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(54) **BROADBAND POWER LINE NETWORK DEVICE AND ETHERNET SIGNAL COUPLING DEVICE THEREOF**

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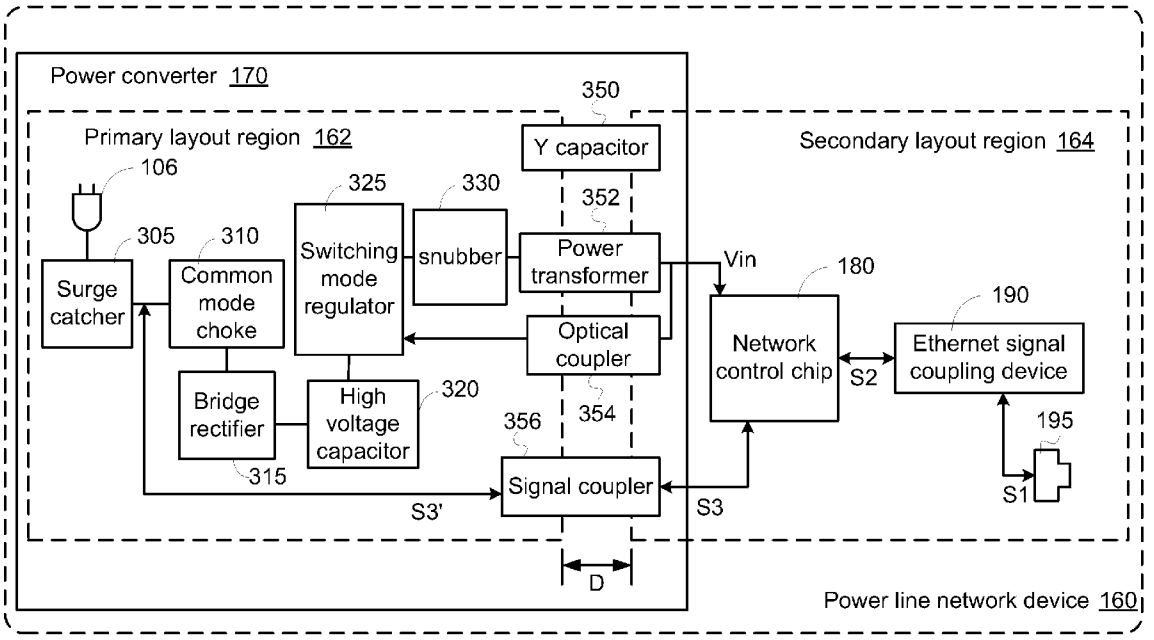
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(57) **ABSTRACT**

An Ethernet signal coupling device comprises: a primary side comprising TX+, TX−, RX+ and RX− signal terminals; a secondary side comprising TD+, TD−, RD+ and RD− signal terminals; a first transformer comprising a primary coil coupled to the TX+ signal terminal and the TX− signal terminal and a secondary coil coupled to the TD+ signal terminal and the TD− signal terminal; and a second transformer comprising a primary coil coupled to the RX+ signal terminal and the RX− signal terminal and a secondary coil coupled to the RD+ signal terminal and the RD− signal terminal. The primary coils of the first and second transformers are wound by triple insulated wires, or the secondary coils of the first and second transformers are wound by triple insulated wires.



