variation produced in the piezoelectric sensor **1** by the **1st** capacitor|condenser **3** is inputted into an operational amplifier **4** and the direct-current|flow component of the voltage V_d between the **1st** resistor **2** and the **2nd** resistor **7** is not inputted into an operational amplifier **4**

The output V_o of an operational amplifier **4** sticks to the reference(standard) electric potential V_b , or is not saturated.

And the operational amplifier **4** forms charge amplifier,

Therefore

About a generating electric charge, if the electrostatic capacitance of Q and the **2nd** capacitor|condenser **8** is set to C_f , Output V_o will become Q/C_f .

[0036] FIG. **4** is a characteristic view which shows the output V_o of the signal-processing apparatus of a piezoelectric sensor and the determination signal J_1 of the determination means **10** in FIG. **1**.

In the figure, in an order from a top, vertical axis|shafts are Output V_o and the determination signal J_1 , and a horizontal axis is Time t .

For example, if some piezoelectric sensors **1** are bent in the time t_1 vicinity, the signal according to the acceleration of the bending deformation|transformation of the piezoelectric sensor **1** will be output by the piezoelectric effect, and the signal which changes to a normal direction with respect to the reference(standard) electric potential V_b as shown in FIG. **4** will be obtained from the piezoelectric sensor **1** by Output V_o .

[0037] And if the bending deformation|transformation of the piezoelectric sensor **1** is returned in the time t_2 vicinity, the signal which changes to a negative direction with respect to the reference(standard) electric potential V_b will be obtained.

By the determination means **10**, the determination signal J_1 is set to H_i noting that the deformation|transformation more than predetermined intensity|strength will be applied to the piezoelectric sensor **1**, if amplitude $|V_o - V_b|$ from the reference(standard) electric potential V_b of Output V_o becomes in more than D_o .

[0038] Next, the case where the center electrode **1a** or the ground electrode **1c** of the piezoelectric sensor **1** was disconnected, or the center electrode **1a** and the ground electrode **1c** short-circuit is demonstrated using FIG. **5**.

FIG. **5** (a) is a characteristic view which shows the determination signal J_2 of the voltage V_d between the **1st** resistor **2** when the center electrode **1a** or the ground electrode **1c** is disconnected, and the **2nd** resistor **7**, and the abnormality-determination means **9**,

FIG.5(b) is a characteristic view which shows the determination signal J2 of the voltage Vd when the center electrode 1a and the ground electrode 1c short-circuit, and the abnormality-determination means 9.

In addition, both sides -- in the figure, in an order from a top, vertical axis|shafts are a voltage Vd and the determination signal J2, and a horizontal axis is Time t.

[0039] The center electrode 1a or the ground electrode 1c is the partial pressure voltage in which Vd is formed of the 1st resistor 2 and the 2nd resistor 7 between the voltage source Vs and the reference(standard) electric potential Vb in FIG. 5 (a) when normal.

It is set to Va,

However,

If the center electrode 1a or the ground electrode 1c is disconnected in the time t3 vicinity, Vd will change from Va to Vs.

[0040] Moreover, if the center electrode 1a and the ground electrode 1c short-circuit in FIG.5(b) in the time t4 vicinity, a voltage Vd will change from Va to Vb.

And by the abnormality-determination means 9, the determination signal J2 is set to Hi noting that abnormality, such as a disconnection and a short circuit, will generate|occur|produce in the piezoelectric sensor 1, if amplitude |Vd-Va| from Va of a voltage Vd is D 1 or more.

[0041] Thus, based on a voltage Vd, abnormality, such as a disconnection and a short circuit, is detectable in the piezoelectric sensor 1,

Therefore

The drive circuit for generate|occur|producing the conventional drive signal which vibrates a piezoelectric material is unnecessary,

The need also of the drive current for vibrating a piezoelectric material is lose|eliminated.

[0042] Since only the alternating-current component of the electric-charge variation produced in the piezoelectric sensor 1 by the 1st capacitor|condenser 3 is inputted into an operational amplifier 4 by said effect|action and the direct-current|flow component of the voltage between the 1st resistor 2 and the 2nd resistor 7 is not inputted into an operational amplifier 4

It becomes possible to determine abnormality, such as a disconnection of the electrode of the piezoelectric sensor 1, and a short circuit, based on the voltage between the 1st resistor 2 and the 2nd resistor 7,

It is simple and abnormality, such as a disconnection of a piezoelectric sensor and a short circuit, can be determined by few|small structure of a consumption current.

