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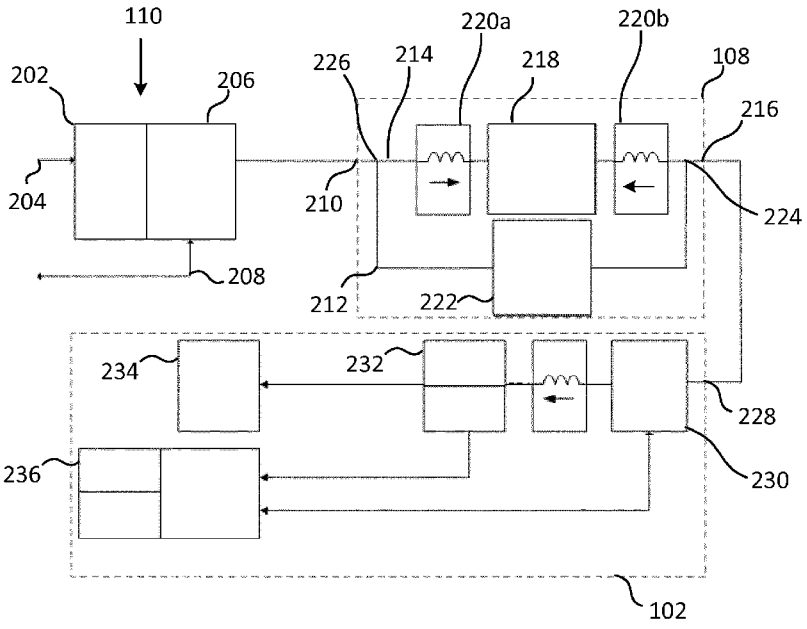

Figure 2

(57) Abstract: A system comprising a power adaptor (108) and a LiFi over PLC enabled device (102), the power adaptor comprising: an input for receiving a first signal from a source, wherein the first signal comprises an outgoing PLC signal modulated into an AC power component; an output for transmitting a second signal to the PLC device, wherein the second signal comprises a version of the outgoing PLC signal modulated into a DC power component; a power path comprising a power converter for converting the AC power component to the DC power component, and filtering circuitry arranged to attenuate the outgoing PLC signal entering the power converter; a signal path comprising insulating circuitry arranged to allow the outgoing PLC signal but not the AC power component to pass from the input to the output, and a junction arranged to produce the second signal by superposing the outgoing PLC signal passed by the insulating circuitry into the DC power component produced by the power converter for delivering the outgoing PLC signal to

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the LiFi over PLC enabled device for emitting the outgoing PLC signal in its light output.

POWER LINE COMMUNICATION POWER ADAPTOR

TECHNICAL FIELD

The present disclosure relates to a power adaptor for providing power line communication signals to a power line communication enabled device.

BACKGROUND

It is known in the art to use power line communication as a means to provide information over existing power lines. For example US granted patent US9,660,696 B2 discloses a power line communication (PLC) AC/DC adaptor that includes a filter, a rectifier, a power factor correction circuitry, and a PLC module. The filter includes a differential mode choke and a common mode choke. The differential mode choke is coupled to the AC. The common mode choke is coupled to the differential mode choke. The rectifier is coupled to the common mode choke. The power factor correction circuitry is coupled to the rectifier. The PLC module is coupled to AC to process a PLC signal from AC and output control signals to loads, such as home appliances.

US patent application US2007/149258 A1 discloses a power line communication modem within a network camera that outputs a communication signal to an AC adaptor. A signal superimposition and separation circuit of the AC adaptor separates a received communication signal from a DC voltage and an amplifier of the AC adaptor amplifies a signal level of the communication signal and then outputs the amplified signal to a power line to an outlet.

Light Fidelity (Li-Fi) refers to techniques whereby information is communicated in the form of a signal embedded in visible light, infrared light or ultraviolet light emitted by a light source. Such techniques are sometimes also referred to as coded light, visible light communication (VLC) or free-space optical communication (FSO).

The encoding of signals into light can be used in a variety of possible applications. For instance a different respective ID can be embedded into the illumination emitted by each of the luminaires in a given environment, e.g. those in a given building, such that each ID is unique at least within the environment in question. E.g. the unique ID may take the form of a unique modulation frequency or unique sequence of symbols. A device

receiving the ID can then use it to look up some information mapped to that ID via another network, such as an RF network (e.g. WLAN, or cellular network, etc.). For instance, one application is to provide information from a luminaire to a remote control unit for control purposes, or to provide status information on the luminaire (e.g. to report errors, warnings, temperature, operating time, etc.). In other example applications, the signals can be used to provide location dependent information (e.g. advertising, or information on museum exhibitions, etc.); or to perform localization (e.g. triangulation, trilateration or multilateration) based on beacon signals embedded in the emitted from luminaires.

In more recent years as Li-Fi bandwidths have increased, it has become possible to embed the data content directly into the light (without requiring a look-up via an RF network). E.g. this may be used to provide location dependent content or even to provide an alternative means of accessing a network such as the internet, as an alternative to access an RF WLAN.

One way of providing a Li-Fi enabled device with a signal to embed in the visible light that it emits is via Power Line Communication (PLC). PLC is a communication technology that enables data to be transmitted over power cables (which may be pre-existing power cable not previously designed for signalling information). This means that the same power cable can be used to power a device as well as to transmit information to and from the device. The data to be transmitted by PLC to the device is modulated into a power line that powers the device, such as a mains power line. A variety of modulation schemes can be used in PLC such as, for example, Orthogonal Frequency Division Multiplexing (OFDM), Binary Phase Shift Keying (BPSK), Frequency Shift Keying (FSK), and Spread-FSK (S-FSK).

SUMMARY

In a PLC system, the quality of the signal depends on the mains power network and the devices that are directly connected to the mains power network, e.g. washing machines, television sets, etc. A typical PLC system adapts the gain (thus the PLC signal power) such that the PLC signal is sufficient for the system to operate but not too high such that it is contained and does not become a disturbance on the total mains network (including neighbouring houses). Within a PLC universe (i.e. a system of one or more PLC enabled devices receiving the same PLC signal), the PLC signal needs to be extracted from the mains power network and passed onto the PLC enabled device embedded in a suitable power line for that device.

According to a first aspect disclosed herein, there is provided a power adaptor for providing power line communication, PLC, signals to a PLC enabled device, wherein the power adaptor comprises: an input for receiving a first signal from a source, wherein the first signal comprises an outgoing PLC signal modulated into an alternating current, AC, power component; an output for transmitting a second signal to the PLC enabled device, wherein the second signal comprises a version of the outgoing PLC signal modulated into a direct current, DC, power component; a power path comprising a power converter for converting the AC power component from the first signal to the DC power component, and filtering circuitry arranged to attenuate the outgoing PLC signal entering the power converter; a signal path comprising insulating circuitry arranged to allow the outgoing PLC signal but not the AC power component of the first signal to pass from the input to the output, and a junction arranged to produce the second signal by superposing the outgoing PLC signal passed by the insulating circuitry onto the DC power component produced by the power converter.

The insulating circuitry prevents high frequency PLC signals from being deteriorated by the devices that are connected to the mains network. Without the insulating circuitry, the PLC signal would need to be injected with a higher current. The power adaptor allows the signal to be passed on effectively to a (low voltage) PLC enabled device while reducing loading of the PLC signal by isolating the AC and DC power components from the outgoing PLC signal with the filtering circuitry.

In embodiments, the filtering circuitry may comprise an input-side filter arranged to attenuate the outgoing PLC signal entering an input of the power converter that receives the AC power component, and an output-side filter arranged to attenuate the outgoing PLC signal entering an output of the power converter that outputs the DC power component.

In embodiments, the input-side filter and/or output-side filter may each comprise at least one of: a low pass filter, a band-pass filter, and a band-stop filter.

In embodiments, the insulating circuitry may comprise one or more capacitors for insulating the input of the power adaptor from the output of the power adaptor.

In embodiments, at least one of the one or more capacitors may be a safety capacitor.

In embodiments, the insulating circuitry may comprise a transformer for providing at least partial galvanic insulation between the input and the output.

In embodiments, the DC power component may be a safety extra low voltage DC power component.

In embodiments, the signal path may comprise protection circuitry for reducing interference spikes on the signal path.

In embodiments, the protection circuitry may comprise a plurality of diodes.

In embodiments, the PLC enabled device may be a light-fidelity, Li-Fi, over PLC enabled device.

In embodiments, the output may be adapted to receive a return PLC signal, wherein the signal path is arranged to allow the return PLC signal to pass from the output to the input, and wherein the input is arranged to transmit the return PLC signal to the source.

For example, a PLC signal may be routed from the PLC-enabled device to the internet via the power adaptor.

In embodiments, the input may comprises a line terminal, a neutral terminal and a protective earth, PE, terminal, wherein the output comprises a positive terminal, a negative terminal and a ground terminal, wherein the power adaptor comprises a PE path connecting the PE terminal to the ground terminal, and wherein the PE path is arranged to pass the outgoing PLC signal from the PE terminal to the ground terminal.

According to a second aspect disclosed herein, there is provided a system comprising: the power adaptor according to any embodiment disclosed herein as well as a LiFi over PLC enabled device, wherein the LiFi over PLC enabled device comprises a PLC signal extraction circuitry arranged to receive the outgoing PLC signal from the power adaptor and an LED driver arranged to generate an LED drive signal to drive one or more LEDs in the LiFi device using the received outgoing PLC signal from the power adaptor.

