(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
17 May 2018 (17.05.2018)

WIPO | PCT

(10) International Publication Number
WO 2018/087039 A1

(51) International Patent Classification:
H04L 12/28 (2006.01) ***H04Q 9/00*** (2006.01)
H04L 12/40 (2006.01) ***H04L 29/08*** (2006.01)

(21) International Application Number:
PCT/EP2017/078322

(22) International Filing Date:
06 November 2017 (06.11.2017)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
16198116.2 10 November 2016 (10.11.2016) EP

(71) Applicant: **PHILIPS LIGHTING HOLDING B.V.** [NL/NL]; High Tech Campus 45, 5656 AE Eindhoven (NL).

(72) Inventors: **RADERMACHER, Harald, Josef, Günther**; c/o High Tech Campus 45, 5656 AE Eindhoven (NL). **WENDT, Matthias**; c/o High Tech Campus 45, 5656 AE Eindhoven (NL). **ZONDAG, Eduard, Gerhard**; c/o High Tech Campus 45, 5656 AE Eindhoven (NL). **BOEKE, Ulrich**; c/o High Tech Campus 45, 5656 AE Eindhoven (NL).

(74) Agent: **VAN EEUWIJK, Alexander, Henricus, Walterus** et al.; Philips Lighting B.V., Intellectual Property, High Tech Campus 45, 5656 AE Eindhoven (NL).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

(54) Title: PASSIVE SENSOR DEVICES IN A WIRED COMMUNICATION NETWORK

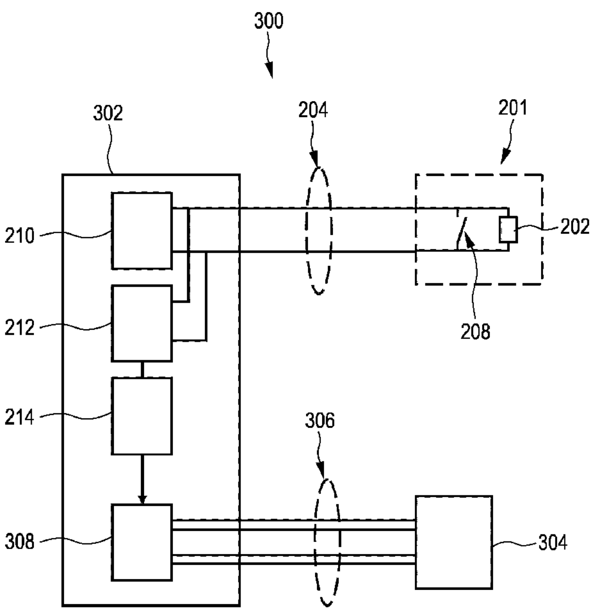

FIG. 3

(57) Abstract: A sensor solution for communication networks is provided. A network switch provides, via a wired protocol-communication channel terminated by a passive sensor device, an output message with an output signal on a physical layer in accordance with a protocol used for data communication, and also including higher-level protocol data. A response monitoring unit is configured to monitor the wired protocol-communication channel for only a physical-layer response receivable from the external sensor device in response to the output message. A sensor response interpreter allocates the received physical-layer response to a prestored sensor response template, the prestored sensor response template being allocated to a predefined state of the external sensor device, and outputs a sensor-state signal indicative of the current state of the external sensor device.

WO 2018/087039 A1

[Continued on next page]

Declarations under Rule 4.17:
— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:
— *with international search report (Art. 21(3))*

PASSIVE SENSOR DEVICES IN A WIRED COMMUNICATION NETWORK

FIELD OF THE INVENTION

The present invention is in the field of sensing via a wired protocol-communication channel. In particular, the invention is related to an electrical arrangement comprising a network switch device, a passive sensor device, and a sensor-response interpreter. The invention is further related to a sensor-response interpreter, to a network switch device, to a method for determining a sensor-device state of a passive sensor device, and to a method for operating an electrical arrangement. The invention can be applied, among others, in the field of sensor-based control via a wired protocol-communication channel.

BACKGROUND OF THE INVENTION

US 7,565,211 B2 describes systems and methods that allow for communication between an Ethernet network and non-Ethernet devices. An Ethernet-to-analog adapter allows a translation of analog signals for Ethernet communication, and further allows a translation of Ethernet signals for analog communication with analog devices. Ethernet-to-analog adapters allow for power management and monitoring of attached devices and employ Power over Ethernet (PoE) to supply power to analog devices.

US 2016/0066068 A1 describes an environmental monitor device with a database that comprises a data bus, a multitude of sensors, at least one processing unit, input/output device(s); communications interface(s), and memory. Communications interface(s) communicate with at least one environmental sensor device comprising with a multitude of sensors. The multitude of sensors may include particle counter(s), pressure sensor(s) and/or the like. The memory is configured to hold data and machine executable instructions. The machine executable instructions are configured to cause at least one processing unit to: collect sensor data from at least one environmental sensor device; store at least some of the sensor data in at least one database; and generate a report of sensor data that exceeds at least one threshold.

US 3,544,806 describes a vehicular electrical system that has power distribution line and a signal distribution line that are disposed throughout a vehicle and connected to control and function performing stations. A master sequencer emits signals over the signal line for sequentially addressing sets of stations, each set of stations having one station emitting a control or indicating signal to a corresponding function performing station. Control and indicating signals are transferred over the signal line intermediate successively occurring address signals. Pulsating power is supplied over the power line and is used to synchronize the station addressing. DC power is distributed over a third line. Stations may have a memory capability.

WO 2016/034773 A1 describes a radio frequency identification (RFID) system that comprises a radio frequency identification reader and at least one passive RFID sensor tag. A backscattered radio frequency signal from the passive RFID tag is modulated with an oscillation frequency which is dependent on a value of a quantity sensed by a sensing element. The RFID reader (11) converts converting the oscillation frequency of the backscattered signal into an actual value of the sensed quantity based on predetermined sensor configuration information of the passive RFID sensor tag. The sensor configuration information includes information on a sensor element or sensor elements available in the passive RFID sensor tag, and particularly information how to convert the oscillation frequency of the backscattered signal into actual values of the quantity sensed by the respective sensing element.

US 2016/0183351 A1 describes a system, method, and apparatus for powering intelligent lighting networks. The power for the intelligent lighting network is supplied by Power-over-Ethemet (PoE) switches and/or Mid-Spans, which are conditioned by a powered device to distribute power tuned specifically for each, at least one light emitting diode (LED) fixture. The Power-over-Ethernet switch and/or Mid-Span with associated router and wireless access point can be used to communicate with, and power a sensor network that collects data relevant to the intelligent lighting network. Optionally, the Power-over-Ethemet switch and/or Mid-Span can be used to communicate with, and power a network of sensors that collects data relevant to the space the intelligent lighting network is operating in, or can be used to communicate with and power a network of AC wall plugs that can be turned on and off, and various switches, relays, and PECs, RFID systems, USB hubs, etc

SUMMARY OF THE INVENTION

It is an object of the present invention to improve, in a wired communication network that uses a plurality of protocol layers according to the OSI reference model for communication, the monitoring of a sensor device.

In order to facilitate and expedite the understanding of the present invention, the following description will first turn to method aspects, before device aspects of the invention will be explained.

According to a first aspect of the invention, a method for determining a sensor-device state of a passive sensor device comprises:

- providing the passive sensor device, which assumes a respective one of a plurality of predetermined sensor states at a given point in time in dependence on a current value of a quantity to be measured, as a termination to a wired protocol-communication channel such that a physical-layer response receivable from the wired protocol-communication channel in response to an output message, which is fed into the wired protocol-communication channel in accordance with a communication protocol requiring protocol data according to at least one second protocol layer higher than the physical layer, forms a sensor signal indicative of a sensor state currently assumed;
- providing a set of prestored sensor response templates, which are indicative of respective physical-layer responses receivable from the wired protocol-communication channel in response to the output message for respective different defined sensor states of the passive sensor device, the different sensor response templates being allocated to the respective different defined sensor states of the passive sensor device;
- providing an output message, which is fed into the wired protocol-communication channel in accordance with the communication protocol and comprises protocol data according to at least one second protocol layer higher than the physical layer;
- monitoring the wired physical protocol-communication channel for only the physical-layer response receivable from the sensor device in response to the output message and providing sensor response data indicative of the received physical-layer response;
- comparing and, based on the comparison, allocating the sensor response data to one of the set of prestored sensor response templates; and
- providing a sensor-state signal indicative of the sensor state of the passive sensor device thus allocated.

Thus, a passive sensor device is used for providing termination to a wired protocol communication channel. Termination of the wired protocol communication channel in the sense of the present specification means that the passive sensor device provides a physical-layer transit point or a physical-layer end point, which, depending on a currently assumed sensor state of the passive sensor device providing the termination, has one effect from a pre-defined set of different possible effects on the physical-layer response of the wired protocol-communication channel to an output message fed into the wired protocol-communication channel. The passive sensor device may thus also be referred to as a terminator device of variable termination effect, wherein a current termination effect which depends on the current sensor state. As non-limiting examples provided for the purpose of illustrating this point, depending on its currently assumed state (which in turn depends on a quantity to be sensed), the passive sensor device of one embodiment will or will not cause an open circuit, in another embodiment a short circuit, in a third embodiment an end point of the wired protocol communication channel with a matching impedance, or in yet another embodiment a channel loop between a transmission channel and a reception channel of the wired protocol communication channel. Based on a monitoring of only a physical-layer response receivable from the wired protocol communication channel for a given output message and based on an allocation of the physical-layer response to sensor response templates, a sensor-state signal is provided that is indicative of the momentaneous state of the passive sensor device, which thus allows determining the momentaneous value of the quantity to be measured.

The method does not require processing of a sensor response on higher protocol layers than the physical layer. Regarding the use of the term protocol layer and regarding names of the different protocol layers, reference is made to the well-known Open Systems Interconnection (OSI) model for communication in telecommunication and computing. The physical protocol layer, or in short, physical layer, specifies the physical characteristics of protocol-compliant communication. For instance, it defines a physical interface and physical signal characteristics required for using the wired protocol communication channel as a physical transmission medium for communicating output messages between, e.g., a network switch device and another device, such as a network device such as a luminaire controlled by the network switch device.

Output messages that in operation are provided by the network switch device via the wired protocol-communication channel are in accordance with not only a physical protocol layer, but additionally with at least one higher protocol layer of a protocol used for data communication between the network communication device and the powered devices. Thus, providing an output in the form of signals without adherence to a protocol that also includes protocol layers higher than the physical layer is not considered as providing an output message in accordance with the present invention.

In accordance with the present invention, a protocol used for providing the output messages via the protocol-communication channel allows performing a measurement of a current value of the quantity to be measured using the passive sensor device on only the physical layer. This means that for the purpose of a measurement according to the present invention only the reception of the physical layer response via the wired protocol communication channel is monitored, regardless of any protocol data or of any payload data (if present) comprised by the output message. Interpreting any of the protocol data it contains on any higher protocol layer or any payload data it may convey is not required for making a measurement using the passive sensor device. In other words, generally, an arbitrary output message may be fed into the wired protocol-communication channel for taking a measurement from the passive sensor device.