[0043] Moreover, the example of a structure which determines abnormality called the disconnection and short circuit about the cable shaped piezoelectric sensor which uses charge amplifier for a signal processing is hardly found conventionally,

However,

The structure which uses charge amplifier in this Embodiment by connecting the 1st resistor 2 between the electrodes of the front-end|tip part 1e of the cable shaped piezoelectric sensor 1

WHEREIN:

Abnormality, such as a disconnection of the cable shaped piezoelectric sensor 1 and a short circuit, can be determined.

[0044] Moreover, the signal-processing board|substrate part 11 provided with an operational amplifier 4, the 1st capacitor|condenser 3, the 2nd capacitor|condenser 6, the 2nd resistor 7, and the abnormality-determination means 9 and the determination means 10 is incorporated in the shield means 12 which consists of metal casing, and is shielded electrically,

Therefore

The influence of electrical noise can be decreased and reliability improves.

[0045] In addition, in this Embodiment, an operational amplifier 4, the 1st capacitor|condenser 3, the 2nd capacitor|condenser 6, the 2nd resistor 7, and all the components of the abnormality-determination means 9 and the determination means 10 are provided at the signal-processing board|substrate part 11,

However,

It is a thing which may provide at least one.

[0046] (Embodiment 2)

2nd Embodiment in the signal-processing apparatus of the electric-charge variation type|mold sensor of this invention is demonstrated with reference to FIG. 6.

FIG. 6 is a block diagram of the signal-processing apparatus of the piezoelectric sensor used as an electric-charge variation type|mold sensor in the 2nd Embodiment of this invention.

In this Embodiment, the ground electrode 1c of the piezoelectric sensor 1 is connected to the gland|grand|ground as a reference(standard) electric potential, and the non-inversion input terminal of an operational amplifier 4 is different from 1st Embodiment shown in FIGS. 1-5 at the point connected to the predetermined bias voltage Vb,

The same code as 1st Embodiment is attached to the structure with the same effect of other than that,

It demonstrates centering on a different place.

[0047] Only the alternating-current component of the electric-charge variation produced in the piezoelectric sensor 1 by the 1st capacitor|condenser 3 like Embodiment 1 is inputted into an operational amplifier 4 by said structure.

Since the direct-current|flow component of the voltage between the 1st resistor 2 and the 2nd resistor 7 is not inputted into an operational amplifier 4, it becomes possible to determine abnormality, such as a disconnection of the electrode of the piezoelectric sensor 1, and a short circuit, based on the voltage between the 1st resistor 2 and the 2nd resistor 7,

It is simple and abnormality, such as a disconnection of the piezoelectric sensor 1 and a short circuit, can be determined by few|small structure of a consumption current.

[0048] Moreover, the ground electrode 1c is connected to the gland|grand|ground as a reference(standard) electric potential,

Therefore

The dynamic range of the voltage Vd when a disconnection and short circuit of the piezoelectric sensor 1 generate|occur|produce can take more widely than Embodiment 1,

Therefore

The reliability of the abnormality determination in the abnormality-determination means 9 improves.

[0049] (Embodiment 3)

3rd Embodiment in the signal-processing apparatus of the electric-charge variation type|mold sensor of this invention is demonstrated with reference to FIG. 7 (a), (b). FIG. 7 (a) is a block diagram of the signal-processing apparatus of the piezoelectric sensor used as an electric-charge variation type|mold sensor in the 3rd Embodiment of this invention, and FIG.7(b) is a schematic sectional drawing of a piezoelectric sensor.

[0050] In this Embodiment, the point which is different from 1st Embodiment 1 and 2nd Embodiment

The 1st return electrode 1i with which the connection side with an operational amplifier 4 is connected with the center electrode 1a in the front-end|tip part 1e of a reverse side, and the piezoelectric sensor 1 is extended to the connection side to an operational amplifier 4,

The 2nd return electrode 1j that is connected with the ground electrode 1c in the front-end|tip part 1e, and is extended to the connection side with an operational amplifier 4 is provided,

It exists in the point which connected the 1st resistor 2 in the connection edge part (on the signal-processing board|substrate part 11) to an operational amplifier 4 between the 1st return electrode 1i and the 2nd return electrode 1j,

The same code as 1st Embodiment 1 and 2nd Embodiment is attached to the structure with the same effect of other than that,

It demonstrates centering on a different place.

[0051] In addition, the 1st return electrode 1i adjoined to the ground electrode 1c, and the 2nd return electrode 1j adjoined an outer side or inside (this Embodiment said outer side) the ground electrode 1c, and it has provided it at the piezoelectric material 1b again.

And the 1st return electrode 1i and the 2nd return electrode 1j are put and formed in the position simultaneously described above at the time of manufacture of the above-mentioned piezoelectric sensor 1.