The above system allows a LiFi over PLC enabled device to emit illumination light or alternatively infrared light having embedded therein the received PLC signal from the power adaptor. The LiFi over PLC enabled device thereby represents an extension of the PLC communication network.

In embodiments the system further comprises a second LiFi over PLC enabled device, wherein the power adaptor is arranged to output the second signal to the first and second LiFi over PLC enabled devices. In this manner multiple LiFi over PLC enabled devices can be connected to transmit, and in bi-directional embodiments also receive, LiFi signals to (and/or from) LiFi devices, thereby extending the PLC universe to also include LiFi devices.

In embodiments, the first and/or second PLC enabled devices may be Li-Fi over PLC enabled devices.

In embodiments, the system may comprise the source, and wherein the source is a secondary instance of the power adaptor.

BRIEF DESCRIPTION OF THE DRAWINGS

To assist understanding of the present disclosure and to show how embodiments may be put into effect, reference is made by way of example to the accompanying drawings in which:

Figure 1 shows schematically a Li-Fi Universe in which PLC signals are passed to PLC enabled devices via a power adaptor,

Figure 2 shows schematically an example system for passing PLC signals to a PLC enabled device via a power adaptor,

Figure 3 shows schematically an example circuit diagram of a power adaptor,

Figure 4 shows schematically an example circuit diagram for extracting and injecting PLC signals,

Figure 5 shows schematically an example system for passing PLC signals to a PLC enabled device via a power adaptor,

Figure 6 shows schematically an example circuit diagram of a power adaptor, and

Figure 7 shows schematically an example circuit diagram for extracting and injecting PLC signals.

DETAILED DESCRIPTION

Figure 1 illustrates an example system 100 in which a plurality of PLC enabled devices 102a, 102b are provided with power from a mains supply 104.

A PLC enabled device 102 is in general any device that can receive a data signal (i.e. a PLC signal) that is embedded into a mains supply, i.e. embedded in the power component of the mains supply 104. The PLC enabled device 102 may be, for example, a television set, a display screen or panel, a PVR (personal video recorder, also known as a DVR or digital video recorder), a DVD player, a Blu Ray player, a set-top box, a desktop or laptop or tablet computer, etc., a video game console, a cellular phone (including a so-called "smart phone"), a media player, a printer, an electric appliance such as a "white goods" item such as a washing machine, a tumble dryer, a combined washing machine and tumble dryer, a dishwasher, a refrigeration apparatus such as a fridge or freezer etc. Some or all of these devices may be Internet-of-Things (IoT) devices. In general, as used herein, an IoT device is

a device that has an addressable interface (e.g. an Internet protocol (IP) address, a Bluetooth identifier (ID), a near-field communication (NFC) ID, etc.) and can transmit information to one or more other devices over a wired or wireless connection. IoT devices may in general include or be incorporated in for example sensors, refrigerators, ovens, microwaves, freezers, dishwashers, clothes washing machines, clothes dryers, furnaces, air conditioners, thermostats, televisions and other consumer electronic devices, light fixtures, vacuum cleaners, sprinklers, electricity meters, gas meters, etc.

In the example of Figure 1, the PLC enabled devices 102a, 102b are Light-Fidelity (Li-Fi) over PLC enabled device. Li-Fi refers to techniques whereby information is communicated in the form of a signal embedded in visible light, infrared light or ultraviolet light emitted by a light source. Such techniques are sometimes also referred to as coded light, visible light communication (VLC) or free-space optical communication (FSO). Reference to "light" hereinafter is to be understood as visible light, infrared light or ultraviolet light unless the context requires otherwise. A Li-Fi over PLC enabled device may be a light emitting device for illuminating an environment or part of the environment occupied by a user, whether providing ambient lighting, task lighting or solely Infra Red light for communication. The Li-Fi over PLC enabled device may take any of a variety of possible forms, such as a ceiling or wall mounted luminaire, a free-standing floor or table light source, a light source mounted on a pole, gantry or rigging, etc., (and the different light sources in the environment need not take the same form as one another). A Li-Fi over PLC enabled device may comprise at least one lamp (lighting element) and optionally any associated housing, socket and/or support. In examples, each lighting element may take the form of one or more LEDs of a single type of light emitting diode (LED) or multiple types of LEDs. In examples, the LEDs may be phosphor converted LEDs or direct LEDs and may emit light in the range of ultraviolet to infrared. It will be appreciated that the lighting elements may also take forms other than LEDs. In some examples, the Li-Fi over PLC enabled device may be a dedicated Li-Fi emitter that receives a PLC signal over the PLC line. That is, the Li-Fi over PLC enabled device need not be a luminaire or other lighting device that also serves to illuminate an environment.

Typically, Li-Fi devices modulate visible light LEDs at frequencies of several tens of MHz (1MHz up to 100MHz). Popular PLC communication, such as homeplug or g.hn, utilizes Orthogonal Frequency Division Multiplexing, OFDM, technology. Orthogonal frequency-division multiplexing is a method of encoding digital data on multiple carrier frequencies. Conceptually, OFDM is a specialized frequency-division multiplexing (FDM)

method. FDM is a technique by which the total bandwidth available in a communication medium is divided into a series of non-overlapping frequency bands, each of which is used to carry a separate signal. This allows a single transmission medium such as a cable or optical fibre to be shared by multiple independent signals. In OFDM, the sub-carrier frequencies within a communication channel are chosen so that the sub-carriers are orthogonal to each other, meaning that cross-talk between the sub-channels is eliminated and inter-carrier guard bands are not required.

As shown in Figure 1, the PLC enabled devices 102a, 102b are configured to communicate with respective user devices 106a, 106b, e.g. a personal computing device such as a laptop or desktop or tablet computer, a video game console, a cellular phone (including a so-called "smart phone"), a media player, etc. In the example of Figure 1, each user device comprises a respective receiver 107a, 107b for communicating with the PLC enabled devices. The receiver may be, for example, a dongle. The PLC enabled devices 102a, 102b comprise a respective transmitter for transmitting signals to the user devices. For example, the transmitter may be a wireless transmitter, e.g. an infrared transmitter or a radio transmitter, or in the case of Li-Fi over PLC enabled device, an optical transmitter. In this case, the receiver 107 may be a LiFi dongle, also referred to as an 'end point'. The communication between the Li-Fi over PLC enabled device 102a and the Li-Fi dongle is an optical data link over LiFi. In some examples, the PLC enabled devices 102a, 102b also comprise a receiver for receiving signals from the user devices. For example, the receiver may be a wireless receiver such as an infrared receiver or a radio receiver.

The system 100 comprises one or more power adaptors 108a, 108b, whose function will be described below in relation to Figure 2. The system 100 also comprises a source 110 (e.g. a domain master) of PLC signals to be transmitted to the PLC enabled devices (e.g. end nodes). The domain master 110 translates (or bridges) the signal from Ethernet to PLC and vice versa. The domain master 110 may combine (e.g. modulates) an outgoing signal into a power component of a mains supply 104. For example, the mains supply 104 may be a mains power supply having an AC power component, such as the mains power typically found in a building, home, office, etc. The AC power component is typically a 220V or 230V AC power component. The outgoing PLC signal 111 may originate from an internet router 112 or ethernet switch that is connected to the internet at one side (e.g. an Ethernet connection) and to PLC signal at its other side. The connection between the domain master 110 and the internet router 112 may be via e.g. an Unshielded/Shielded Twisted Pair

(UTP) cable. The domain master 110 is configured to inject data into the AC power component and optionally extract data from the AC power component.

The system 100 of Figure 1 represents a "PLC universe" (i.e. PLC network) having two PLC enabled devices connected to the source. Figure 2 illustrates an example PLC universe 100 having a single PLC end node 102 (in some examples the end node is the receiver, e.g. the dongle). The PLC universe 100 comprises a PLC filter 202 that receives an AC power component 204 and contains the PLC signal within a PLC universe 100 for devices that are connected to the output of the PLC filter 202. By using a PLC filter 202, multiple PLC universes can be created within a single mains network. A single PLC universe 100 may contain multiple PLC end points 102a, 102b and a single PLC domain master 206. The PLC domain master acts as a bridge PLC universe and an internet or Ethernet connection. The PLC domain master 206 can have a wired or wireless connector towards the internet 208. The system may operate as a master-slave system, with the domain master acting as the master device and the end points PLC-enabled devices 102 connected to the source via the power adaptor 108 operating as slave devices.

All PLC enabled devices 102 that are connected within the same PLC universe 100 will be able to receive all data within this domain (i.e. outgoing PLC signal) from/to the domain master 110. OFDM modulation can be used to directly inject the data into the light intensity modulation of a Li-Fi device without the need of any translation. This is advantageous from a cost perspective. In addition, PLC can be operated in in half-duplex mode to prevent data collision between outgoing and return signals. This overcomes potential cross talk problems in the optical Li-Fi channel.

In the case of Li-Fi enabled PLC devices, by transmitting the same PLC signal to each PLC enabled device (e.g. desk lamp), a user can hop between different lamps (i.e. move their user device 106 between areas covered by the illumination of different lamps) whilst maintaining the same data link.