The term “output message” is deliberately chosen in the context of the present specification for distinction from the provided output signal. The latter is restricted to the physical layer, while the former also covers all used protocol layers higher than the first protocol layer. In other words, the output signal serves to convey the output message. The protocol data are in accordance with the used protocol on at least the second layer of the OSI model, but may in addition cover further layers of the protocol.

Passive sensor devices form a subset of passive electrical components, which are passive in the sense of being incapable of controlling electrical current by means of another electrical signal. The passive sensor device can advantageously be formed by, or comprise, any device that is capable of providing a physical-layer response to the output message, which response allows meaningfully distinguishing between different states assumed by the external sensor device in response to a currently given situation. Resistors, capacitors, inductors, transformers, and even diodes are only a few examples of passive devices. Depending on the quantity to be measured, any passive device that, when used for terminating the wired protocol-communication channel, provides a physical-layer response to the output message, which response is indicative of a current value of the desired quantity to be measured, can be used in the context of the present invention. A simple example of a suitable passive sensor device is a light-dependent resistor (photoresistor). Other examples of suitable passive sensor devices for different application cases will be given further below by way of the description of embodiments.

Since according to the present invention the monitoring and evaluation of the passive sensor device is based only on the physical layer response to the output message via the wired protocol-communication channel terminated by the passive sensor device, data processing on any of the second and higher protocol layers of the protocol is not required for ascertaining the currently assumed state of the passive sensor device and thus determining the current value of the quantity to be measured. Any processing on the second and any further protocol layer of the OSI layer may thus performed in parallel for other purposes of data communication or may be omitted completely. In both cases, data processing resources on the second and any higher protocol layer are used in a very efficient way.

Furthermore, the technological complexity of the passive sensor device in terms of communication and data processing capacity can be reduced to the minimum. In this way, the functionality of the network communication device is expanded by allowing the use of passive sensor devices that do not comply with the protocol.

In the following, embodiments of the method of the first aspect of the invention will be described.

The provided sensor-state signal enables a variety of application scenarios such as, but not limited to, informing a user about the detected state of the external sensor device via a user interface of the network communication device, or controlling operation of at least one of the external powered devices connected to the network communication device in dependence on the allocated state of the external sensor device.

According to embodiments of the invention, the output messages used for making a measurement with the passive sensor device thus comprise at least protocol data, in some embodiments suitably both protocol data and payload data, according to at least one second protocol layer that according to the OSI model is higher than the physical layer. The protocol data of the output messages serves different control functions of data communication. On the second layer of the OSI mode, these functions for instance include defining the given protocol, establishing, controlling and terminating data communication with one or more network devices, such as controlled network devices, powered network devices etc. Protocol data in some embodiments for instance includes header data or overhead data used for enabling delivery of payload data. The payload data usually encodes an actual intended message to be conveyed by the output message. As indicated, an inclusion of payload data in the output message forms an embodiment, but not a necessary requirement of the present invention.

Based on at least one prestored sensor response template and on an allocation of a respective one of these templates to a respective one of a plurality of predefined states of the sensor device, identifies which one of the predefined states the external sensor device currently assumes. To give a simple illustrative example, a two-state switch can implement a very simple form of such a sensor device. The predefined states of some passive sensor devices thus may include an on-state and an off-state. Further examples of passive sensor devices have more than two predefined states resulting in a corresponding number of distinguishable prestored sensor response templates. Such states are in some illustrative embodiments indicative of distinct ranges of values assumed by a quantity measured by the sensor device. The measured quantity may be, but is not limited to, a temperature, a light intensity in a certain light-frequency range, a humidity or pressure of an ambient gaseous atmosphere, etc.

For providing the output message to and for assessing the physical-layer response from the wired protocol-communication channel terminated by the passive sensor device, a suitable network switch device may be used. According to the present invention a suitable network switch device comprises

- a communication unit configured to provide, via a wired protocol communication port and an external wired protocol-communication channel that is terminated by an external passive sensor device, an output message in the form of an output signal on a physical layer according the OSI reference model, in accordance with a protocol to be used for data communication, the output message also comprising protocol data according to at least one second protocol layer that according to the OSI reference model is higher than the physical layer; and
- a response monitoring unit, which is configured to monitor the wired physical protocol-communication channel for only a physical-layer response receivable from the external sensor device in response to the output message and to provide sensor response data indicative of the received physical-layer response.

For interpreting the physical-layer response, a specific sensor-response interpreter is provided in accordance with a second aspect of the invention, as will be explained in the following.

According to a second aspect of the invention, thus, a sensor-response interpreter is provided for interpreting sensor response data pertaining to an external passive sensor device, the passive sensor device providing termination to an external wired protocol-communication channel such that a physical-layer response receivable from the wired protocol-communication channel in response to an output message, which is fed into the wired protocol-communication channel in accordance with a communication protocol requiring protocol data according to at least one second protocol layer higher than the physical layer, forms a sensor signal indicative of a sensor state currently assumed. The sensor-response interpreter comprises:

- a response input unit, which is configured to receive the sensor response data that is indicative of the physical-layer response that has been received from the external wired protocol-communication channel terminated by the external passive sensor device in response to the output message;
- a response allocation unit, which is configured to compare and, based on the comparison, allocate the sensor response data to one of a set of prestored sensor response templates, which are indicative of respective physical-layer responses receivable from the wired protocol-communication channel in response to the output message for respective different defined sensor states of the passive sensor device, the different sensor response templates being allocated to the respective different defined sensor states of the external passive sensor device; and
- a sensor-state output unit, which is configured to provide a sensor-state signal indicative of the sensor state of the external passive sensor device thus allocated.

The sensor response interpreter according to the second aspect of the invention provides functionality required for interpreting the physical-layer response received via the wired protocol-communication channel terminated by the passive sensor device. It thus shares the advantages of the method of the first aspect of the invention.

In the following, embodiments of the sensor response interpreter will be described. The additional features of the sensor response interpreter form additional method features of embodiments the method of the first aspect of the invention.

The sensor-response interpreter can be implemented in an interpreter device on its own. In such embodiments, the response input unit forms an interface to an external network environment and is suitably configured to receive the sensor response data from an external network switch device that receives the physical-layer response in operating one of its wired protocol communication ports in a wired connection with the passive sensor device via the wired protocol-communication channel. The sensor response data can be provided from the network switch device to the sensor response interpreter via any suitable communication channel for data communication, be it a wired or a wireless communication channel. In one exemplary embodiment, the sensor-response interpreter is connected with the network switch device through one of the wired protocol communication ports that the network switch device provides.

In other embodiments the sensor-response interpreter is an integral part of a network switch device. In these embodiments, the sensor response data is provided to the sensor-response interpreter internally within the network switch device.

Prestored sensor response templates may be provided as stored data sequences representing an expected physical-layer response signal as a function of time. However, this is a rather elaborate embodiment. In simpler embodiments, the sensor response interpreter uses prestored sensor response templates that only distinguish between “response received” and “response not received”. In other embodiments, the sensor response templates determine, and thus distinguish between wired protocol-communication channels, on which the physical-layer response is received. For example, a sensor response template of this type would be “physical-layer response “xyz” received on wired transmission channel 1”, “physical-layer response “abc” received on wired reception channel 1”, etc. In yet other embodiments, the sensor-response interpreter uses sensor response templates that only determine (and distinguish between) times or time intervals measured from a suitable reference point in time, at which a physical-layer response is received via the wired protocol-communication channel. In general, thus, a sensor response template represents information on a suitable measurable feature of a physical-layer response receivable via the wired protocol-communication channel terminated by the passive sensor device.

It is an advantageous option, but not a necessary requirement to store the sensor response template in a memory. The memory can be implemented in different kinds, as a part of the sensor response interpreter or as a remote memory. The sensor response template is in other embodiments represented by circuitry that is provided in sensor-response interpreter and suitable for detecting or distinguishing between the predefined distinguishable and measurable features of the physical-layer response.

In some embodiments, the response input unit of the sensor-response interpreter is configured to receive a channel identifier in association with the response data, the channel identifier being suitable for identification of that wired protocol-communication channel among a plurality of wired protocol-communication channels, through which the physical-layer response was received. In these embodiments, the response allocation unit is configured to determine the respective defined sensor state of the external passive sensor device additionally using the received channel identifier. This embodiment allows for instance operating different passive sensor devices terminating different wired-protocol communication channels using different wired-protocol communication ports of the same network switch device.

In other embodiments of the sensor-response interpreter, the prestored sensor response template, which are physical-layer response templates, are indicative of reception or no reception of a reflected signal during a predetermined time span, and, in case of reception of the reflected signal, of a point in time within the predetermined time span at which the reflected signal has been received. Embodiments using templates of this kind are suitable for implementing a time-domain reflectometry technique for taking measurements using the passive sensor device.

In further embodiments of the sensor-response interpreter, at least two of the prestored sensor response templates are indicative, respectively, of reception or no reception of a reflected signal during provision of the output message. In such embodiments, the response allocation unit is configured to allocate the received physical-layer response to either a collision response template, which is indicative of a reflection signal detected in response to the output message during provision of the output message, or to a non-collision response template, which is indicative of no detected response to the output message on the wired protocol-communication channel during provision of the output message, and to determine the sensor state based on the allocation of the collision response template and the non-collision response template to respective sensor states.

The response allocation unit is in some embodiments configured to generate, upon determining the state of the external passive sensor device, an output command instructing the network switch to continue operation of the protocol communication port. These embodiments allow operation of existing some types of network switch devices in the context of the present invention. Such known network switch devices are often not configured to treat for instance a signal collision as a desired sensor response. Rather, they treat a signal collision as a signaling error that may lead to interrupting normal operation on a given wired protocol-communication port, to which a respective passive sensor device that forms a termination of the corresponding wired protocol-communication channel is connected. The present embodiment allows overruling this error assessment by the described output command.

The following description turns to further embodiments of a network switch device, which integrates a sensor-response interpreter according to the second aspect of the invention.

The network switch device as such is typically not configured to power an external powered network device, i.e., does not deliver electrical supply power required for operation of the external powered network device. The external powered network device may thus be powered by any suitable power source, including autonomous forms of power supply such as a battery or photovoltaic cells.

However, in the context of further embodiments, the network switch device additionally has the function of providing power, i.e., AC power or DC power, whichever is necessary according to powering requirements of a given external powered network device or whichever is necessary in the context of a given electrical arrangement containing the network switch device, the passive sensor device, and the external powered network device.

In some embodiments, the communication unit of the network switch device is configured to operate the wired protocol-communication channel in accordance with an Ethernet technology. Ethernet technology as such is well known in the art. In some embodiments the communication unit is configured to provide the output message in accordance with a protocol used for data communication with at least one external powered network device that is a DC-powered external network device. In preferred embodiments of this kind, the protocol is in accordance with a Power over Ethernet (PoE) technology, in particular as defined in one of the well-known PoE standards. This is particularly useful in applications that additionally serve for controlling power delivery to an external DC-powered network device, as will be described further below. The wired protocol-communication channel in such embodiments thus suitably comprises electrically conductive metal wires, as provided for instance by commercially available Ethernet cables, which are suitable for providing both, data communication and DC power.