[0052] By said structure, the 1st resistor 2 can be arranged on the signal-processing board|substrate part 11 with the 1st return electrode 1i and the 2nd return electrode 1j,

Therefore

The 1st resistor 2 is connected to the front-end|tip part 1e like the piezoelectric sensor 1 of the 1st and 2nd Embodiment,

When it is not necessary to insulate and to take a complicated structure which is shielded, the outer diameter of the front-end|tip part 1e can be made smaller,

Therefore

The degrees of freedom of an arrangement of the piezoelectric sensor 4 improves more.

[0053] In addition, in FIG. 7 (a), this Embodiment is shown in the example linked to the signal-processing board|substrate 1 shown in FIG. 1,

However,

Even if it connects with the signal-processing board|substrate part 11 shown in FIG. 6, an effect equivalent to this Embodiment is expectable.

[0054] (Embodiment 4)

4th Embodiment in the signal-processing apparatus of the electric-charge variation type|mold sensor of this invention is demonstrated with reference to FIG. 8.

FIG. 8 is a block diagram of the signal-processing apparatus of the piezoelectric sensor used as an electric-charge variation type|mold sensor in the 4th Embodiment of this invention.

In this Embodiment, the piezoelectric sensor 1 is equipped with the connection part 21 with the coaxial cable 20, and the point which is different from the 1st - 3rd Embodiment has it in the point connected with the operational amplifier 4 via the coaxial cable 20,

The same code as the 1st - 3rd Embodiment is attached to the structure with the same effect of other than that,

It demonstrates centering on a different place.

[0055] Even if there exists an area|region which receives the influence of unnecessary vibration noise in said product by said structure, for example when the piezoelectric sensor 1 is mounted in a product, it can be made the structure which arranges the coaxial cable 20 at the area|region, and the noise signal by vibration noise does not generate|occur|produce,

The degrees of freedom of the layout at the time of mounting in a product improves. Moreover, even if a disconnection and a short circuit arise in not only the piezoelectric sensor **1** but the coaxial cable **20**, or the connection part **21**, based on a variation of V_d , a disconnection and a short circuit can be determined by the abnormality-determination means **9**,
Therefore
Reliability improves.

[0056] In addition, in FIG. **8**, this Embodiment is shown in the example linked to the signal-processing board|substrate **1** shown in FIG. **1**.
Even if these connect with each signal-processing board|substrate part **11** shown in FIG. **6** and FIG. **7**, an effect equivalent to this Embodiment is expectable.

[0057] (Embodiment **5**)
5th Embodiment in the signal-processing apparatus of the electric-charge variation type|mold sensor of this invention is demonstrated with reference to FIG. **9**.

[0058] FIG. **9** is a block diagram of the signal-processing apparatus of the piezoelectric sensor used as an electric-charge variation type|mold sensor in the 5th Embodiment of this invention.
In this Embodiment, the point which is different from the 1st - 4th Embodiment is one of the points which formed the polarization area|region **31** and the non-polarization area|region **32** in the piezoelectric material **1b** of the piezoelectric sensor **1**,
The same code as the 1st - 4th Embodiment is attached to the structure with the same effect of other than that,
It demonstrates centering on a different place.

[0059] The said structure
WHEREIN:

As a formation method of the polarization area|region **31** and the non-polarization area|region **32**, the extruding processing of the piezoelectric material **1b** was carried out to the piezoelectric material **1b** which is the center electrode **1a** of the piezoelectric sensor **1** around the center electrode **1a**,
Then, when applying a several kilovolts DC voltage between the center electrode **1a** and the pseudo|simulation electrode made to contact the surface of the piezoelectric material **1b** and performing the polarization of the piezoelectric material **1b**, it can implement|achieve by making the area|region which does not make a pseudo|simulation electrode contact the surface of the piezoelectric material **1b**.

[0060] Under the present circumstances, a magnetic coating material is applied to the boundary part **30** of the polarization area|region **31** and the non-polarization area|region **32** as a marker, or the magnetic tape is wound.
A magnetism also permeate|transmits a band electrode with an aluminum film|membrane,

Therefore

A band electrode with the aluminum film|membrane stated to the circumference|surroundings of the piezoelectric material **1b** in **1st** Embodiment is wound, and the ground electrode **1c** is formed,

Furthermore, even if it forms **1d** of coating layers from on the ground electrode **1c**, it is practical, if the position of a marker can be pinpointed from on **1d** of coating layers with a magnetic sensor and the marker of the boundary part **30** is given to the position which is **1d** of identify|isolated said coating layers.