Embodiments of the present invention will now be described. Figure 2 illustrates a PLC universe 100 comprising a power adaptor 108, a PLC enabled device 102 (in particular, a Li-Fi over PLC enabled device) and a source 110. In this example, the source 110 comprises the PLC filter 202 for receiving an AC power component and passes the AC power component to the PLC modem 206, which receives a PLC signal (e.g. data from the internet) and embeds (i.e. modulates) the PLC signal into the AC power component to form a first signal. The source 110 outputs the first signal to the power adaptors 108.

The power adaptor 108 comprises an input 210 for receiving the first signal from the source 110. The power adaptor 108 comprises a signal path 212 and a power path 214. The power adaptor 108 also comprises an output 216 for outputting a second signal, the second signal being the outgoing PLC signal embedded (i.e. superposed) into a direct current (DC) power component. The outgoing PLC signal output by the output 216 is a version (e.g. a filtered version) of the outgoing PLC signal received by the input 210, but at a lower DC voltage.

The power path 214 comprises a power converter 218 for converting the AC power component into a DC power component. The DC power component is used to power the PLC enabled device 102. For example, the DC power component may be a 12V DC power component. The power converter 218 may be an electrical circuit that converts electrical energy from one form to another, in particular from AC power to DC power. For example, the power converter 218 may comprise a rectifier for converting an AC input to a DC output, a regulator for adjusting the voltage, and/or a smoothing capacitor to smooth the pulsating DC power component.

The power path 214 also comprises filtering circuity 220 arranged to prevent the PLC signal from getting deteriorating/attenuated by entering the power converter 218. That is, the filtering circuity 220 prevents loading of the PLC signal by the components used in the power converter 218. Preferably, the outgoing PLC signal is prevented from entering the power converter 218. Whilst the PLC signal is blocked from entering power converter 218, the filtering circuitry 220 allows the AC power component to pass through the power converter 218 in order to be converted into the DC power component.

The signal path 212 comprises insulating circuitry 222 arranged to prevent the AC power component from passing from the input 210 to the output 216 along the signal path 212. That is, the AC power component may pass from the input 210 along the signal path 212 up until the insulating circuitry 222 at which point it is blocked. Whilst the AC power component is blocked by the insulating circuitry 222, the insulating circuitry 222 is arranged to allow the outgoing PLC signal to pass from the input 210 to the output 216 in order to be transmitted to the PLC enabled device 102 (e.g. the PLC enabled LiFi device) as part of the second signal. In this sense, the outgoing PLC signal passed by the insulating circuitry 222 is a version of the outgoing PLC that reaches the insulating circuitry 222. Therefore the outgoing PLC is insulated (or isolated) from the AC power component, allowing the outgoing PLC signal to be superposed onto the DC power component. This allows low voltage devices to be powered by the power adaptor 108. The filtering circuitry

220 prevents a (OFDM) signal path towards the power converter 218. If the (OFDM) signal was to enter the power adapter, it would be deteriorated. The insulating circuitry 222 forms a low impedance path for the (OFDM) signal and coupled the signal from AC mains to the DC output.

The power adaptor 108 also comprises a junction 224 arranged to superpose the outgoing PLC signal onto the DC power component, as a result of interconnecting the power path 214 and the signal path 212, to form the second signal. That is, between a DC output of the power converter and the output 216 of the power adaptor 108, the junction 224 combines the signal path 212 and the power path 214 and thus combines the outgoing PLC signal and the DC power component. The junction is not a modulator (or modulation circuitry).

The power adaptor 108 may comprise a different junction 226 between the input 210 of the power adaptor 108 and an input of the power converter 218. This junction 226 splits an incoming path into the signal path 212 and the power path 214. However, this junction 226 need not be present. Instead the input 210 may itself separate into the signal path 212 and the power path 214.

The output 216 of the power adaptor 108 is connected (e.g. by wiring) to an input 228 of the PLC enabled device 102. The second signal powers the PLC enabled device 102 and transmits the outgoing PLC signal to the PLC enabled device 102. In the example of Figure 2, the PLC enabled device 102 is a Li-Fi over PLC enabled device that modulates the intensity of its emitted light according to the outgoing PLC signal that it receives from the power adaptor 108.

For example, the Li-Fi over PLC enabled device may comprise PLC signal extraction circuitry 230 for extracting/injecting the PLC signal from the second signal received from the power adaptor 108 and optical receiver of 236. The extraction/injection circuity 230 is not a demodulator (or demodulation circuitry). The PLC signal extraction circuitry 230 will be described below in relation to Figure 4. The Li-Fi over PLC enabled device further comprises an LED driver 232 for driving one or more first LEDs 234 for lighting purposes. The LED driver 232 also drives one or more second LEDs 234 for communicating with the user device 106 using an optical communication path. The first and second LEDs 234 may be the same LEDs, or they may be separate (e.g. the second LEDs may be infrared LEDs).

The LED driver 232, may superposition the received PLC signal from the second signal as received from the power adaptor 108 onto the drive current of one or more

illumination LEDs. As a result of this the luminous flux emitted by the LEDs will comprise the received PLC signal, which may be received by a LiFi receiver. In order to enable such superpositioning, it may be advantageous to limit the minimum and maximum drive level for the illumination LEDs in such a manner that there remains sufficient headroom to superposition the received PLC signal. By doing so, there will not be a need to dim up or down the light output of the illumination LEDs when a PLC signal is received.

Alternatively when using IR LEDs, the received PLC signal is offset, so as to convert the bipolar PLC signal into a unipolar drive signal for driving the IR LEDs in a manner analogous to that for the illumination LEDs.

The optical receiver 236 in turn may be used to receive an incoming light signal that comprises a PLC-style modulated return signal in the light impinging on the optical receiver. The modulated return signal is modulated in an analogous manner as a PLC signal, but modulated into the impinging light. The optical receiver converts this optical signal to the electrical domain. In the electrical domain the return PLC signal may then optionally be amplified and filtered, so as to suppress noise outside the frequency range of the PLC signal. The return signal and/or the amplified and filtered return signal is then forwarded to the extraction/injection circuity 230 as a return PLC signal from the PLC enabled LiFi device 102 to the power adaptor 108. In embodiments, the filtering circuitry 220 may comprise an input-side filter 220a and an output-side filter 220b. The input-side filter 220a is connected between the input 210 of the power adaptor 108 and an input of the power converter 218. The output-side filter 220b is connected between an output of the power converter 218 and the output 216 of the power adaptor 108. The input-side filter 220a allows the AC power component to enter the power converter 218 via the input of the power converter 218 for conversion into the low voltage DC supply. However, the input-side filter 220a blocks the PLC signal (RX and TX) from entering the input of the power converter 218. Similarly, the output-side filter 220b allows the DC power component to pass from the output of the power converter 218 to the junction 224 (and so to the output 216 of the power adaptor 108). However, the output-side filter 220b blocks the outgoing PLC signal from entering the output of the power converter 218. In some embodiments, the filtering circuitry 220 blocks any PLC signals (i.e. both outgoing signals and return signals) from entering the power converter 218.

The filtering circuitry 220 creates a high impedance to high frequency signals, therefore blocking the high frequency PLC signal. In contrast, the filtering circuitry 220 creates a low impendence to low frequency signals, therefore allowing the AC power

component to pass. This ensures that the PLC signal is not deteriorated by the power converter 218.

The input-side filter 220a and/or output-side filter 220b may each comprise one or more low pass filters that pass signals with a frequency lower than a selected cut-off frequency and attenuates signals with frequencies higher than the cut-off frequency. The cut-off frequency may be set such that a typical AC power component of 50 Hz or 60 Hz can pass, but signal with higher frequencies (i.e. PLC signals) cannot. Additionally or alternatively, the input-side filter 220a and/or output-side filter 220b may each comprise one or more band-pass filters that pass signals with frequencies within a certain range and attenuate signals with frequencies outside that range. Similarly, the input-side filter 220a and/or output-side filter 220b may each comprise one or more band-stop filters that pass most frequencies unaltered, but attenuates signals having a frequency within a specific range. For example, a notch filter may be used. Any combination of the abovementioned filters may be used for each of the input-side 220a and output-side filters 220b.

The insulating circuitry 222 may comprise one or more capacitors for insulating the input 210 of the power adaptor 108 from the output 216 of the power adaptor 108. The one or more capacitors create a low impedance to high frequency signals, therefore allowing the high frequency PLC signal to pass. In contrast, the one or more capacitors create a high impendence to low frequency signals, therefore blocking the AC power component. The one or more capacitors are connected between the input 210 and output 216 of the power adaptor 108. Therefore between the input 210 of the power adaptor 108 and the insulating circuitry 222 (e.g. capacitors) the signal path 212 comprises the outgoing PLC signal and the AC power component, whereas beyond the insulating circuitry 222 the signal path 212 comprises only the outgoing PLC signal.

Some or all of the one or more capacitors may be safety capacitors. Safety capacitors have safe failing condition making sure AC power is never short circuited to the safety extra low voltage circuit 216. The safety capacitor(s) may be Y class capacitors, e.g. Y1 class capacitors or a combined version of X-Y capacitor.