However, in other embodiments the communication unit and response monitoring unit of the network switch device are configured to operate on optical fiber channels for transmitting and receiving optical signals in accordance with the claimed invention.

In yet other embodiments that involve AC power delivery to the external powered device, the network communication device is configured to provide the output message according to one of the well-known communication protocols involving a second or higher OSI protocol layer for communication via an AC power line.

In other embodiments, a plurality of identical or different kinds of wired protocol-communication channels is supported by the network switch device, with different kinds of physical layer support being provided by the communication unit for different kinds of wired protocol-communication channels, and with a respective response monitoring unit provided for each of the different wired protocol-communication channels.

In some embodiments, the communication unit of the network switch device is configured to provide output messages at predetermined times to the wired protocol-communication channel for communication with the external sensor device. The output messages can be used in such embodiments for probing, with the aim of determining a current state of the passive sensor device by monitoring the physical-layer response in response to the output message.

The wired protocol-communication channel may comprise either a single wire or a plurality of wires as a carrier for signal communication on the physical layer. In some embodiments, the communication unit is configured to operate the wired protocol-communication channel as a half duplex communication channel.

Furthermore, in these embodiments, the response monitoring unit preferably comprises a signal-collision detector that is configured to monitor the wired protocol-communication channel for only a physical-layer response receivable in response to the output message during provision of the output message.

The fact that the wired protocol-communication channel in the present group of embodiments is operated as a half duplex communication channel means that the physical layer response to the output message is received via the same individual wire, or, where applicable, the same individual wire pair that is used for transmission of the output message to the external sensor device. In this configuration, the response monitoring unit may detect the physical-layer response while the communication unit of the network switch device is still in the process of providing the output message to the wired protocol-communication channel. This situation is normally referred to as a “collision”. The occurrence of this situation is more likely if the output message is longer, for instance due to an inclusion of protocol data and potentially also payload data on higher layers of the protocol. As explained in the context of corresponding embodiments of the sensor-response interpreter, a prestored collision response template is provided for this case, which is indicative of such a reception of physical layer response to the output message even during the limited time span of provision of the output message. Such collision of the output message with its physical layer response can thus be identified, and the response allocation unit correspondingly is configured to allocate the received physical-layer response to such a collision response template. On the other hand, if during the provision of the output message to the wired protocol-communication channel no physical-layer response is detected, the response allocation unit is configured to allocate this received alternative physical-layer response to a prestored non-collision response template.

These embodiments are particularly suitable for application in combination with a passive sensor device that terminates the wired protocol-communication channel and that, depending on the state of the passive sensor device, does reflect or does not reflect at least a part of the output signal provided by the network switch device and forming the output message. A push-button terminating the wired-protocol communication channel used for the transmission of the output message and configured in one of its states to electrically by-pass a resistive load that has a value matching an impedance value of the individual wire or individual wire-pair of the wired protocol-communication channel forms an example of such a passive sensor device. If the push-button is currently in a state not by-passing the resistive load of the passive sensor device, there is an impedance match between the passive sensor device and the wired protocol-communication channel operating as a half-duplex communication channel. In this case the output signal of the output message will not be reflected at the passive sensor device and the physical-layer response will be formed by "no reflection" received by the response monitoring unit of the network switch device.

The response allocation unit of the sensor-response interpreter allocates in this case the lack of detected physical-layer response to the corresponding non-collision response template that is indicative of the "non-by-passing" state of the push-button. On the other hand, if the push-button is in a state which is configured to electrically by-pass the resistive load, there will be an impedance mismatch between the individual wire or the individual wire-pair and the sensor device. When an output message is provided, at least a part of the output signal forming the output message will be reflected at the passive sensor device due to the impedance mismatch, and a reflection signal will be received as the physical-layer response at the response monitoring unit, and will be allocated by the response allocation unit to a corresponding prestored collision response template indicative of the "by-passing" state of the push-button.

In these embodiments, a time duration of the output message and a length (geometrical extension) of the wired protocol-communication channel have to be suitably chosen so as to guarantee that, in case a reflected signal is provided from the passive sensor device in response to the output signal, the reflected signal will be received by the response monitoring unit of the network switch device while the communication unit is still providing the output signal. This can for instance be done by providing the output message with a suitable amount of payload data, which may be extended by dummy payload data in case no actual payload data is currently scheduled for transmission in the context of performing a given application task.

In some embodiments, the signal-collision detector of the response monitoring unit of the network switch device is configured to execute a media access control method such as, but not limited to, carrier sense multiple access with collision detection (CSMA/CD).

This media access control method is per se known and uses a carrier sensing scheme. In typical known network switch devices using a half-duplex communication channel, the detection of a collision using such known media access control method causes an immediate termination of the transmission of the output message. The transmission of the output message is in such known application cases retried after a predetermined time. According to embodiments of the present invention, however, such detection of a collision is employed in addition, to obtain an indication of the state of the external sensor device, and can thus be used for control action based on the detected state of the external passive sensor device. Thus, for the purpose of detecting the current state of the external sensor device, a detection of a collision in response to the output message need not necessarily require a retransmission, which is therefore omitted in some variants of the present embodiment. As mentioned above, such embodiments involve exceptional control operation by the sensor-response interpreter for overriding a retransmission attempt via the wired protocol communication channel that would normally be initiated by a network switch device in such collision situations if the channel was not terminated by the passive sensor device in accordance with the present invention.

These embodiments of the network communication device advantageously achieve operation with external sensor devices that have allowed states that can be allocated to distinguishing the cases of reception of a signal or no reception of a signal as the physical-layer response to the output message.

In other such embodiments, where the communication unit is also configured to operate the wired protocol-communication channel as a half-duplex communication channel, an extension of the time span of response monitoring can be achieved by a time-domain reflectometry detector, which is additionally or alternatively comprised by the response monitoring unit and which is configured to monitor the wired physical-layer channel for reception of a reflected signal in response to the output message for a predetermined time span. In these embodiments, the response evaluation unit is configured to allocate the received physical-layer response in dependence of the reception or not of the reflected signal during the predetermined time span, and, in case the reflected signal is received, in dependence of the point in time within the predetermined time span at which the reflected signal is received. The predetermined time span is suitably chosen in dependence of a length of the wired protocol-communication channel, so that a reception of the physical-layer response to the output message occurs during the predetermined time span. The predetermined time span begins in some variants with a starting time of provision of the output message. In other variants, in particular where collision detection is performed in parallel, the response monitoring unit monitors the wired protocol-communication channel in a suitable time span only after provision of the output message.

The output message of such embodiments is thus also used as a probing signal on the physical protocol layer. However, it does at least comprise protocol data and can additionally comprise additional useful information in the form of payload data that is communicated according to the protocol on the second or (which implies “and”) higher protocol layer(s). Despite that, the time-domain reflectometry unit is in some variants additionally configured to provide a probing signal of a predetermined time duration that does not comprise protocol data or payload data, and the response monitoring unit is configured to additionally monitor the wired physical-layer channel for reception of a reflected signal in response to the probing signal for a predetermined time span. This variant can be used to improve allocation accuracy.

In another group of embodiments of the network switch device of the present invention, the communication unit is configured to operate the wired protocol-communication channel as at least one full-duplex communication channel. In these embodiments, the communication unit comprises at least one output stage configured to provide the output message via a transmission physical channel of the full-duplex communication channel, and at least one input stage different from the output stage and configured to receive, via a reception physical channel of the full-duplex communication channel, an input message. The number of input stages in these embodiments is equal to the number of output stages. In addition, the response signal monitoring unit is configured to monitor the at least one full-duplex communication channel for only a physical-layer response receivable in response to the output message.

In this group of embodiments, the transmission physical channel, on which the output messages are transmitted, and the reception physical channel, on which the input messages are received, form a full-duplex communication channel. The response signal monitoring unit is in different variants configured to monitor the transmission physical channel, the reception physical channel, or both the transmission physical channel and the reception physical channel.

Monitoring only the transmission physical channel enables the detection of reflected signals on the transmission physical channel as described for the embodiments that operate the wired protocol-communication channel as a half-duplex physical channel.

Monitoring only the reception physical channel enables, for example, the detection of physical channel loops that occur when the output message provided by the output stage via the transmission physical channel is received at the input stage via the reception physical channel. In these embodiments, the occurrence of a reception of a physical layer response to the output message at the input stage is indicative of a certain predetermined state of the external sensor device, which is associated with the current existence of a channel loop. On the other hand, if no physical-layer response to the output message is received at the input stage, no channel loop is present, and the lack of physical-layer response can be allocated to a respective other predetermined state of the external sensor device.

By being configured to monitor both the transmission physical channel and the reception physical channel, the response-monitoring unit of the network switch device advantageously enables detecting both reflected signals and channel loops, which in turn increases the number of distinguishable physical-layer responses that the response allocation unit of the signal-response interpreter is able to allocate to respective sensor response templates. Thus, the number of sensor device states of the external sensor device which can distinguished by signal response interpreter, be it as an independent device or as an integral part of the network switch device, is increased, which implies that more information can be retrieved from the external passive sensor device based on the technology of the present embodiment.

In the cases where the communication unit of the network switch device comprises a plurality of input stages and output stages, the response monitoring unit is preferably further configured to determine if a channel loop is present between any of the output stages and any of the input stages, and to determine between which of the plurality of output stages and of the plurality of input stages the channel loop is formed. The signal-response interpreter is in such embodiments configured to allocate the determined channel loop or the absence thereof to the corresponding prestored sensor response template in order to determine the state of the passive sensor device and thus take a measurement. This further increases the number of physical-layer responses that the response interpreter is able to allocate to respective sensor response templates.

In an exemplary advantageous embodiment, the wired protocol-communication channel comprises two input stages and two output stages. The response monitoring unit is configured to monitor both transmission physical channels (Tx1 and Tx2) and reception physical channels (Rx1 and Rx2), which form two full-duplex communication channels (Tx1-Rx1 and Tx2-Rx2). The passive sensor device is in one of a predefined set of different states, depending on the quantity to be measured, and as such can for example cause a an open end, a short circuit, an impedance match, a loop on Rx1, a loop from Rx1 to Tx2, and/or other kinds of termination, depending on the configuration of the passive sensor device, its arrangement with respect to the wired protocol-communication channel, and of course depending on the current value of the quantity to be measured. A list of possible physical-layer responses that can be allocated to a respective sensor response template indicative of the state of the external sensor device comprises the following:

- provision of output signal via Tx1, no reception of reflected signal via Tx1,
- provision of output signal via Tx2, no reception of reflected signal via Tx2,
- provision of output signal via Tx1, reception of reflected signal via Tx1,
- provision of output signal via Tx2, reception of reflected signal via Tx2,
- provision of output signal via Tx1 and Tx2, reception of reflected signal via Tx1 and Tx2;
- provision of output signal via Tx1, reception of output signal via Rx1,
- provision of output signal via Tx1, reception of output signal via Rx2,
- provision of output signal via Tx2, reception of output signal via Rx1,
- provision of output signal via Tx2, reception of output signal via Rx2,
- provision of output signal A via Tx1 and output signal B viaTx2, reception of output signal A via Rx1 and reception of output signal B via Rx2,
- provision of output signal A via Tx1 and output signal B viaTx2, reception of output signal A via Rx2 and reception of output signal B via Rx1.