In addition, a predetermined vibration is applied from on the coating layer **1d**, shifting a position,

The amplitude of V_0 at that time may use the specification|determination method which makes a boundary part the point which changes a lot.

[0061] Even if there exists an area|region which receives the influence of unnecessary vibration noise in said product by said structure when the piezoelectric sensor **1** is mounted in a product, it becomes possible to make it the structure which arranges the non-polarization area|region **32** of the piezoelectric sensor **1** at the area|region, and the noise signal by vibration noise does not generate|occur|produce, Even if it does not use a coaxial cable like **4th** Embodiment, the degrees of freedom of the layout at the time of mounting in a product improves.

[0062] In addition, in FIG. **9**, this Embodiment is shown in the example linked to the signal-processing board|substrate part **11** shown in FIG. **1**,

However,

Even if it connects with each signal-processing board|substrate part **11** shown in FIG.**6** and FIG.**7**, an effect equivalent to this Embodiment is expectable.

[0063] In addition, the piezoelectric sensor is made into object in each said Embodiment,

However,

It is sufficient to apply this invention with respect to sensors of an electric-charge variation type|mold, such as an electrostatic-capacitance type|formula and a frictional-electricity system.

[0064] INDUSTRIAL APPLICATION

As mentioned above, the signal-processing apparatus of the electric-charge variation type|mold sensor concerning this invention is a signal-processing apparatus of the electric-charge variation type|mold sensor which uses charge amplifier.

WHEREIN:

The signal-processing apparatus which detects the abnormality of an electric-charge variation type|mold sensor by the structure which is simple and has few|small consumption currents can be provided,

Therefore

For example, it can apply to various devices and apparatuses, and the system which applied the piezoelectric sensor as an electric-charge variation type|mold sensor. Especially a cable shaped piezoelectric sensor in the case of the application to be used when the full length of a piezoelectric sensor is comparatively short.

If charge amplifier is used, a signal attenuation in a low-frequency region will occur with electrostatic-capacitance C_s of a piezoelectric sensor, and the high-pass filter of the cutoff frequency $f_c (=1/(2\pi \cdot C_s \cdot R))$ formed by the resistance R connected in parallel with a piezoelectric sensor,

Therefore

There exists a merit which uses charge amplifier.

And in the application as which especially reliability is request|required, abnormality determinations, such as a disconnection of a piezoelectric sensor and a short circuit, are calculated|required,

Therefore

An application of this invention can be performed.

For example, the application to an insertion|trapping detection with the power sliding door and power hatchback of a motor vehicle, the penetration|invasion sensor for crime prevention, etc., the application as a switch, and the application to the micro movement detection which synchronized with the heart rate in a bed or respiration can be performed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0065]

FIG. 1: The block diagram of the signal-processing apparatus of the electric-charge variation type|mold sensor in Embodiment 1 of this invention

FIG. 2: Sectional drawing of the piezoelectric sensor 1 in AA line|wire of FIG. 1

FIG. 3: Sectional drawing of the front-end|tip-part 1e vicinity of the piezoelectric sensor 1 in Embodiment 1 of this invention

FIG. 4: The characteristic view which shows the output V_o of the operational amplifier 4 of the signal-processing apparatus of a piezoelectric sensor and the determination signal J1 of the determination means 10 in Embodiment 1 of this invention

FIG. 5: (a) Determination signal J2 of voltage V_d between 1st resistor 2 when center electrode 1a or ground electrode 1c of piezoelectric sensor 1 in Embodiment 1 of signal-processing apparatus of electric-charge variation type|mold sensor is disconnected, and 2nd resistor 7, and abnormality-determination means 9 of this invention

Characteristic view (b) to show Characteristic view which shows the determination signal J2 of the voltage Vd when the center electrode 1a and the ground electrode 1c of the piezoelectric sensor 1 similarly short-circuit, and the abnormality-determination means 9

FIG. 6: The block diagram of the signal-processing apparatus of the electric-charge variation type|mold sensor in the 2nd Embodiment of this invention

FIG. 7: (a) Schematic sectional drawing of piezoelectric sensor as block-diagram (b) electric-charge variation type|mold sensor of signal-processing apparatus of electric-charge variation type|mold sensor in 3rd Embodiment of this invention

FIG. 8: The block diagram of the signal-processing apparatus of the electric-charge variation type|mold sensor in the 4th Embodiment of this invention

FIG. 9: The block diagram of the signal-processing apparatus of the electric-charge variation type|mold sensor in the 5th Embodiment of this invention