Optionally, the insulating circuitry 222 may comprise a signal transformer for providing galvanic insulation between the input 210 of the power adaptor 108 and the output 216 of the power adaptor 108. The galvanic insulation may be partial or complete. For example, the signal transformer may be connected between the one or more capacitors and the output 216 of the power adaptor 108. An advantage of this is that any potential current leakage from the insulation circuitry 222, in particular from the safety capacitors which cause

low capacitive leakage current from the AC power component, is prevented from flowing to the output 216 of the power adaptor 108. This is particularly beneficial for PLC enabled devices 102 that operate at a safety extra low voltage (SELV), as defined by International Electrotechnical Commission (IEC) standard 60364. IEC defines a SELV system as an electrical system in which the voltage cannot exceed extra-low voltage (50 V AC or 120 V DC. (ripple free)) under normal conditions, and under single-fault conditions, including earth faults in other circuits. SELV may require supplying power at extra-low voltage from the secondary windings of isolating transformers designed according to IEC standard 60742, or the safety insulation is realized by safety capacitors.

Some PLC enabled devices 102 do not require galvanic isolation, e.g. if the device has no accessible live parts. However, some PLC enabled devices 102, e.g. those requiring an SELV, require a safety insulation from the mains power, i.e. the AC power component. An effective way of realising this is by means of safety capacitors, but they result in a reactive leakage current. The galvanic insulation provided by the transformer prevents the leakage current passing to the PLC enabled device 102.

The power adaptor 108 may also comprise protection circuitry for reducing interference spikes on the signal path. For example, the protection circuitry may be a clamp circuit for clamping the interference spikes at a maximum level. The protection may comprise one or more diodes, wherein some of those diodes may be Zener diodes. In the event of a disturbance (e.g. in the AC power component from the mains power supply 204), surge current will be passed from the insulating circuitry 222 (e.g. the capacitors) to the output 216 of the power adaptor 108, which may damage the connected PLC enabled device 102. The protection circuitry also prevents inrush currents flowing to the PLC enabled device 102 at the instant of the power being switched on.

Optionally, as well as outputting the second signal (i.e. the outgoing PLC signal superposed into the DC power component) to the PLC enabled device 102, the output 216 may be adapted to receive a return PLC signal. The return PLC signal may be a signal received from the same PLC enabled device 102 that the outgoing PLC signal is transmitted to. Additionally or alternatively, the return PLC signal may be received from a secondary instance of the power adaptor 108b, or indeed any device capable of transmitted PLC signals via power lines. The signal path 212 of the power adaptor 108 is configured to allow the return PLC signal to pass from the output 216 of the power adaptor 108 to the input 210 of the power adaptor 108. The input 210 of the power adaptor 108 is arranged to transmit the return PLC signal to the domain master 110, e.g. to the internet.

Figure 3 illustrates a circuit diagram of an example power adaptor 108. The input 210 of the power adaptor 108 may comprise first and second input terminals 210a, 210b (e.g. Line and Neutral terminals respectively) and the output 216 of the power adaptor 108 may comprise first and second output terminals 216a, 216b (e.g. positive and negative terminals respectively).

The power path 214 may comprise two branches (or sub-paths). A first branch of the power path 214 couples the first input terminal 210a of the power adaptor 108 with the first output terminal 216a of the power adaptor 108, and the second branch of the power path 214 couples the second input terminal 210b of the power adaptor 108 with the second output terminal 216b of the power adaptor 108. The power converter 218 may comprise first and second input terminals 302a, 302b (e.g. line and neutral terminals respectively) and first and second output terminals 304a, 304b (e.g. positive and negative terminals respectively). The input terminals 302a, 302b of the power converter 218 receive the AC power component and the output terminals 304a, 304b of the power converter 218 output the DC power component. The power converter 218 separates an input-side of the power path 214 (i.e. from the input terminals 210a, 210b of the power adaptor 108 to the input terminals 302a, 302b of the power converter 218) and an output-side of the power path 214 (i.e. from the output terminals 304a, 304b of the power converter 218 to the output terminals 216a, 216b of the power adaptor 108). The input-side of the power path 214 comprises the input-side filter 220a. Each branch of the input-side power path may comprise one or more filters. In the example of Figure 3, a first branch 306a of the input-side power path 214 comprises a first filter 308a and the second branch 306b of the input-side power path 214 comprises a second filter 308b. Similarly, the output-side of the power path 214 comprises the output-side filter 220b. A first branch 310a of the output-side power path 214 comprises a first filter 312a and the second branch 310b of the output-side power path 214 comprises a second filter 312b.

The signal path 212 may comprise two branches (or sub-paths). A first branch of the signal path 212 couples the first input terminal 210a of the power adaptor 108 with the first output terminal 216a of the power adaptor 108, and a second branch of the signal path 212 couples the second input terminal 210b of the power adaptor 108 with the second output terminal 216b of the power adaptor 108. The insulating circuitry 222 may comprise one or more capacitors (e.g. a first capacitor 314a and a second capacitor 314b, the first capacitor 314a being in the first branch of the signal path 212 and the second capacitor 314b being in the second branch of the signal path 212.

In some embodiments, the signal path 212 comprises the first capacitor 314a, the second capacitor 314b and a signal transformer 316. The signal transformer 316 comprise an input-side coil 316a and an output-side coil 316b. The signal transformer 316 separates an input-side of the signal path 212 (i.e. from the input terminals 210a, 210b of the power adaptor 108 to the input-side coil 316a of the transformer) from an output-side of the signal path 212 (i.e. from the output-side coil 216b of the transformer to the output terminals 216a, 216b of the power adaptor 108).

On the input-side of the signal path 212, the first branch of the signal path may comprise a first input line 318a connecting the first input terminal 210a of the power adaptor to a first terminal of the input-side coil 316a of the transformer, and the second branch of the signal path may comprise a second input line 318b connecting the second input terminal 210b of the power adaptor to a second terminal of the input-side coil 316a of the transformer. On the output-side of the signal path 212, the first branch of the signal path may comprise a first output line 320a connecting a first output-side coil 316b of the transformer to the first output terminal 216a of the power adaptor, and the second branch of the signal path may comprise a second output line 320b connecting a second output-side coil 316b of the transformer to the second output terminal 216b of the power adaptor.

The first capacitor 314a may be connected in series with the input side coil 316a in the first input line 318a of the first branch of the signal path, and the second capacitor 316b may be connected in series with the input side coil 316a in the second input line 318b of the second branch of the signal path. A third capacitor 315a may be connected in series with the output side coil 316b in the first output line 320a of the first branch of the signal path, and a fourth capacitor 315b may be connected in series with the output side coil 316b in the second output line 320b of the second branch of the signal path.

In alternative embodiments no transformer is needed. In this case the first input terminal 210a of the power adaptor is coupled to a first plate of the first capacitor 314a and a second plate of the first capacitor 314a is coupled to the first output terminal 216a of the power adaptor. Similarly, the second input terminal 210b of the power adaptor is coupled to a first plate of the second capacitor 314b and the second plate of the second capacitor 314b is coupled to the second output terminal 216b of the power adaptor. In these embodiments, the first and second capacitors 314a, 314b separate an input-side of the signal path (i.e. from the input terminals of the power adaptor to the first plates of the capacitors) and an output-side of the signal path (i.e. from the second plates of the capacitors to the output terminals of the power adaptor).

That is, the first branch of the signal path 212 may connect the first input terminal 210a to the first output terminal 216a directly without the transformer 316 and the second branch of the signal path 212 may connect the second input terminal to the second output terminal directly without the transformer 316. The first capacitor 314a may be connected in series in the first branch and the second capacitor 314b may be connected in series in the second branch to provide said insulation.

The junction 224 arranged to superpose the outgoing PLC signal into the DC power component to form the second signal may comprise a first junction node 224a and a second junction node 224b. The first junction node 224a joins the first branch of the signal path 212 (on the output-side of the signal path) with the first branch of the power path (on the output-side of the power path), and the second junction node 224b joins the second branch of the signal path 212 (on the output-side of the signal path) with the second branch of the power path (on the output-side of the power path).

This junction 226 arranged to split the incoming path into the signal path 212 and the power path 214 may comprise a first junction node 226a and a second junction node 226b. The first junction node 226a splits the incoming path into the first branch of the signal path (on the input-side of the signal path) and the first branch of the power path (on the input-side of the power path), and the second junction node 226b splits the second branch of the signal path (on the input-side of the signal path) with the second branch of the power path (on the input-side of the power path).

The protection circuit 322 may comprise two diodes 326a, 324b and two Zener diodes 324a, 326b. The protection circuit 322 may be connected between the output branches and the junction 224. The protection circuitry 322 may be connected in parallel across the first and second output terminals 216a, 216b (across the first and second branches on the output side, after the junction nodes 224a, 224b). The protection circuitry 322 comprises first and second parallel connections. The first parallel connection comprises a first Zener diode 324ain a first direction, from the first output terminal 216a to the second output terminal 216b, and a first diode 326a in series with and in reverse bias to the first Zener diode 324a. The second connection comprises a second Zener diode 326b, in a second direction, from the second output terminal 216b to the first input terminal 216a, and a second diode 324b in series with and in reverse bias to the second Zener diode 326b. That is, the first and second diodes are positioned to face in different directions to each other. Similarly, the first and second Zener diodes are positioned to face in different directions to each other.