In other embodiments, the network switch device comprises

- at least one control-communication port for providing control information to at least one external controlled device using control output messages in accordance with the protocol; and
- a control unit, which is configured to receive the sensor-state signal from the sensor-response interpreter and to provide control information to the at least one controlled device in dependence on the received current sensor-state signal. These embodiments are advantageously configured to make use of the determined state of the external passive sensor device for controlling data communication between the network communication device and an external controlled device. Therefore, a change of the state of the external sensor device influences the control of the communication between the network communication device and

the external powered device. The data communication may involve providing control information for controlling operation of the controlled device.

As a non-limiting example, consider an embodiment of the network switch device that is connected to an external controlled DC-powered device in the form of a luminaire and to an external passive sensor device in the form of a two-state switch, that in a first state terminates the wired protocol-communication channel by an equivalent impedance matching the impedance of the wired protocol-communication channel, and that in a second state has an impedance that does not match the impedance of the wired protocol-communication channel. When the communication unit of the network switch device provides an output message while the two-state switch is in the first state, no reflected signal will be detected by the response monitoring unit. This particular physical-layer response, i.e., the case of no response, can be identified by the sensor response interpreter using a corresponding first prestored sensor response template, which in turn is allocated to the first state of the two-state switch. This state can, by mere definition via a suitable allocation table or other comparable means, be associated with any desired meaning, such as “Luminaire OFF selected by user”, “Low-level illumination selected by user”, or “Automatic adaptation of luminaire brightness to current window-shade position and daylight level triggered by user”. If, on the other hand, the communication unit provides an output message while the two-state switch is in its second allowed state, a reflected signal will be detected, and this particular physical layer response, i.e., the case of a detection of a reflected signal, can be identified by the sensor response interpreter using a corresponding second prestored sensor response template allocated to the second state of the two-state switch. This state can, by mere definition via a suitable allocation table or other comparable means, be associated with a corresponding other desired meaning, such as “Luminaire ON selected by user”, “High-level illumination selected by user”, or “Fixed luminaire brightness selected by user”.

The response allocation unit of the sensor response interpreter outputs the current sensor-state signal indicative of the allocated state of the two-state switch. The control unit is configured to receive the current sensor-state signal and to control the data communication with the luminaire and possibly with other DC-powered devices (such as further sensors, actuators) in a given network in dependence on the state of the two-state switch. Specifically, control information for controlling operation of the luminaire and/or possibly other DC-powered devices is generated and provided in dependence on the determined state of the two-state switch, thus, in the above examples, switching the luminaire on or off or setting a illumination level desired by the user operating the two-state switch.

Other embodiments allow controlling the state of a two-state switch by machine-generated control signals. In another, particularly simple embodiment the first state of the two-state switch is interpreted by the control unit as an instruction to turn on the DC-powered luminaire, whereas the second state of the two-state switch is interpreted as an instruction to turn off the DC-powered luminaire.

In a further embodiment, the network switch device further comprises a network power control unit, which is configured to control delivery of power to the at least one external powered device - preferably, but not necessarily in dependence on the received sensing-device state signal. The network switch device of this embodiment makes use of the received sensor-state signal for controlling delivery of power to the at least one external powered device. Accordingly, the network switch device of this embodiment provides a particularly simple means of controlling power delivery to external powered devices.

In some of these embodiments, the network switch device additionally comprises a network power supply unit, which is in communication with the network power control unit and configured to provide electrical power that can be used by external powered devices under control of the network power control unit.

In other embodiments, a network power supply device is provided as a device separate from the network switch device, and operating under control of the network power control unit of the network switch device. In such embodiments, the power control is suitably performed via a communication channel, which is preferably, but not necessarily, the wired protocol-communication channel. The communication of control can thus be performed the communication unit.

According to a third aspect of the present invention, an electrical arrangement is provided. The electrical arrangement comprises:

- a network switch device comprising a communication unit configured to provide, via a wired protocol communication port and a wired protocol-communication channel, an output message in the form of an output signal on a physical layer according the OSI reference model and in accordance with a communication protocol requiring protocol data according to at least one second protocol layer higher than the physical layer; wherein
- a passive sensor device, which is configured to assume a respective one of a plurality of predetermined sensor states at a given point in time in dependence on a current value of a quantity to be measured, is arranged to provide termination to the wired protocol-communication channel such that a physical-layer response receivable via the wired protocol communication port from the terminated wired protocol-communication channel in response

to an output message, which is fed into the wired protocol-communication channel, forms a sensor signal indicative of the sensor state currently assumed;

wherein network switch further comprises

- a response monitoring unit, which is configured to monitor the wired physical protocol-communication channel for only the physical-layer response receivable from the external sensor device in response to the output message and to provide sensor response data indicative of the received physical-layer response; and

wherein the electrical arrangement further comprises

- a sensor-response interpreter according to the second aspect of the present invention or one of its embodiments, which receives the sensor response data from the network switch device.

The term “passive sensor device” in the context of the second aspect refers to the same device which in the context of the first aspect is called the “external passive sensor device”.

The electrical arrangement of the third aspect of the present invention and its embodiments share features and advantages of the method of the first aspect of the invention, the sensor response interpreter of the second aspect of the invention, and of the respective embodiments of the network switch device. Embodiments of the electrical arrangement thus include respective embodiments of the sensor response interpreter or network switch device, as described hereinabove. Further embodiments will be described in the following.

The passive sensor device is thus configured to form a terminator device of variable termination effect to the wired protocol communication channel, wherein a momentaneous termination effect depends on the momentaneous sensor state, which in turn depends on the current value of the quantity to be measured by the passive sensor device. In particular embodiments, a respective one of the currently assumed sensor states has one of the following termination effects: causing an open circuit, a short circuit, an end point of the wired protocol communication channel with a matching impedance, or a channel loop between a transmission channel and a reception channel of the wired protocol communication channel. When the value of the quantity to be measured changes, the sensor state also changes to another state, causing another termination effect, which differs from the one previously assumed. It is noted that, of course, not all of these possible termination effects have to be provided by a given passive sensor device

In one embodiment, the electrical arrangement additionally comprises

- at least one controlled device connected to the network switch device; and

- a control device, which is connected to the network switch device and configured to receive the sensor state signal from the sensor-response interpreter and to provide control information to the at least one controlled device in dependence on the received current sensor-state signal.

The controlled device of the electrical arrangement is in one variant of this embodiment a user interface device configured to provide a visual, audio or other suitable output to a user in order to inform the user of the current state of the sensor device. This way, the electrical arrangement is advantageously configured to provide the determined current sensor-state signal to the user interface device which then processes it to provide a corresponding output via the user interface.

In a particularly advantageous embodiment of the electrical arrangement, in which the network switch device comprises the communication control unit mentioned above, the network switch device of the electrical arrangement is further configured to control the data communication between the network switch device and the at least one controlled network device of the electrical arrangement in dependence on the current (i.e., momentaneous) state of the sensor-state signal. This way, in the context of control communication, an operational status of the controlled network device can be controlled in response to a (changing) current state of the passive sensor device.

In a further particularly advantageous embodiment of the electrical arrangement, which comprises the network switch device of the second aspect of the invention, the network power control unit of the network switch device is configured to control delivery of power to the at least one external powered device in dependence on the received sensor-state signal. This way, in the context of control communication, the power delivery to the powered device can be controlled in response to a (changing) current state of the sensor device. This way, powering can be adapted in a very simple manner to changing conditions, such as a temperature sensed by the passive sensor device, which can advantageously be arranged at or in the powered device.

The passive sensor device is configured to provide, in response to an output message provided by the network switch device, a physical-layer response that is indicative of a respective current sensor device state. In particularly advantageous embodiments, which achieve a very simple sensing solution, the passive sensor device is configured to provide only a physical-layer response in response to the output message received from the network switch device. In other words, irrespective of the content of the output message on the second or any given higher protocol layer, the sensor device responds only to the physical-layer signal that represents the output message. The sensor device is preferably configured to not process the output message on the second and any given higher protocol layer. Thus, the sensor device can be provided with minimum device expenditure, for instance a simple passive electrical device, as will be explained further below.

Different embodiments of the electrical arrangement include different sensor devices which are suitable in this framework conceived by the present invention, such as switches, pressure sensors, temperature sensors, humidity sensors, light sensors, movement sensors, charge sensors, etc. The sensors are, in some embodiments, digital sensors, and in other embodiments they are analogue sensors, such as a light dependent resistor, which exhibits an electrical resistance depending on an intensity of light impinging on it. The maximum number of allowed sensor device states that can be allocated to the prestored sensor response templates by the sensor-response interpreter may be chosen in dependence on the embodiment of the network switch device that is used in a given electrical arrangement.

In some advantageous embodiments of the electrical arrangement of the third aspect of the invention, the sensor device is a resistor, an inductor, a capacitor, a transformer, or a diode. Such passive electrical devices interact only with the electrical physical-layer signal of the output message provided by the network communication device via the wired protocol-communication channel, regardless of protocol data or payload data that is provided with the output message by the communication unit on the second or any given higher protocol layer. Many suitable passive electrical devices do not even require an electrical power supply for operation as the sensor device in the context of the present invention. Therefore, the device complexity of the sensor device can be drastically reduced in comparison with known sensors for use in electrical arrangements providing network communication. This compensates a certain reduction in functionality of the sensor device when compared to functionality that a known sensor device configured to communicate with the network switch device on two or more layers according to the OSI reference model has.

In some embodiments, the passive sensor device is integrated into a network plug that is configured to be plugged into one of the protocol-communication ports of the network switch device. Thus, the passive sensor device can be integrated in a very simple device, such as in a plug providing wired termination for a respective protocol-communication port of the network switch.

In some embodiments of the electrical arrangement that also include a powered device, the sensor device forms a part of the powered device. This allows performing the physical-layer sensing in addition to the data communication between the network communication device and the powered device according to the protocol on the second and any higher protocol layer without having to generate separate signals for the physical-layer sensing and the data communication according to the protocol.

According to a fourth aspect of the present invention, a method for operating an electrical arrangement is presented. The method comprises:

- providing an electrical arrangement according to the third aspect or one of its embodiments;
- performing the method of the first aspect or one of its embodiments;
- receiving the sensor-state signal;
- providing control information to the at least one controlled device in dependence on the received current sensor-state signal.

It shall be understood that the sensor response interpreter of claim 1, the network switch device of claim 6, the electrical arrangement of claim 12, the method for determining a sensor-device state of a passive sensor device of claim 14, and the method for operating an electrical arrangement in accordance with claim 15have similar and/or identical preferred embodiments, in particular, as defined in the dependent claims.

It shall be understood that a preferred embodiment of the present invention can also be any combination of the dependent claims or above embodiments with the respective independent claim.