DESCRIPTION OF SYMBOLS

[0066] 1 piezoelectric sensor (electric-charge variation type|mold sensor)

1a center electrode

1b piezoelectric material

1c ground electrode

1e front-end|tip part

The return electrode of 1i 1st

The return electrode of 1j 2nd

The resistor of 2 1st

The capacitor|condenser of 3 1st

Four operational amplifiers

The capacitor|condenser of 6 2nd

The resistor of 7 2nd

Nine abnormality-determination means

11 signal-processing board|substrate part

20 coaxial cables

21 connection parts

31 polarization area|region

32 non-polarization area|region

[Claims]

1. The electric-charge variation type|mold sensor which has several electrodes,

It has the non-inversion input terminal which connected at least one to the inverting-input terminal connected to one electrode of said electric-charge variation type|mold sensor via the 1st capacitor|condenser, and the other electrode of said electric-charge variation type|mold sensor, or a reference(standard) electric potential, The operational amplifier which connected the 2nd capacitor|condenser between said inverting-input terminal and the output terminal,
 The 1st resistor connected between the electrodes of said electric-charge variation type|mold sensor, and the 2nd resistor connected between the predetermined voltage source and said 1st resistor,
 The signal-processing apparatus of the electric-charge variation type|mold sensor provided with an abnormality-determination means to determine the abnormality of the electrode of said electric-charge variation type|mold sensor based on the voltage between said 1st resistor and said 2nd resistor.

2. An electric-charge variation type|mold sensor comprises a piezoelectric sensor,
 The said piezoelectric sensor is a center electrode connected to an inverting-input terminal via the 1st capacitor|condenser,
 The piezoelectric material formed in the circumference|surroundings of said center electrode,
 While shape|molding in the shape of a coaxial cable, the ground electrode which is formed in the circumference|surroundings of said piezoelectric material and is connected to at least one of a non-inversion input terminal or a reference(standard) electric potential
 The connection side with an operational amplifier is a signal-processing apparatus of the electric-charge variation type|mold sensor of Claim 1 which connected the 1st resistor between said center electrode and said ground electrode in the front-end|tip part of a reverse side.

3. An electric-charge variation type|mold sensor comprises a piezoelectric sensor,
 The said piezoelectric sensor is a center electrode connected to an inverting-input terminal via the 1st capacitor|condenser,
 The piezoelectric material formed in the circumference|surroundings of said center electrode,
 While shape|molding the ground electrode which is formed in the circumference|surroundings of said piezoelectric material and is connected to at least one of a non-inversion input terminal or a reference(standard) electric potential in the shape of a coaxial cable
 The connection side with an operational amplifier is 1st return electrode that is connected with said center electrode in the front-end|tip part of a reverse side, and is extended to the connection side to said operational amplifier,
 The 2nd return electrode that is connected with said ground electrode in said front-end|tip part, and is extended to the connection side with said operational amplifier is provided,

The signal-processing apparatus of the electric-charge variation type|mold sensor of Claim **1** which connected the **1st** resistor between said **1st** return electrode and said **2nd** return electrode in the connection edge part to said operational amplifier.

4. A piezoelectric sensor is a signal-processing apparatus of the electric-charge variation type|mold sensor of Claim **2** or **3** which was equipped with the connection part with a coaxial cable, and was connected with the operational amplifier via said coaxial cable.

5. The signal-processing apparatus of the electric-charge variation type|mold sensor of Claim **2** or **3** which formed the polarization area|region and the non-polarization area|region in the piezoelectric material.

6. An operational amplifier, the **1st** capacitor|condenser, the **2nd** capacitor|condenser, the **2nd** resistor, and the signal-processing board|substrate part provided with at least one with an abnormality-determination means,
The shield means which shields said signal-processing board|substrate part electrically
The signal-processing apparatus of the electric-charge variation type|mold sensor of any one of Claims **1-5** provided with these.

7. One electrode of the electric-charge variation type|mold sensor provided with several electrodes is connected to the inverting-input terminal of an operational amplifier via the **1st** capacitor|condenser,
The other electrode of said electric-charge variation type|mold sensor is connected to the non-inversion input terminal of said operational amplifier, or at least one of a reference(standard) electric potential,
While connecting the **2nd** capacitor|condenser between the inverting-input terminal of said operational amplifier, and an output terminal, the **1st** resistor is connected between the electrodes of said electric-charge variation type|mold sensor,
The **2nd** resistor is connected between a predetermined voltage source and said **1st** resistor,
The signal-processing method of an electric-charge variation type|mold sensor of determining the abnormality of said electrode based on the voltage between said **1st** resistor and said **2nd** resistor.