Figure 4 illustrates an example PLC signal extraction and injection circuitry 230 for receiving the second signal from and outputting the return PLC signal to the power adaptor 108. The output terminals 216a, 216b of the power adaptor 108 are connected to the input terminals 402a, 402b of the extraction and injection circuitry 230, e.g. in the PLC enabled device 108. The outgoing/return PLC signal is extracted/injected via first and second coupling capacitors 404a, 404b and passed through a first transformer coil 406. Outgoing PLC signals are passed through the first transformer coil 406 and a second transformer coil 408 to a transmission path 416, whilst return PLC signals are passed from a return path 418 through a third transformer coil 410 and the first transformer coil 406. The DC power component is passed through a filter 412 (e.g. a low pass filter) to input terminals 414a, 414b of a device driver (e.g. an LED driver). High frequency PLC signals are blocked by the filter 412. The DC component is supplied to the PLC enabled device's electronics without deteriorating the data signals. The filter 412 may comprise resistors (e.g. damping resistor) to damp parasitic resonance across the filter's inductors.

Figure 5 illustrates a further embodiment of the invention. Like reference numerals are used to indicate like features from Figures 2 and 3. A data signal (e.g. from the internet 208) and a mains supply 204 enters the domain master which includes a PLC filter. The domain master 206 outputs a PLC signal in a mains power signal. The power adaptor 108 receives the first signal via the input 210. The first signal comprises, as before, an outgoing PLC signal modulated into an alternating current, AC, power component. The power adaptor comprises a signal path 212a and a power path 214. The power path 214 comprises filtering circuitry 220a, 220b to prevent the PLC signal from being deteriorated by the power converter 218, i.e. the filtering circuitry 220a, 220b (partially or fully) blocks the PLC signal entering the power converter 218. The signal path 212 comprises insulating circuitry (e.g. one or more capacitors 314, 315). The signal path 212 passes PLC signals along line and neutral wires.

In contrast to the power adaptor of Figure 2 and Figure 3, the power adaptor of Figure 5 comprises an additional signal path 502. This additional signal path 502 is a protective earth (PE) line 502 connecting the input 210 to the output 216, via the insulating circuitry (e.g. the capacitors 314 and 315). The PE line 502 is configured to pass the PLC signal from the input 210 to the output 216. The PE line will be described in more detail with reference to Figure 6.

Figure 6 illustrates a circuit diagram of an example power adaptor 108. The input 210 of the power adaptor 108 may comprise first, second and third input terminals

210a, 210b, 210c (e.g. Line, Neutral and Protective Earth terminals respectively) and the output 216 of the power adaptor 108 may comprise first, second and third output terminals 216a, 216b, 216c (e.g. positive, negative and shield or ground terminals respectively).

Figure 6 comprises features that are common to Figure 3 and have been described above with reference to Figure 3. In this example, the PE line 502 may comprise insulating circuitry 602 (for example, first and second capacitors 602a, 602b, such as Y1 safety capacitors). The PE line may additionally or alternatively comprise a signal transformer 606, having an input-side coil 606a and an output-side coil 606b. The first capacitor 602a is connected between the third input terminal 210c and the input-side coil 606a. The second capacitor 602b is connected between the output-side coil 606b and the third output terminal 216c. The signal transformer 606 has the effect of creating at least partial galvanic insulating between the third input terminal 210c and the third output terminal 216c. Optionally, the power adaptor 108 may comprise grounding circuitry connected to a signal ground 610.

The signal transformer 606 separates an input-side of the PE line 502a (i.e. from the input terminals 210c of the power adaptor 108 to the input-side coil 606a of the transformer) from an output-side of the PE line 502b (i.e. from the output-side coil 606b of the transformer to the output terminal 216c of the power adaptor 108). In alternative embodiments no transformer is needed.

In these embodiments, the insulating circuitry 222 of the power adaptor 108 may comprise an additional signal transformer 614 having an input-side coil 614a and an output-side coil 614b. The input-side coil 614a is connected in series with the input-side coil 316a. The output-side coil 614b is connected in series with the output-side coil 316b. The insulating circuitry 222 may also comprise one or more additional capacitors 612a, 6142b. The additional capacitors 612a, 6142b are connected in series between input-side coil 316a and input-side coil 614a. Optionally, an inter-connection to a signal ground 616 may be connected between output-side coil 316b and output-side coil 614b.

Whilst not shown in Figure 6, the power adaptor may also comprise an additional protection circuit, similar to the protection circuit 322. The protection circuit may comprise two diodes and two Zener diodes. The protection circuitry may be connected in parallel across the second and third output terminals 216b, 216c. The protection circuitry comprises first and second parallel connections. The first parallel connection comprises a first Zener diode in a first direction, from the second output terminal 216b to the third output terminal 216c, and a first diode in series with and in reverse bias to the first Zener diode. The

second connection comprises a second Zener diode, in a second direction, from the third output terminal to the second input terminal, and a second diode in series with and in reverse bias to the second Zener diode. That is, the first and second diodes are positioned to face in different directions to each other. Similarly, the first and second Zener diodes are positioned to face in different directions to each other.

Figure 7 illustrates an example PLC signal extraction and injection circuitry for receiving the second signal from and outputting the return PLC signal to the power adaptor 108. The output terminals 216a, 216b, 216c of the power adaptor 108 are connected to the input terminals 402a, 402b, 402c of the extraction and injection circuitry, e.g. in the PLC enabled device 108. Input terminal 402c is a PE input terminal. Figure 7 comprises features that are common to Figure 4 and have been described above with reference to Figure 4. The circuitry comprises a capacitor 702 for extracting data from the PE line. Outgoing PLC signals are passed through the first transformer coil 704 and a second transformer coil 706 to a transmission path 708, whilst return PLC signals are passed from a return path 710 through a third transformer coil 712 and the first transformer coil 704. Optionally, the PLC signal extraction and injection circuitry may comprise grounding circuitry connected to a signal ground 714 and 716 (both ground/shield connections require the same potential). In some examples, the outgoing PLC signals on the line path are passed through a first transformer coil 406a and the second transformer coil 408 to a transmission path 416, whilst return PLC signals are passed from a return path 418 through a third transformer coil 410 and a fourth transformer coil 406b.

In these examples, instead of only transmitting the PLC signal via the line and neutral lines of the signal path, e.g. from the first and second input terminals to the first and second output terminals of the power adaptor, the PLC signal may additionally be transmitted using the PE path. The PLC signal may be transmitted using any combination of the mains terminals, i.e. the PLC signal may be transmitted using one or both branches of the signal path 212 and the PE path. That is, the PLC signal may be transmitted over the line, neutral and PE paths, the line and the PE paths, or the neutral and the PE paths. An advantage of this is that the data rate may be improved. A further advantage is that the power adaptor complies with the ITU G.hn standard.

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 single processor or other unit may fulfil the functions of several items recited in the claims. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. 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 system (100) comprising a power adaptor (108) and a light fidelity, LiFi, over PLC enabled device (102) wherein:

the power adaptor (108) is arrange to provide power line communication, PLC, signals to the LiFi over PLC enabled device (102), wherein the power adaptor (108) comprises:

an input (210) arranged to receive a first signal from a source (110), wherein the first signal comprises an outgoing PLC signal modulated into an alternating current, AC, power component;

an output (216) arranged to transmit a second signal to the LiFi over PLC enabled device (102), wherein the second signal comprises a version of the outgoing PLC signal modulated into a direct current, DC, power component;

a power path (214) comprising a power converter (218) arranged to convert the AC power component from the first signal to the DC power component, and filtering circuitry (220) arranged to attenuate the outgoing PLC signal entering the power converter (218);

a signal path (212) comprising insulating circuitry (222) arranged to allow the outgoing PLC signal but not the AC power component of the first signal to pass from the input (210) to the output (216), and

a junction (224) arranged to produce the second signal by superposing the outgoing PLC signal passed by the insulating circuitry (222) onto the DC power component produced by the power converter (218)

and wherein the LiFi over PLC enabled device (102) comprises:

a PLC signal extraction circuitry (230) arranged to receive the outgoing PLC signal from the power adaptor (108) and

an LED driver (232) arranged to generate an LED drive signal to drive one or more LEDs in the LiFi device using received outgoing PLC signal from the power adaptor (108).

2. The system according to claim 1, wherein the filtering circuitry (220) comprises an input-side filter (220a) arranged to attenuate the outgoing PLC signal entering an input of the power converter (218) that receives the AC power component, and an output-side filter (220b) arranged to attenuate the outgoing PLC signal entering an output of the power converter (218) that outputs the DC power component.

3. The system according to claim 2, wherein the input-side filter (220a) and/or output-side filter (220b) each comprise at least one of: a low pass filter, a band-pass filter, and a band-stop filter.

4. The system according to any preceding claim, wherein the insulating circuitry (222) comprises one or more capacitors (314) for insulating the input (210) of the power adaptor (108) from the output (216) of the power adaptor (108).

5. The system according to claim 4, wherein at least one of the one or more capacitors (314) is a safety capacitor.

6. The system according to any preceding claim, wherein the insulating circuitry (222) comprises a transformer (316) for providing at least partial galvanic insulation between the input and the output.

7. The system according to any preceding claim, wherein the DC power component is a safety extra low voltage DC power component.

8. The system according to any preceding claim, wherein the signal path (212) comprises protection circuitry (322) for reducing interference spikes on the signal path.

9. The system according to claim 8, wherein the protection circuitry (322) comprises a plurality of diodes.

10. The system according to any preceding claim, wherein the output (216) is adapted to receive a return PLC signal from the LiFi over PLC enabled device (102), wherein the signal path (212) is arranged to allow the return PLC signal to pass from the

output (216) to the input (210), and wherein the input (210) is arranged to transmit the return PLC signal to the source (110).