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

BRIEF DESCRIPTION OF THE DRAWINGS

In the following drawings:

Fig.1 shows an exemplary electrical arrangement;

Fig. 2 shows an exemplary embodiment of an electrical arrangement with a network switch device and a passive sensor device;

Fig. 3 shows an exemplary embodiment of an electrical arrangement including a network switch device, powered network devices and passive sensor devices;

Fig. 4 shows another embodiment of an electrical arrangement comprising a sensor device and a network communication device;

Fig. 5 shows an embodiment of a method for determining a sensor-device state of a passive sensor device;

Fig. 6 is a flow diagram of an embodiment of a method for operating an electrical arrangement; and

Fig. 7 is a more detailed block diagram of an embodiment of a sensor-response interpreter in accordance with the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS

Fig. 1 shows an exemplary electrical arrangement 100 including a network switch device 102 that is configured to perform data communication with controlled network devices in the form of powered network devices and sensor devices. In the present embodiment the powered network devices are DC-powered devices, for instance luminaires 104 and the passive sensor devices are formed by a switch 106 and a light sensor 108. Even if the following description of embodiments sometimes focuses on application cases involving the use of DC-powered devices as the powered network device, as opposed to AC-powered devices, the involvement of a DC-powered device is not to be misunderstood as an essential element of the present invention. The embodiments described herein can easily be adapted for operation with AC-powered devices instead of DC-powered devices, or even for operation with a mix of AC-powered devices and DC-powered devices in a given electrical arrangement.

The powered network devices and the passive sensor devices will also be referred to in common as “connected devices” in the following, where suitable for the purpose of brevity.

Operational messages that form output messages in the sense used hereinabove are provided by the network switch device 102 and are transmitted via a dedicated respective wired protocol-communication channel 112 connecting the network switch device 102 to a respective one of connected devices 104, 106, and 108. The wired protocol-communication channel 112 is for instance a twisted-pair type conductor. The communication between the network switch device 102 and the connected devices 104, 106, 108 is performed according to a protocol. In particular, output messages provided by the network switch device 102 comprise protocol-compliant signals as carriers of protocol-compliant data, such as signals having protocol-defined physical parameters on the physical layer, and forming data headers in accordance with the second and, optionally, higher layers of the OSI model. The protocol is suitable for exchanging messages, which are used at least for sensing the status of at least the passive sensor device 108, as described below, and for controlling operation of the one or more powered devices 104. In some embodiments employing DC powering, the protocol is in accordance with a Power-over-Ethernet (PoE) standard. In such PoE systems, the network switch device 102 may additionally assume the functions of a power sourcing equipment. However, neither the power sourcing capability nor the use of PoE forms a requirement in the context of the present invention. The network switch device can be used as such, without the powering function. Also, other protocols may be used, depending also on the field of application of the electrical arrangement 100. In the field of lighting control, there are a large number of known protocols that can be used, one of them being the Digital Addressable Lighting Interface (DALI) protocol. Depending on an application case, suitable payload data can be provided in accordance with the protocol, indicative of, for example, control information such as an operational instruction and/or operational parameters for execution by one or more of the powered devices 104.

Unlike in many known protocol environments, such as typical Power over Ethernet (PoE) systems, in which sensor devices are also powered by the a network switch device and include a communication unit with an Ethernet communication frontend and a microcontroller for receiving and processing the output messages of the network switch device including the payload data they convey, the switch 106 and the sensor 108 are passive sensor devices as introduced hereinabove, and, in this case, passive electrical devices in particular. That means, they terminate the respective wired protocol-communication channel 112 and only passively provide a response to output messages sent by the network switch device 102 on the respective wired protocol-communication channel, which response is provided on the physical layer only. Thus, these passive sensor devices 106 and 108 do not have any Ethernet communication frontend and are unable to interpret any of the output messages that they receive from the network switch device 102. They can however interact with the signals on the physical protocol layer provided by output messages sent by network switch device 102. This means that these sensor devices 106 and 108 are not configured to actively generate protocol-compliant messages for reception by the network switch device 102. They only passively respond to only the physical layer representation of the output messages provided by the network switch device 102. They do not interpret any protocol data nor any payload data in compliance with the protocol. Interaction occurs only at the physical layer, i.e., with the physical signals representing protocol data or payload data according to the protocol, and thus regardless of the actual information content of the operational message.

It is noted that other embodiments of sensor devices do include means for operation on higher protocol layers and still interact with the network switch device via the wired protocol-communication channel in accordance with the present invention, i.e., on the physical protocol layer.

The operation of the electrical arrangement of Fig. 1 will also become clear from the following description electrical arrangements and sensor devices.

Fig. 2 shows an electrical arrangement 200 having exemplary passive sensor device 201 in the form of a switching device (also referred to in short as “switch” in the following) which is configured to be in one of two allowed states, the states being labeled as on-state and off-state. The sensor device 201 includes a resistive load 202 that matches an impedance of the wired protocol-communication channel 204 connecting the sensor device 201 to a network switch device 206. The wired protocol-communication channel 204 is in this embodiment configured for operation as a half-duplex communication channel.

The sensor device 201 further comprises a push-button 208 that can also be in two states A or B. While in a state A (open state), the sensor device 201 presents an equivalent resistive load that matches the impedance of the wired protocol-communication channel 204. Any output message provided by the network switch device 206 to the sensor device 201 will be terminated correctly. No signal reflection occurs in response to receiving the physical-layer representation of the output message. In other words, is the physical-layer signal of an output message fully absorbed by the switch 201 in state A. If, however, the push-button is in a state B (closed state), the matching resistance is short-circuited, resulting in an impedance mismatch between the wired protocol-communication channel 204 and the switch 201. As a consequence, at least a part of the physical signal forming the output message will be reflected back to the network switch device 206.

In the following, the network switch device 206 will be described in more detail. The network switch device 206 comprises a communication unit 210 which is configured to provide, via the wired protocol-communication channel 204 for communication with the sensor device 201, the output message in the form of an output signal according to a physical protocol layer of the OSI reference model. The output message comprises protocol data and suitably also payload data according to at least one second protocol layer that according to the OSI reference model is higher than the physical protocol layer. A response signal monitoring unit 212 is configured to monitor the wired protocol-communication channel for only a physical layer response receivable in response to the output message.

More specifically, in the present electrical arrangement, if the push button 208 of the sensor device 201 is in the state B, a physical-layer response is formed by a reflected signal of at least part of the output message, the reflected signal being generated at the sensor device 201 due to the mentioned impedance mismatch. This reflection signal is detected by the response signal monitoring unit 212. A sensor response interpreter 214 allocates the received physical-layer response to a prestored sensor response template that in turn is allocated to one of the two states A and B of the sensor device 201.

This allocation can be performed by known signal-processing techniques. For instance, it may involve a comparison of a representation of at least a part of the reflected signal with a respective prestored signal pattern that is expected for either of the two state. In a particularly simple embodiment, the mere fact of a detection of a reflected signal is used by the sensor response interpreter 214 as an indication of state B of the sensor device 201.

The sensor response interpreter is 214 therefore configured to allocate the presence or absence of a reflected signal on the wired protocol-communication channel 204 to one of the states A and B of the sensor device 201, in accordance with the actual state, A or B, of the push-button 208. The sensor response interpreter outputs a sensor-state signal that is indicative of the allocated state of the sensor device 201.

In some network switch devices, the response signal monitoring unit 212 monitors the physical-layer response according to a collision detection algorithm such as Carrier Sense Multiple Access with Collision Detection (CSMA/CD). In these network switch devices, the response signal monitoring unit 212 detects if, during the provision of the output message, another signal is present at the wired protocol-communication channel, which is this case, would be the reflected signal. In these cases, a length of the output message and a maximum length of the wired protocol-communication channel have to be chosen so that, in case a reflection happens due to the push-button being in state B, the reflected signal arrives before the output message has been finally transmitted, so that a collision can be detected by the response signal monitoring unit.

Other response signal monitoring units comprise a time-domain reflectometry unit that is configured to monitor the wired physical-layer channel for reception of a reflected signal in response to the output message for a predetermined time span beginning with a starting time of provision of the output message. In these network switch devices, the signal response interpreter 214 is configured to allocate the received physical-layer response in dependence of the reception or not of the reflected signal during the predetermined time span, and, in case the reflected signal is received, in dependence of the point in time within the predetermined time span at which the reflected signal is received.

The sensor-state signal that is indicative of the current allocated state of the sensor device 201 and that forms an output signal provided by the signal response interpreter

214 network switch device can be used for controlling operation of DC-powered devices, such as the luminaires 104 of the electrical arrangement 100 of Fig. 1, in dependence on the current state of the sensor device, such as the sensor device 201.

This will be explained in the following in more detail with additional reference to Fig. 3.

Fig. 3 shows an exemplary embodiment of another electrical arrangement 300, comprising the passive sensor device 201 described above in the context of Fig. 2 (for which the same reference labels as above will be used also in the present context), a network switch device 302 and a DC-powered device 304 connected to the network switch device 302 via a wired full-duplex communication channel 306 comprising two pairs of conductors. A PoE compliant Ethernet cable is an example of a suitable wired full-duplex communication channel. The network switch device comprises a control unit 312 that receives the current sensor-state signal and controls data communication with the DC-powered device 304 in dependence on the current sensing-device state signal. In this example, the DC-powered device is a luminaire, such as one of the luminaires 104 of the electrical arrangement of Fig. 1. The network switch device 302 is configured to provide output messages at predetermined times for performing the physical-layer sensing described hereinabove via the wired protocol-communication channel 204.

A user may at any time press the push-button 208, causing it to assume state B (Fig. 2) and form a by-pass of the resistive load 202, thus creating an impedance mismatch between the wired protocol-communication channel 204 and the passive sensor device 201. Suitably, the network switch device provides output messages at a repetition rate high enough so that during the time the push-button is in state B, the response monitoring unit 212 will detect a reflected signal as a physical-layer response in response to the output message. The sensor response interpreter 214 outputs the corresponding current sensor state signal. This is used by the control unit 308 to control the data communication with the DC-powered device 304. In the exemplary case of the DC-powered device 304 being a luminaire, a change in the current state of the sensor device will change the operational status of the luminaire from an on-status to an off-status or vice versa, as defined by an operator of the electrical arrangement 300.

Fig. 4 is a schematic illustration of another embodiment of an electrical arrangement 400, comprising a sensor device 401 connected to a network switch device 402. The network switch device operates a wired protocol-communication channel 404 as a full-duplex communication channel with a transmission physical channel Tx and a reception physical channel Rx. The network switch device is shown with reduced detail due to its similarity with those network switch device of the embodiments of Figs. 1 to 3. The following description concentrates on differences to those other embodiments.

In the arrangement 400 of Fig. 4, the sensor device 401 comprises temperature switches 406 and 408 that are used to both control an impedance match or mismatch between the transmission physical channel Tx and the sensor device 401, e.g., by connecting or disconnecting a matching impedance Z to the transmission physical channel Tx, as well as to create or not create a channel loop. Consider, for instance, a temperature that is lower than a first threshold value. The temperature switch 406 is configured to be closed in this temperature range, while temperature switch 408 is configured to be open in this temperature range. In this configuration, the transmission physical channel Tx is properly terminated by an impedance Z and no signals are reflected. This corresponds to a first prestored sensor response template, which is a physical layer response template distinguishable by the response evaluation unit (not shown) of the network switch device 402. Furthermore, in case the temperature is between the first threshold value and a second threshold value, the temperature switch 406 is configured to open. Thus, there will be an impedance mismatch that will result in a reflection of at least part of the output message which can be detected by the response monitoring unit (not shown) of the network switch device 402. For instance, the reflection will cause a signal collision that will be detected by the response monitoring unit (not shown in Fig. 4) of the network switch device 402. This physical-layer response will be allocated to a second predetermined sensor response template, which is a physical layer response template by the sensor response interpreter (not shown in Fig. 4). Furthermore, if the temperature rises above the second threshold value, temperature switch 408 is configured to be closed, and a channel loop will be created. In other words, the output message provided via the transmission physical channel Tx will be coupled into the reception physical channel Rx, and the response monitoring unit will allocate this physical-layer response, i.e. the reception of the output message via an input stage, to a third prestored sensor response template prestored in the sensor response interpreter.

The sensor device state signal is in some cases used to inform an external entity, such as a central server or a user about the current state of the sensor device. In some particularly advantageous electrical arrangements, the current sensor state signal is provided to a control unit that will control data communication with a powered device such as for example a cooling/heating unit that will change its operational status as a function of the sensed temperature range, as determined by the temperature switches.

In variants of the electrical arrangement 400, a network switch device for controlling data communication with the at least one external powered device is used. It comprises the network switch device 402, and further comprises a network power control unit (not shown), which is configured to control delivery of power to the at least one external powered device in dependence on the received sensing-device state signal.

Fig. 5 shows an embodiment of a method for determining a sensor-device state of a passive sensor device. The method comprises providing, in a step 502, the passive sensor device, which assumes a respective one of a plurality of predetermined sensor states at a given point in time in dependence on a current value of a quantity to be measured, as a termination to a wired protocol-communication channel such that a physical-layer response receivable from the wired protocol-communication channel in response to an output message, which is fed into the wired protocol-communication channel in accordance with a communication protocol requiring protocol data according to at least one second protocol layer higher than the physical layer, forms a sensor signal indicative of a sensor state currently assumed.

In a further step 504, the method comprises providing a set of prestored sensor response templates, which are indicative of respective physical-layer responses receivable from the wired protocol-communication channel in response to the output message for respective different defined sensor states of the passive sensor device, the different sensor response templates being allocated to the respective different defined sensor states of the passive sensor device.

After these preparatory measures, the method comprises, at step 506, providing an output message, which is fed into the wired protocol-communication channel in accordance with the communication protocol and comprises protocol data according to at least one second protocol layer higher than the physical layer.

A further step is formed by monitoring, at step 508, the wired physical protocol-communication channel for only the physical-layer response receivable from the sensor device in response to the output message and providing sensor response data indicative of the received physical-layer response.

A further step 510 is formed by comparing and, based on the comparison, allocating the sensor response data to one of the set of prestored sensor response templates.

At a further step 512, the method comprises providing a sensor-state signal indicative of the sensor state of the passive sensor device thus allocated.

Fig. 6 is a flow diagram of a method for operating an electrical arrangement. The method comprises, in a step 602, providing an electrical arrangement as described in the context of the third aspect of the present invention, exemplified by electrical arrangements as those shown in Figs. 1 to 4. Consecutively, the electrical arrangement provided is used for performing the method of the first aspect of the present invention described hereinabove, exemplified by of Fig. 5, as indicated by reference label 500 in Fig. 6. In step 606 the sensor-state signal provided by the method 500 is received. Subsequently, in a step 608 control information is provided to at least one controlled device in dependence on the received current sensor-state signal.

Fig 7 shows a more detailed block diagram of an embodiment of a sensor-response interpreter 700 in accordance with the present invention. The sensor-response interpreter comprises a response input unit 702, which is configured to receive sensor response data that is indicative of the physical-layer response that has been received from an external wired protocol-communication channel (not shown) terminated by an external passive sensor device (not shown) in response to the output message. The response input unit forms a communication interface for receiving sensor response data from a network switch device (not shown in Fig. 7).

The sensor-response interpreter further comprises a response allocation unit 704, which is configured to compare and, based on a comparison or other suitable allocation algorithm, allocate the sensor response data to one of a set of prestored sensor response templates stored in a template memory 706, and which are indicative of respective physical-layer responses receivable from the wired protocol-communication channel in response to the output message for respective different defined sensor states of the passive sensor device. The different sensor response templates are allocated to the respective different defined sensor states of the external passive sensor device, which in turn a indicative of respective values or value ranges to be measured by the passive sensor device.

A sensor-state output unit 708 is configured to provide a sensor-state signal indicative of the sensor state of the external passive sensor device thus allocated.

In summary, a new network sensing solution is provided. A network switch provides, via a wired protocol-communication channel terminated by a passive sensor device, an output message with an output signal on a physical layer in accordance with a protocol used for data communication. A response monitoring unit is configured to monitor the wired protocol-communication channel for only a physical-layer response receivable from the external sensor device in response to the output message. A sensor response interpreter suitably allocates the received physical-layer response to a prestored sensor response template, the prestored sensor response template being allocated to a predefined state of the external sensor device, and outputs a sensor-state signal indicative of the current state of the external sensor device.

Other variations to the 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.

A computer program may be stored/distributed on a suitable medium, such as an optical storage medium or a solid-state medium, supplied together with or as part of other hardware, but may also be distributed in other forms, such as via the Internet or other wired or wireless telecommunication systems.

Any reference signs in the claims should not be construed as limiting the scope.

CLAIMS:

1. A sensor-response interpreter (700) for interpreting sensor response data pertaining to an external passive sensor device (201), the passive sensor device providing termination to an external wired protocol-communication channel such that a physical-layer response receivable from the wired protocol-communication channel in response to an output message, which is fed into the wired protocol-communication channel in accordance with a communication protocol requiring protocol data according to at least one second protocol layer higher than the physical layer, forms a sensor signal indicative of a sensor state currently assumed, the sensor-response interpreter comprising:

- a response input unit (702), which is configured to receive the sensor response data that is indicative of the physical-layer response that has been received from the external wired protocol-communication channel terminated by the external passive sensor device in response to the output message;
- a response allocation unit (704), which is configured to compare and, based on the comparison, allocate the sensor response data to one of a set of prestored sensor response templates (706), which are indicative of respective physical-layer responses receivable from the wired protocol-communication channel in response to the output message for respective different defined sensor states of the passive sensor device, the different sensor response templates being allocated to the respective different defined sensor states of the external passive sensor device; and
- a sensor-state output unit (708), which is configured to provide a sensor-state signal indicative of the sensor state of the external passive sensor device thus allocated.

2. The sensor-response interpreter of claim 1, wherein

- the response input unit is configured to receive a channel identifier in association with the response data, the channel identifier being suitable for identification of that wired protocol-communication channel among a plurality of wired protocol-communication channels, through which the physical-layer response was received; and wherein
- the response allocation unit is configured to determine the respective defined

sensor state of the external passive sensor device additionally using the received channel identifier.

3. The sensor-response interpreter of claim 1 or 2, wherein

- the prestored sensor response templates are indicative of reception or no reception of a reflected signal during a predetermined time span, and, in case of reception of the reflected signal, of a point in time within the predetermined time span at which the reflected signal has been received.

4. The sensor-response interpreter of claim 1, wherein

- at least two of the prestored sensor response templates are indicative, respectively, of reception or no reception of a reflected signal during provision of the output message,
- the response allocation unit is configured to allocate the received physical-layer response to either a collision response template, which is indicative of a reflection signal detected in response to the output message during provision of the output message, or to a non-collision response template, which is indicative of no detected response to the output message on the wired protocol-communication channel during provision of the output message, and to determine the sensor state based on the allocation of the collision response template and the non-collision response template to respective sensor states.

5. The sensor-response interpreter of claim 2, wherein

- the response input unit is configured to receive the response data from an external network switch device (206) that receives the physical-layer response in operating one of its wired protocol communication ports in a wired connection with the passive sensor device via the wired protocol-communication channel;
- the response allocation unit is configured to generate, upon determining the state of the external passive sensor device, an output command instructing the network switch to continue operation of the protocol communication port.

6. A network switch device (206) comprising,

- a communication unit (210) configured to provide, via a wired protocol communication port and an external wired protocol-communication channel that is terminated by an external passive sensor device, an output message in the form of an output signal on a physical layer according the Open Systems Interconnection (OSI) reference model, in accordance with a protocol to be used for data communication, the output message also comprising protocol data according to at least one second protocol layer that according to the OSI reference model is higher than the physical layer;

- a response monitoring unit (212), which is configured to monitor the wired physical protocol-communication channel for only a physical-layer response receivable from the external sensor device in response to the output message and to provide sensor response data indicative of the received physical-layer response; and
- a sensor-response interpreter according to claim 1.

7. The network switch device of claim 6, wherein

- the communication unit is configured to operate the wired protocol-communication channel as a half-duplex communication channel;
- the response monitoring unit comprises a time-domain reflectometry detector, which is configured to monitor the wired physical-layer channel for a predetermined time span and for reception of the physical-layer response in the form a reflected signal in response to the output message; and wherein
- the sensor-response interpreter is in accordance with claim 3.

8. The network switch device of claim 6, wherein

- the communication unit is configured to operate the wired protocol-communication channel as a half-duplex communication channel;
- the response monitoring unit comprises a signal-collision detector that is configured to monitor the wired protocol-communication channel for only a physical-layer response receivable in response to the output message during provision of the output message; and wherein
- the sensor-response interpreter is in accordance with claim 4.

9. The network switch device of claim 6, wherein

- the communication unit is configured to operate the wired physical protocol-communication channel as at least one full-duplex communication channel and comprises:
- at least one output stage configured to provide the output message via a transmission physical channel of the full-duplex communication channel; and
- at least one input stage different from the output stage and configured to

receive, via a reception physical channel of the full-duplex communication channel, an input message; wherein

- the number of input stages is equal to the number of output stages; and
- the response monitoring unit is further configured to monitor the at least one full-duplex communication channel for only the physical-layer response receivable in response to the output message.

10. The network switch device of claim 6, further comprising

- at least one control-communication port for providing control information to at least one external controlled device using control output messages in accordance with the protocol to be used for data communication; and
- a control unit, which is configured to receive the sensor-state signal and to provide control information to the at least one controlled device in dependence on the received current sensor-state signal.

11. The network switch device of claim 6, wherein the protocol to be used for data communication is in accordance with a Power-over-Ethernet standard.

12. An electrical arrangement (300), comprising:

- a network switch device (302) comprising a communication unit configured to provide, via a wired protocol communication port and a wired protocol-communication channel, an output message in the form of an output signal on a physical layer according the OSI reference model and in accordance with a communication protocol requiring protocol data according to at least one second protocol layer higher than the physical layer; wherein
- a passive sensor device (201), which is configured to assume a respective one of a plurality of predetermined sensor states at a given point in time in dependence on a current value of a quantity to be measured, is arranged to provide termination to the wired protocol-communication channel such that a physical-layer response receivable via the wired protocol communication port from the terminated wired protocol-communication channel in response to an output message, which is fed into the wired protocol-communication channel, forms a sensor signal indicative of the sensor state currently assumed; wherein network switch further comprises
- a response monitoring unit, which is configured to monitor the wired physical protocol-communication channel for only the physical-layer response receivable from the

external sensor device in response to the output message and to provide sensor response data indicative of the received physical-layer response; and

wherein the electrical arrangement further comprises

- a sensor-response interpreter according to claim 1, which receives the sensor response data from the network switch device.