11. The system according to any preceding claim, wherein the input (210) comprises a line terminal (210a), a neutral terminal (210b) and a protective earth, PE, terminal (210c), wherein the output comprises a positive terminal (216a), a negative terminal (216b) and a ground terminal (216c), wherein the power adaptor (108) comprises a PE path (502) connecting the PE terminal (210c) to the ground terminal (216c), and wherein the PE path is arranged to pass the outgoing PLC signal from the PE terminal to the ground terminal.

12. The system (100) according to any preceding claim, comprising a second LiFi over PLC enabled device (102b),

wherein the power adaptor (108) is arranged to also output the second signal to the second LiFi over PLC enabled devices (, 102b), the second LiFi over PLC enabled device (102b) comprising:

a second PLC signal extraction circuitry arranged to receive the outgoing PLC signal from the power adaptor (108) and

a second LED driver arranged to generate a second LED drive signal to drive one or more second LEDs in the second LiFi device using the received outgoing PLC signal from the power adaptor (108) as received by the second PLC signal extraction circuitry.

13. A system (100) according to any of claims 1 to 12, wherein the system (100) comprises the source (110), and wherein the source (110) is a secondary instance of the power adaptor (108b).

14. A power adaptor (108) for providing power line communication, PLC, signals to a PLC enabled device (102), wherein the power adaptor (108) comprises:

an input (210) arranged to receive a first signal from a source (110), wherein the first signal comprises an outgoing PLC signal modulated into an alternating current, AC, power component;

an output (216) arranged to transmit a second signal to the PLC enabled device (102), wherein the second signal comprises a version of the outgoing PLC signal modulated into a direct current, DC, power component;

a power path (214) comprising a power converter (218) arranged to convert the AC power component from the first signal to the DC power component, and filtering circuitry (220) arranged to attenuate the outgoing PLC signal entering the power converter (218);

a signal path (212) comprising insulating circuitry (222) arranged to allow the outgoing PLC signal but not the AC power component of the first signal to pass from the input (210) to the output (216), and

a junction (224) arranged to produce the second signal by superposing the outgoing PLC signal passed by the insulating circuitry (222) onto the DC power component produced by the power converter (218),

wherein the input (210) comprises a line terminal (210a), a neutral terminal (210b) and a protective earth, PE, terminal (210c), wherein the output comprises a positive terminal (216a), a negative terminal (216b) and a ground terminal (216c), wherein the power adaptor (108) comprises a PE path (502) connecting the PE terminal (210c) to the ground terminal (216c), and wherein the PE path is arranged to pass the outgoing PLC signal from the PE terminal to the ground terminal.

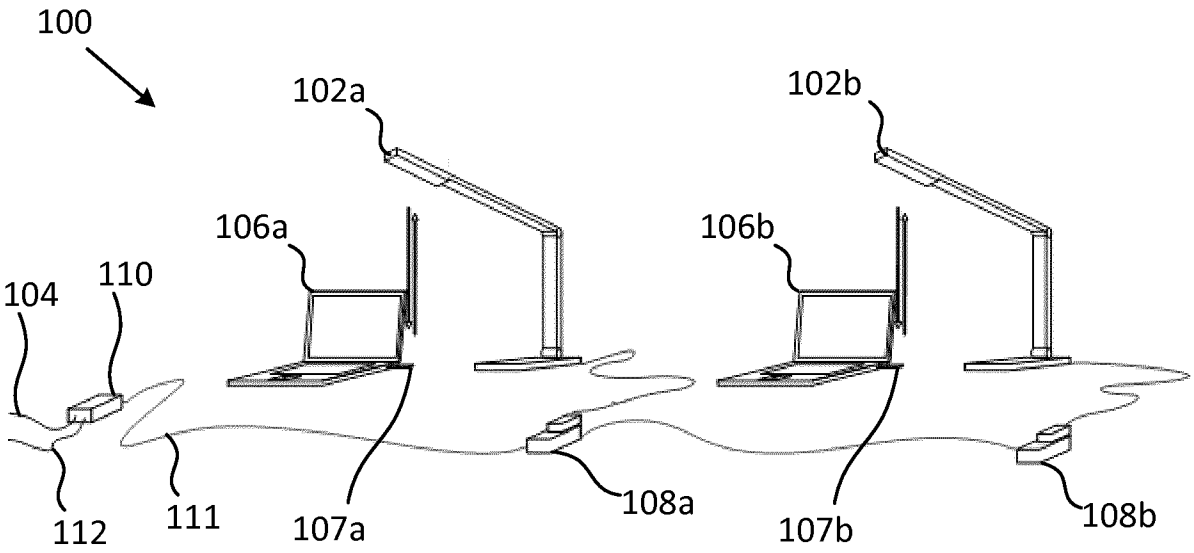


Figure 1

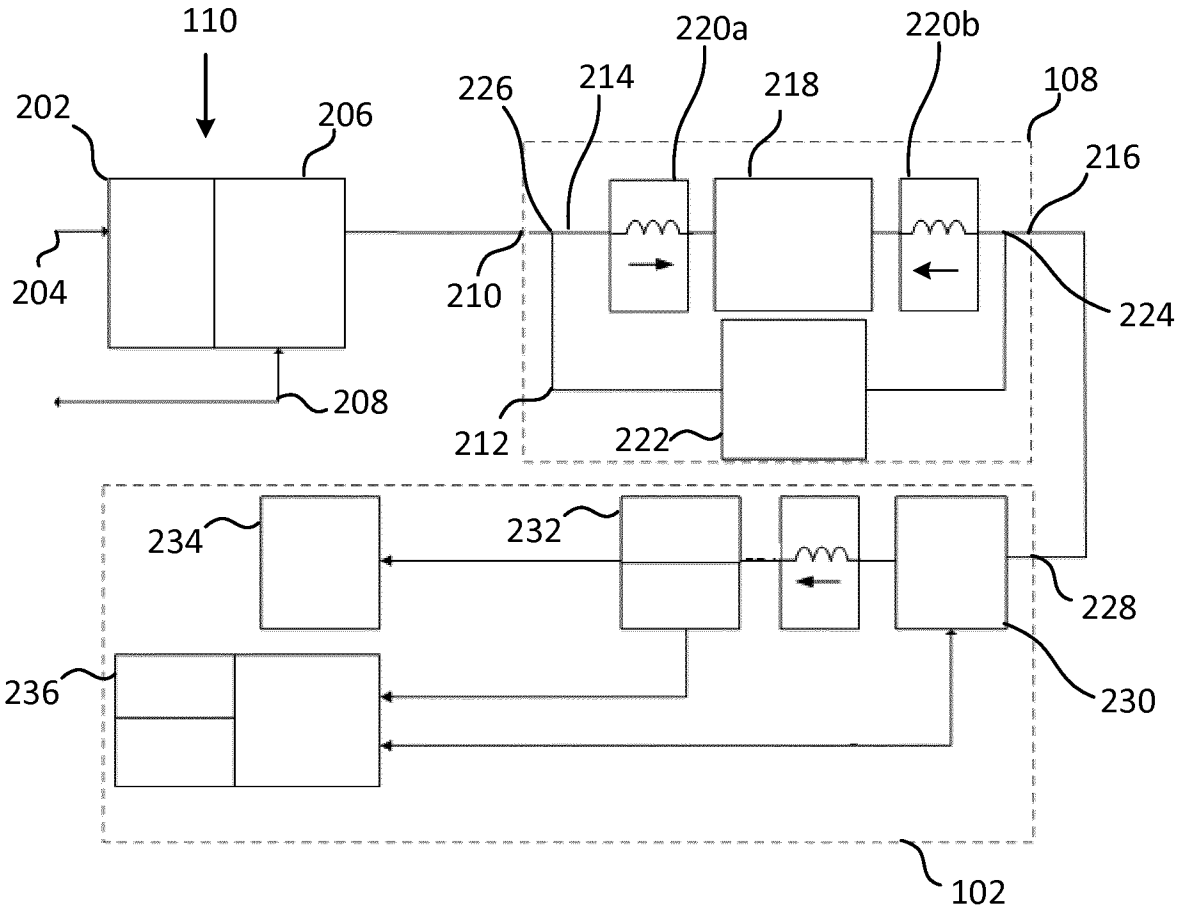
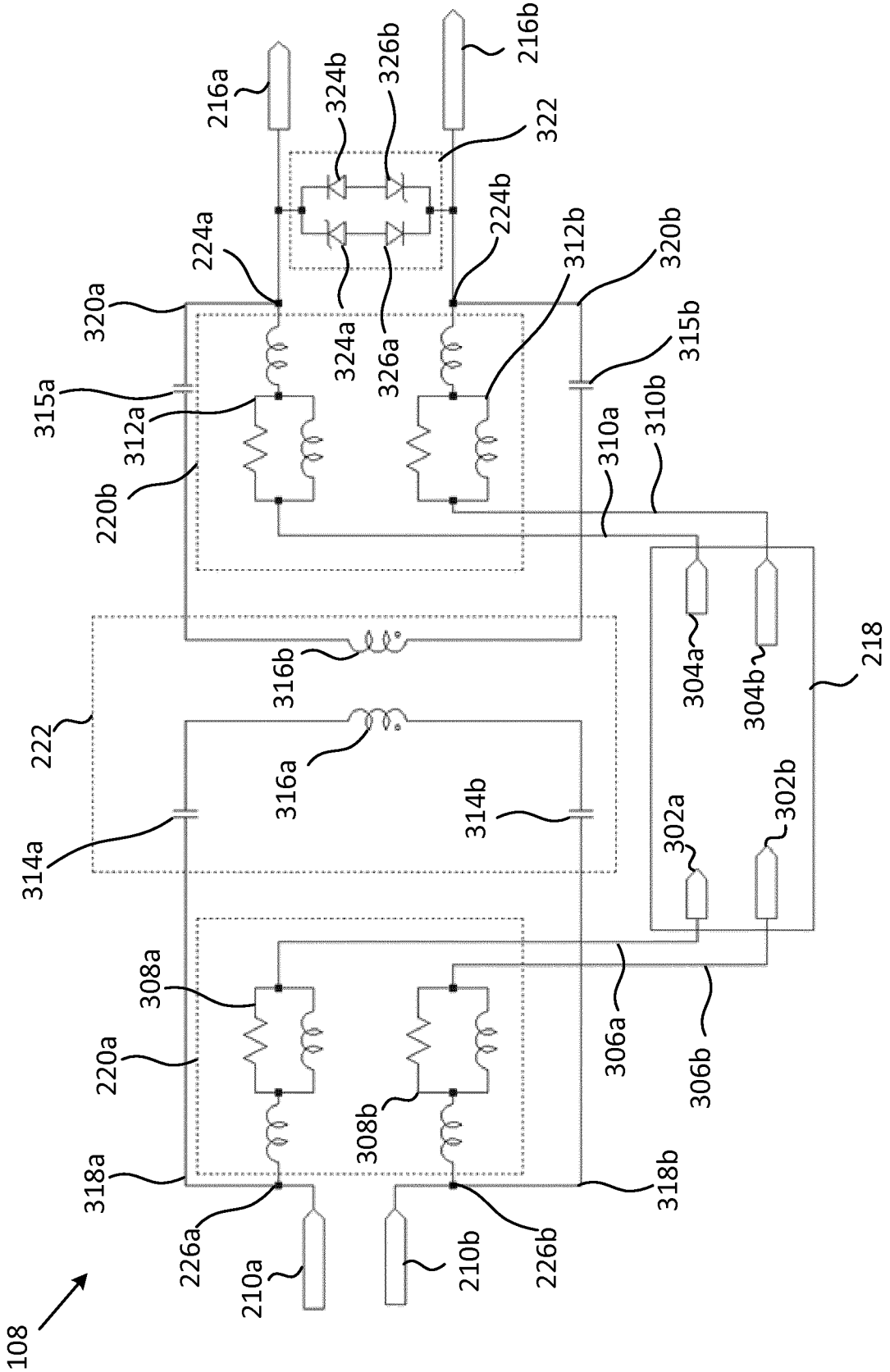