13. The electrical arrangement of claim 12, further comprising

- at least one controlled device (304) connected to the network switch device; and
- a control device, which is connected to the network switch device and configured to receive the sensor state signal from the sensor-response interpreter and to provide control information to the at least one controlled device in dependence on the received current sensor-state signal.

14. A method (500) for determining a sensor-device state of a passive sensor device, the method comprising:

- providing (502) the passive sensor device, which assumes a respective one of a plurality of predetermined sensor states at a given point in time in dependence on a current value of a quantity to be measured, as a termination to a wired protocol-communication channel such that a physical-layer response receivable from the wired protocol-communication channel in response to an output message, which is fed into the wired protocol-communication channel in accordance with a communication protocol requiring protocol data according to at least one second protocol layer higher than the physical layer, forms a sensor signal indicative of a sensor state currently assumed;
- providing (504) a set of prestored sensor response templates, which are indicative of respective physical-layer responses receivable from the wired protocol-communication channel in response to the output message for respective different defined sensor states of the passive sensor device, the different sensor response templates being allocated to the respective different defined sensor states of the passive sensor device;
- providing (506) an output message, which is fed into the wired protocol-communication channel in accordance with the communication protocol and comprises protocol data according to at least one second protocol layer higher than the physical layer;
- monitoring (508) the wired physical protocol-communication channel for only the physical-layer response receivable from the sensor device in response to the output

message and providing sensor response data indicative of the received physical-layer response;

- comparing and, based on the comparison, allocating (510) the sensor response data to one of the set of prestored sensor response templates; and
- providing (512) a sensor-state signal indicative of the sensor state of the passive sensor device thus allocated.

15. A method (600) for operating an electrical arrangement, the method comprising:

- providing (602) an electrical arrangement according to claim 13;
- performing (500) the method of claim 14;
- receiving (606) the sensor-state signal;
- providing (608) control information to the at least one controlled device in dependence on the received current sensor-state signal.