Figure 2


108
210a
210b
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216b
218
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220b
222
224a
224b
226a
226b
302a
302b
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306a
306b
308a
308b
310a
310b
312a
312b
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326a
326b

Figure 3

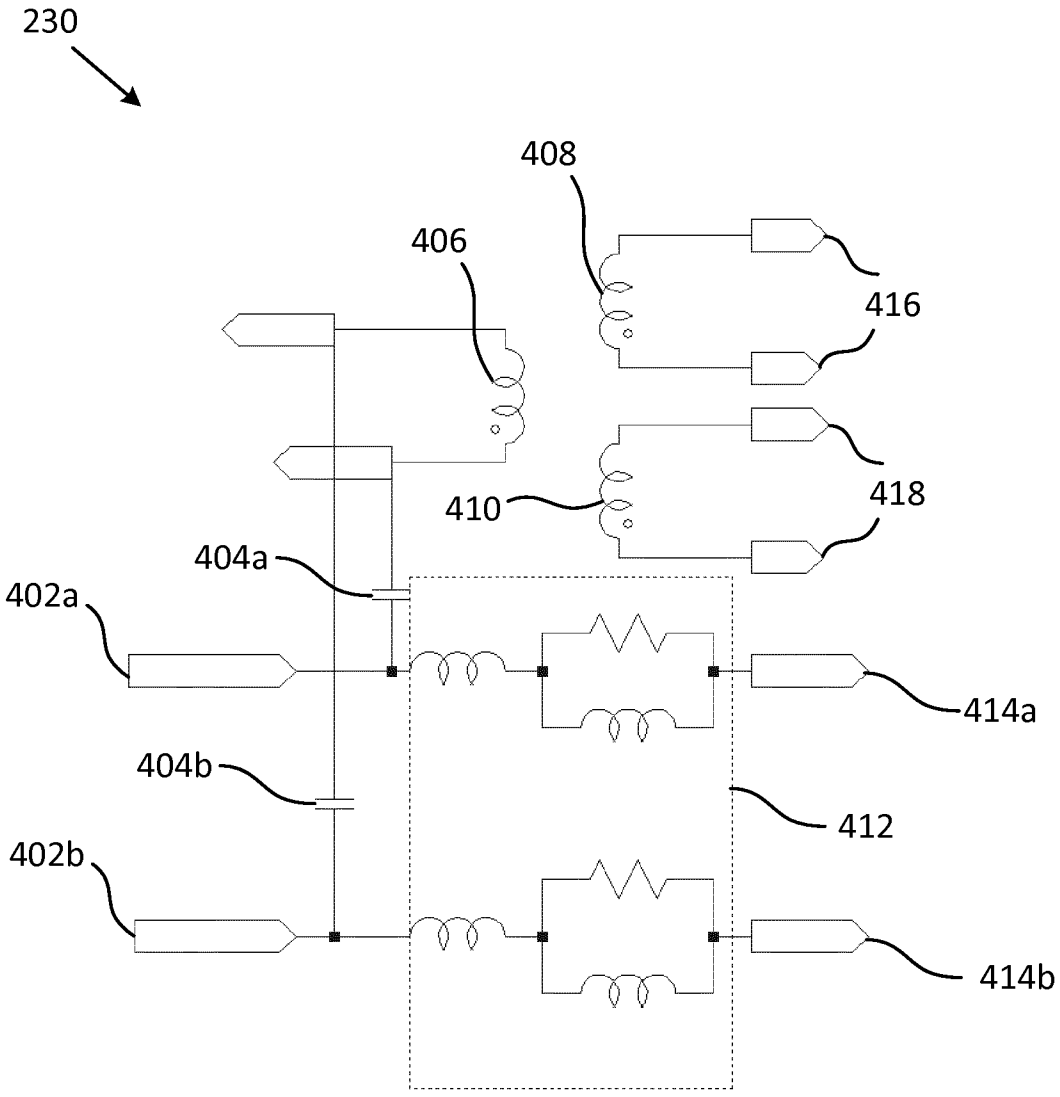


Figure 4

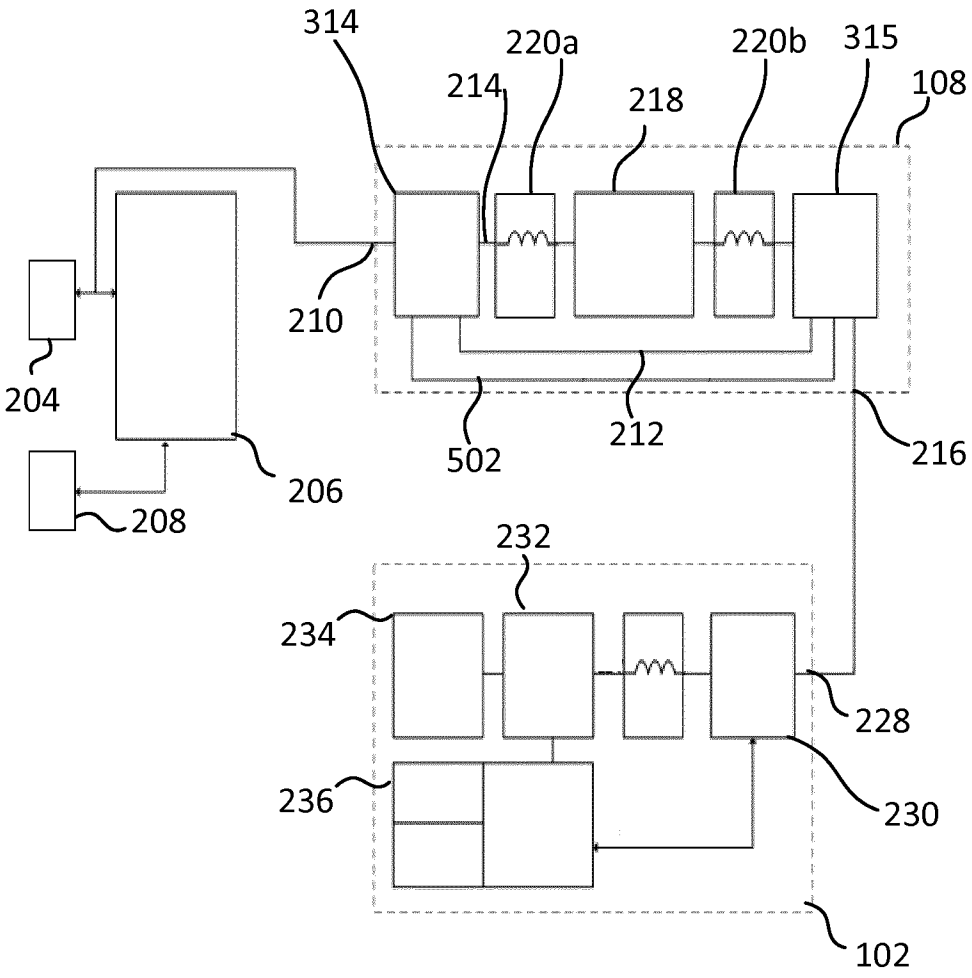
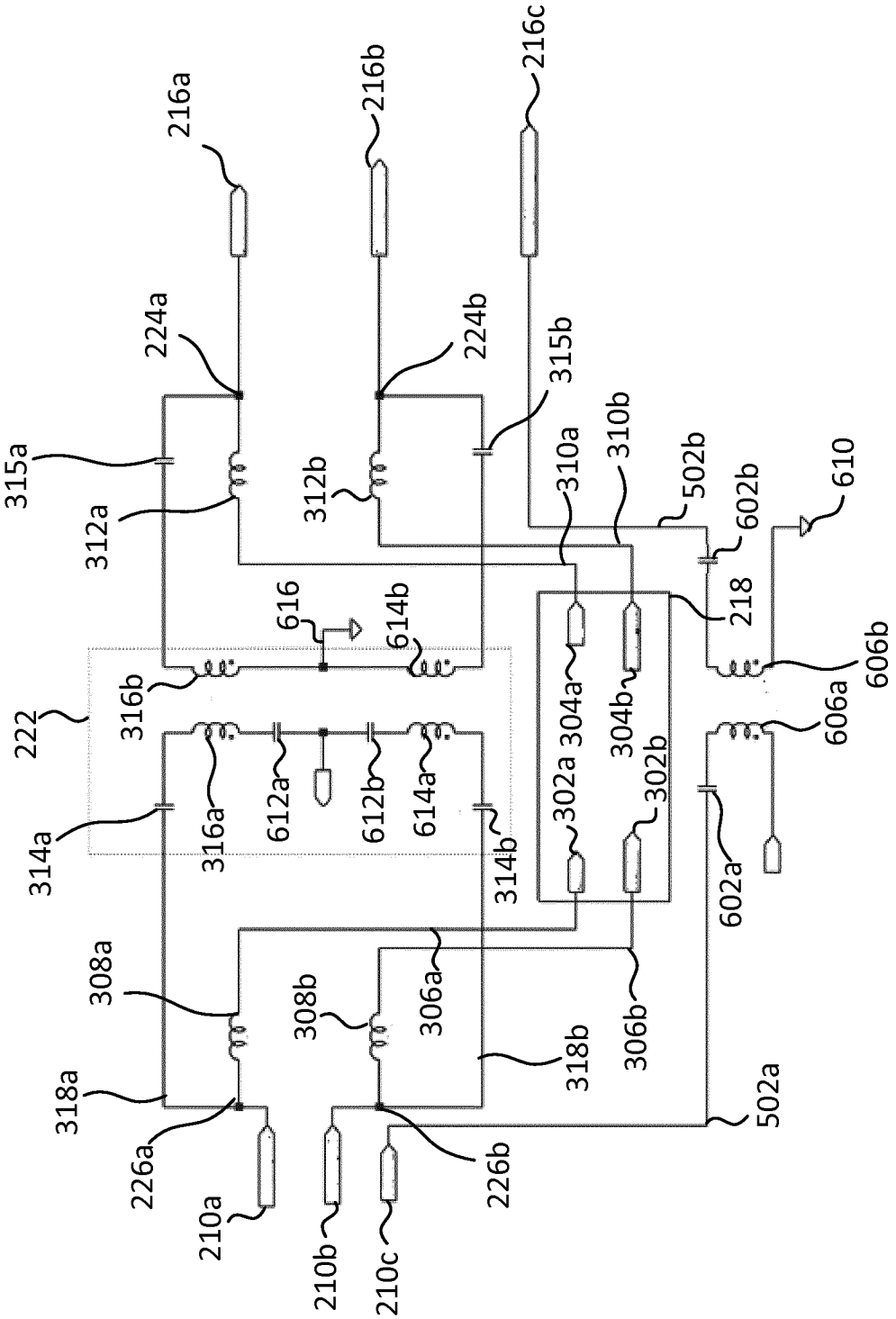

314
220a
214
218
220b
315
108
210
204
206
208
502
212
216
232
234
228
236
230
102

Figure 5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216b
216c
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224b
315b
315a
312a
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310a
310b
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602b
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606b
222
316b
606a
316a
612a
612b
614a
304a
304b
314a
314b
302a
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502a
226a
226b
210a
210b
210c

Figure 6

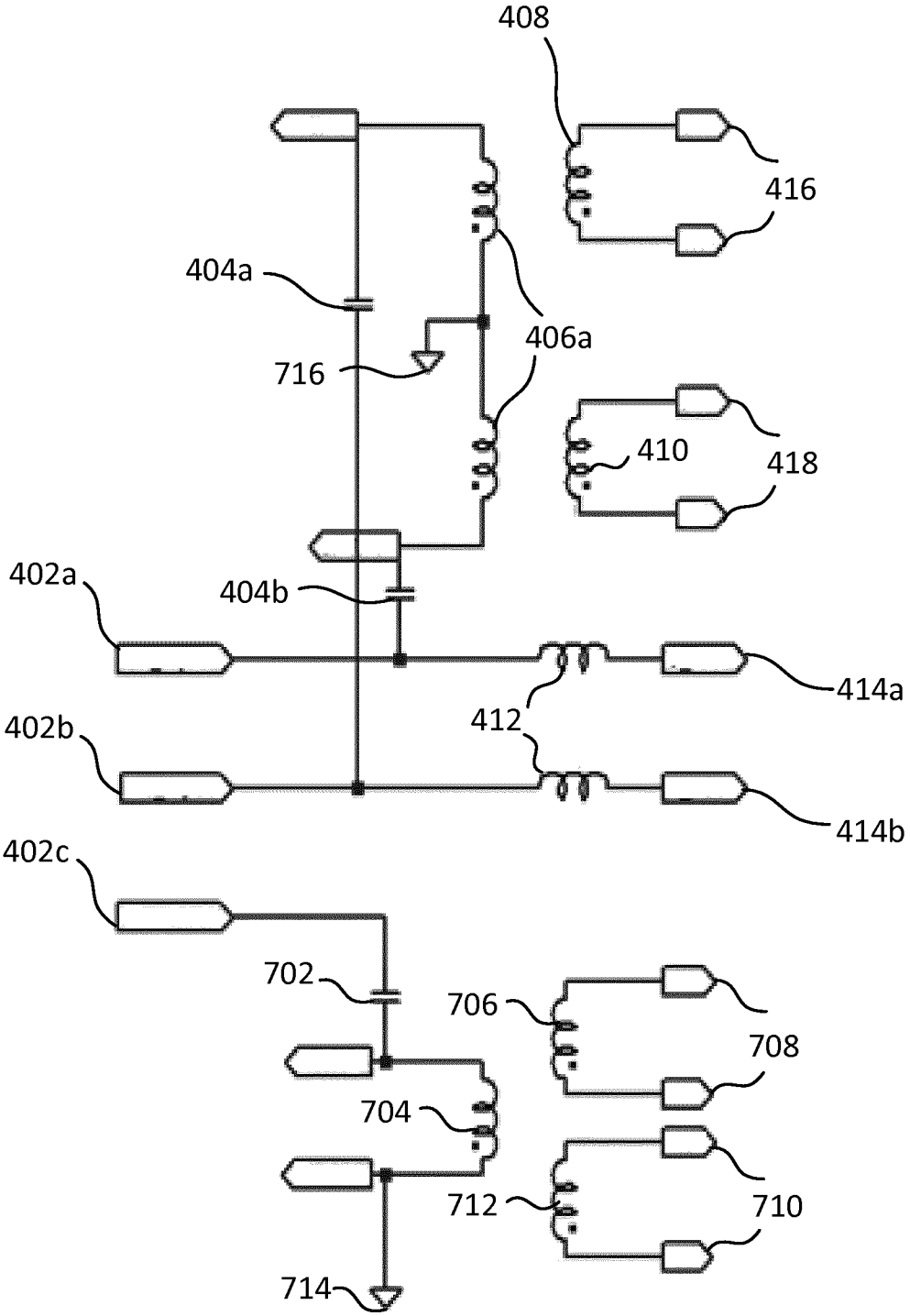
408
416
404a
406a
716
410
418
402a
404b
414a
412
402b
414b
402c
702
706
708
704
712
710
714

Figure 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/082205

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04B3/54 H04B3/56 H04B10/116 H05B37/02
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)
H04B H05B

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, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 2006/056855 A1 (NAKAGAWA MASAO [JP] ET AL) 16 March 2006 (2006-03-16) paragraph [0137] - paragraph [0139] paragraph [0141] paragraph [0145] - paragraph [0147] paragraph [0247] - paragraph [0249] figures 1-4	1-10,12, 13 11,14

X A	EP 2 874 472 A1 (RENESAS ELECTRONICS CORP [JP]) 20 May 2015 (2015-05-20) paragraph [0114] - paragraph [0118] paragraph [0120] - paragraph [0124] figures 6-8	1-10,12, 13 11,14

Y	US 9 577 707 B1 (BERNAL ANTONIO JIMENEZ DE PARGA [ES]) 21 February 2017 (2017-02-21) column 1, line 45 - column 2, line 43 column 2, line 57 - column 3, line 3	11,14

☐ Further documents are listed in the continuation of Box C.

☒ 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

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