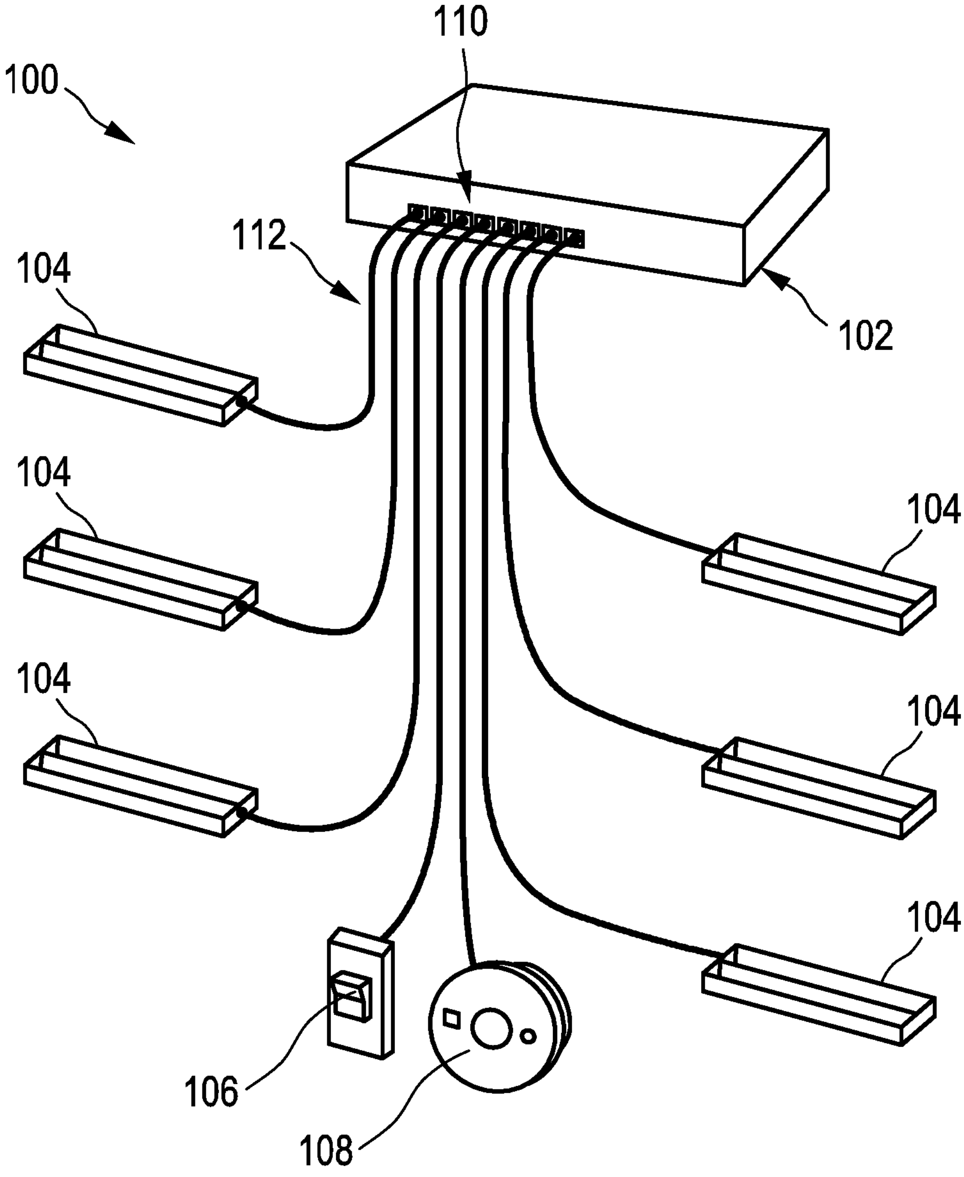

FIG. 1

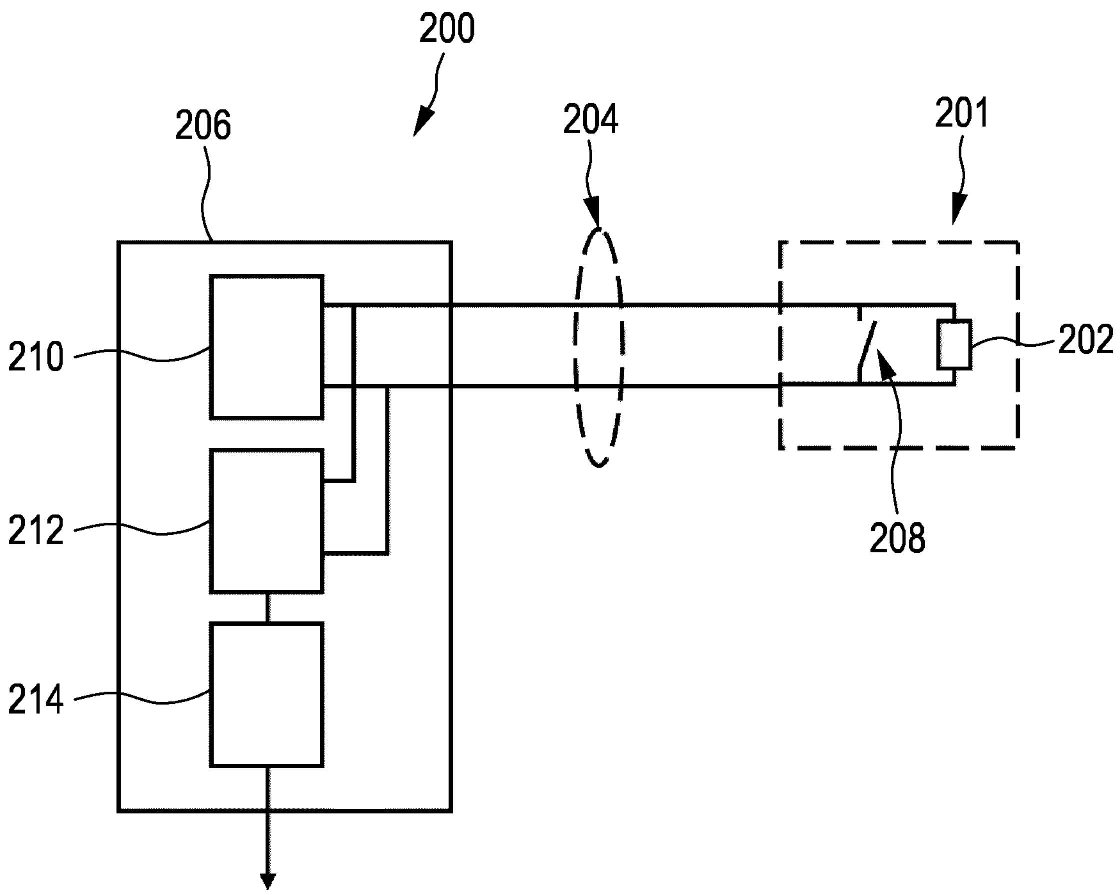

FIG. 2

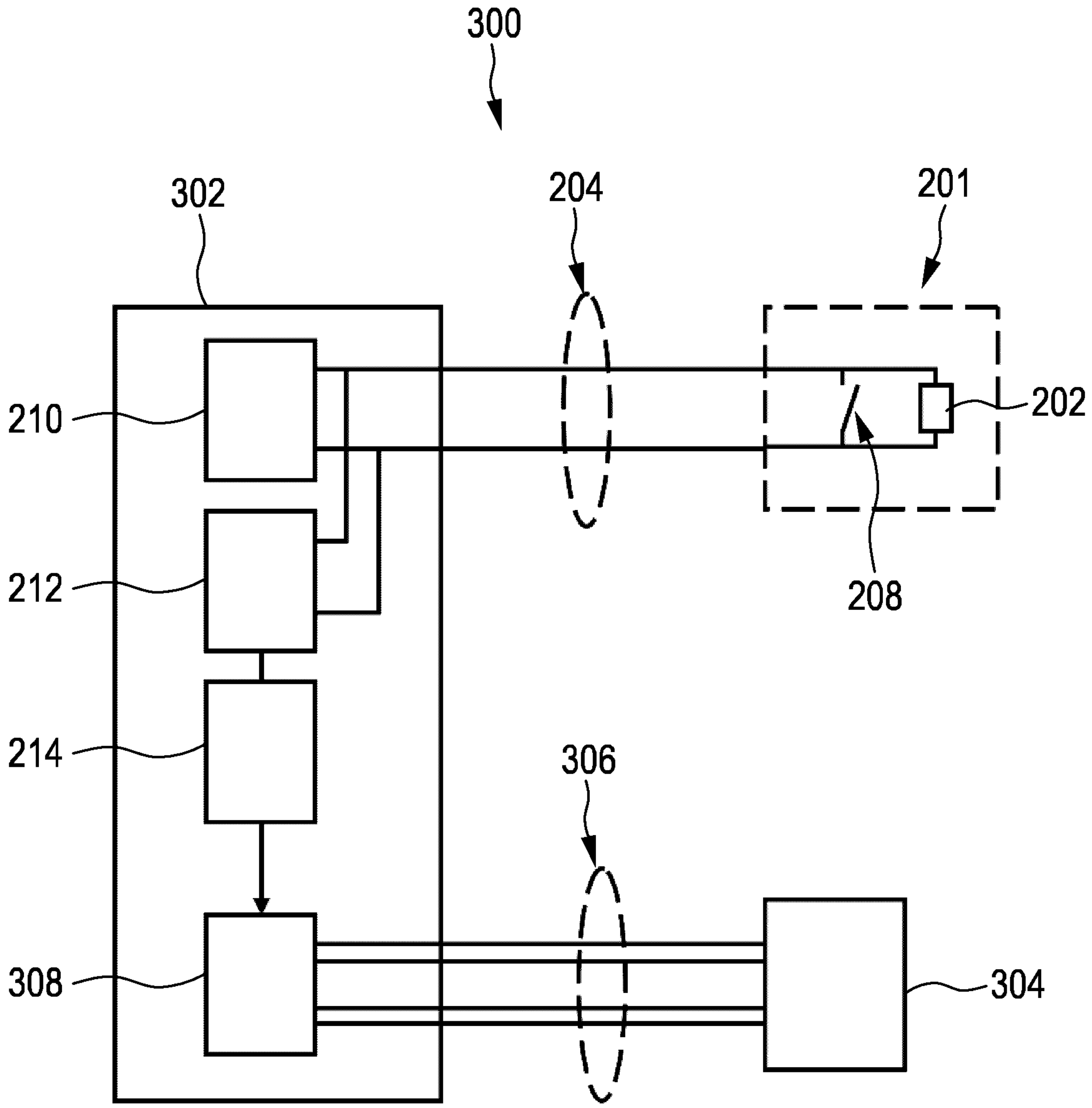

FIG. 3

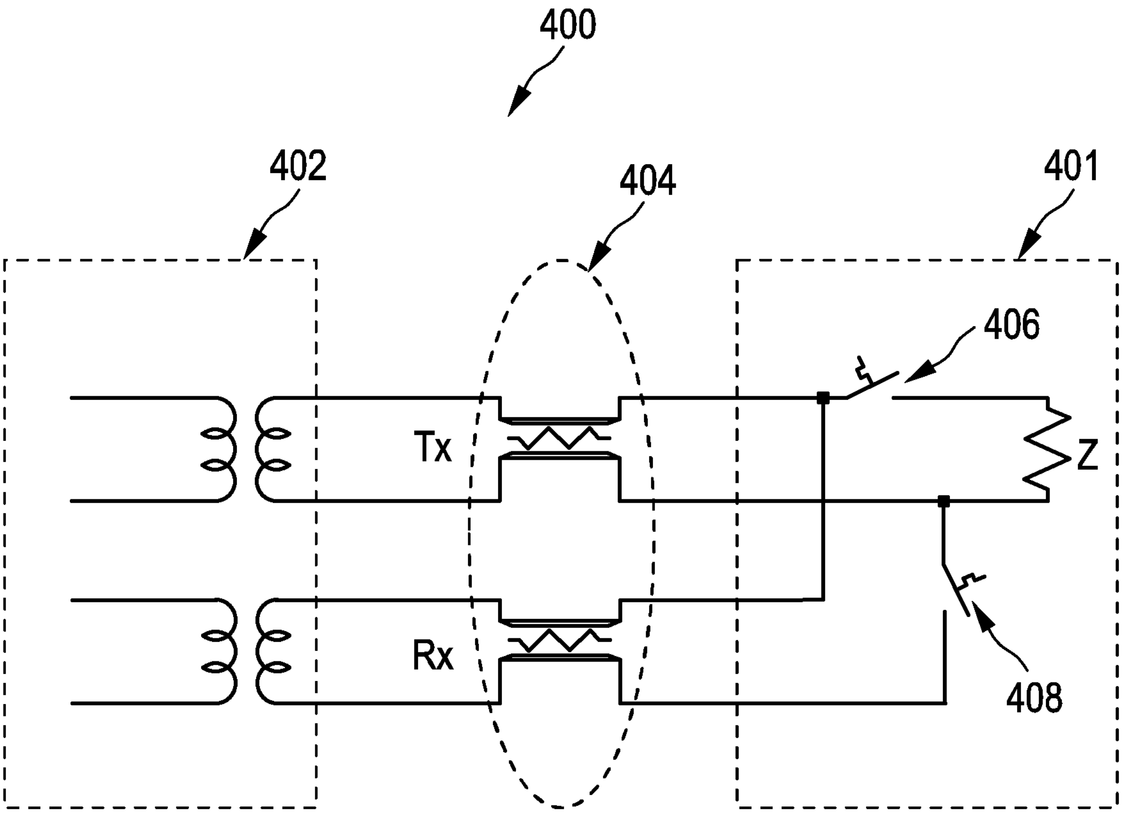

FIG. 4

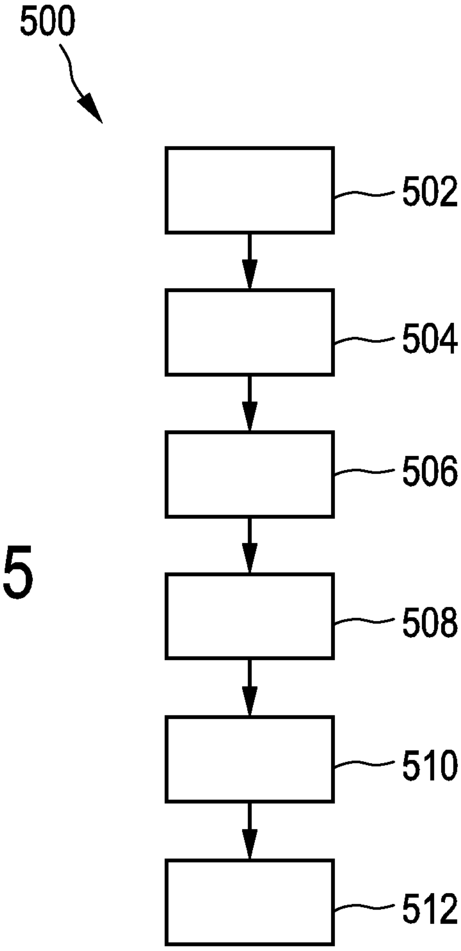

FIG. 5

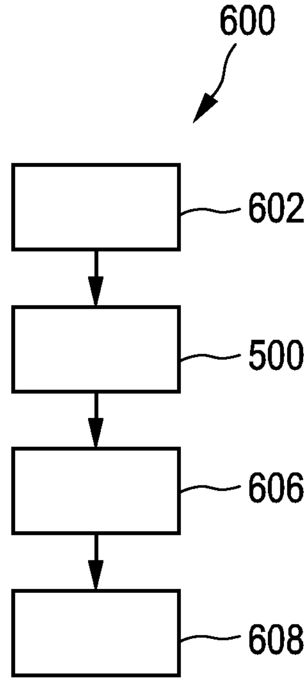

FIG. 6

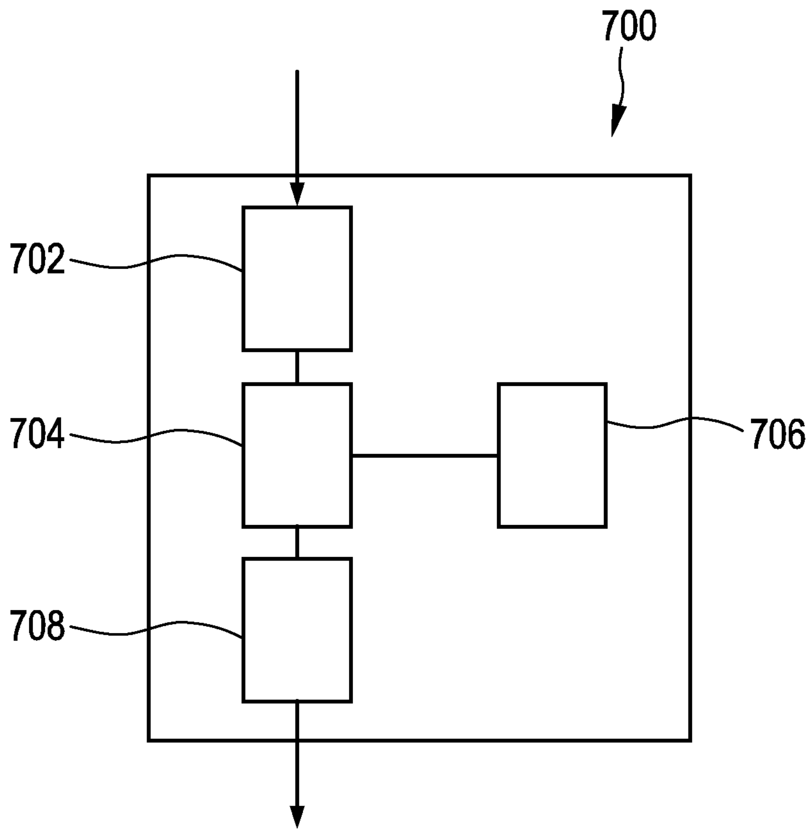

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/078322

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L12/28 H04L12/40 H04Q9/00 H04L29/08
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04L H04Q

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2016/066068 A1 (SCHULTZ RICHARD DOUGLAS [US] ET AL) 3 March 2016 (2016-03-03)	1,2,5,6, 8,9,11, 12,14
Y	paragraph [0013] - paragraph [0029]	10,13,15
A	paragraphs [0050], [0080] paragraph [0104] - paragraph [0109] figure 1	3,4,7

X	US 3 544 803 A (TAYLOR DOUGLAS W) 1 December 1970 (1970-12-01)	1,5,8,14
A	column 2, line 16 - column 3, line 69 column 5, line 37 - line 41 column 10, line 62 - line 68 figure 1	2-4,6,7, 9-13,15

	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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

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

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

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

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 January 2018	22/01/2018

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Oechsner, Simon

1

International application No
PCT/EP2017/078322

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2016/034773 A1 (METSO FLOW CONTROL OY [FI]) 10 March 2016 (2016-03-10) page 5, line 11 - line 30 page 19, line 12 - page 21, line 5 -----	1-15
Y	US 2016/183351 A1 (SNYDER DAVID M [US] ET AL) 23 June 2016 (2016-06-23)	10,13,15
A	paragraph [0044] - paragraph [0047] paragraph [0093] figure 1 -----	1-9,11, 12,14

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2017/078322

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
US 2016066068	A1	03-03-2016	NONE			
US 3544803	A	01-12-1970	BE	730801	A	30-09-1969
			DE	1916020	A1	29-01-1970
			FR	2005329	A1	12-12-1969
			GB	1252632	A	10-11-1971
			SE	370361	B	14-10-1974
			US	3544803	A	01-12-1970
WO 2016034773	A1	10-03-2016	CN	107077587	A	18-08-2017
			EP	3189467	A1	12-07-2017
			FI	127115	B	15-11-2017
			JP	2017529615	A	05-10-2017
			KR	20170066389	A	14-06-2017
			US	2017286820	A1	05-10-2017
			WO	2016034773	A1	10-03-2016
US 2016183351	A1	23-06-2016	NONE			