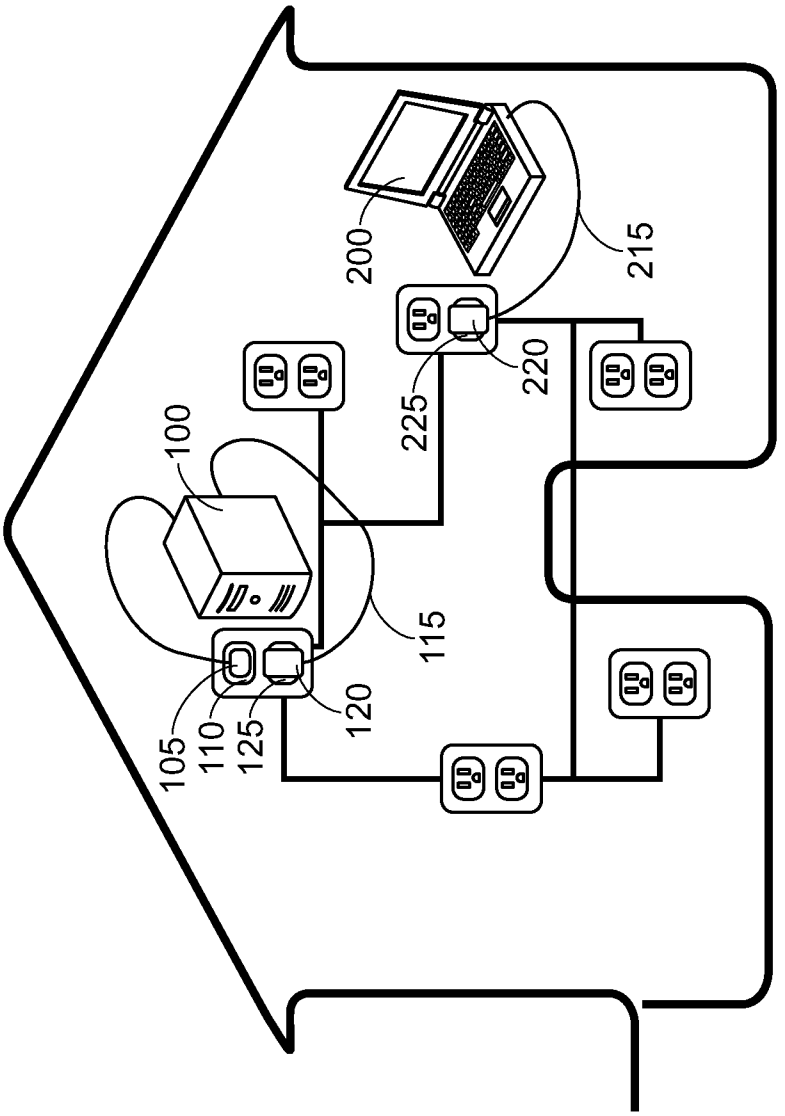


FIG. 1 (PRIOR ART)

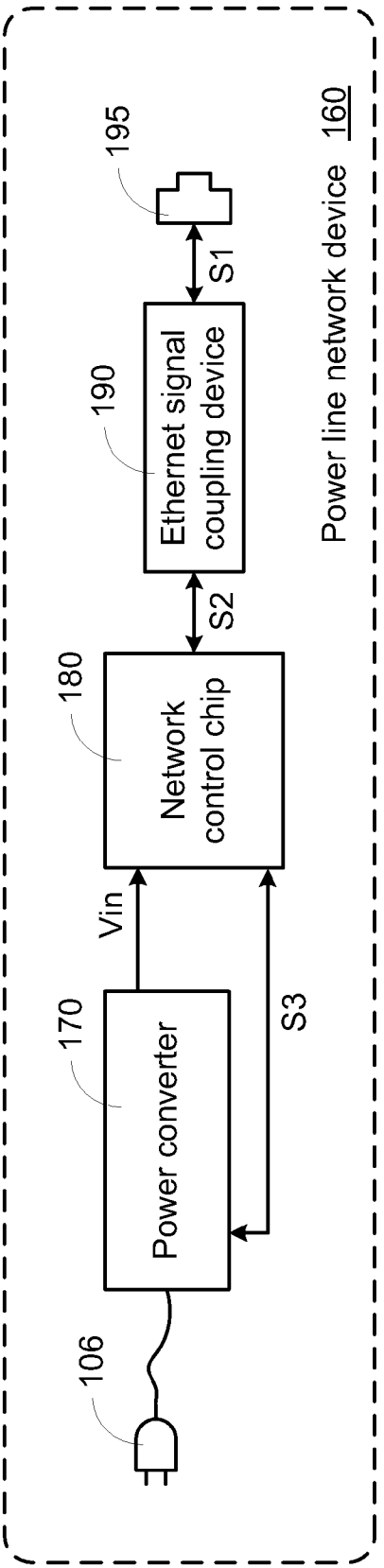

Power line network device 160
195
S1
190
Ethernet signal coupling device
S2
180
Network control chip
Vin
S3
170
Power converter
106

FIG. 2

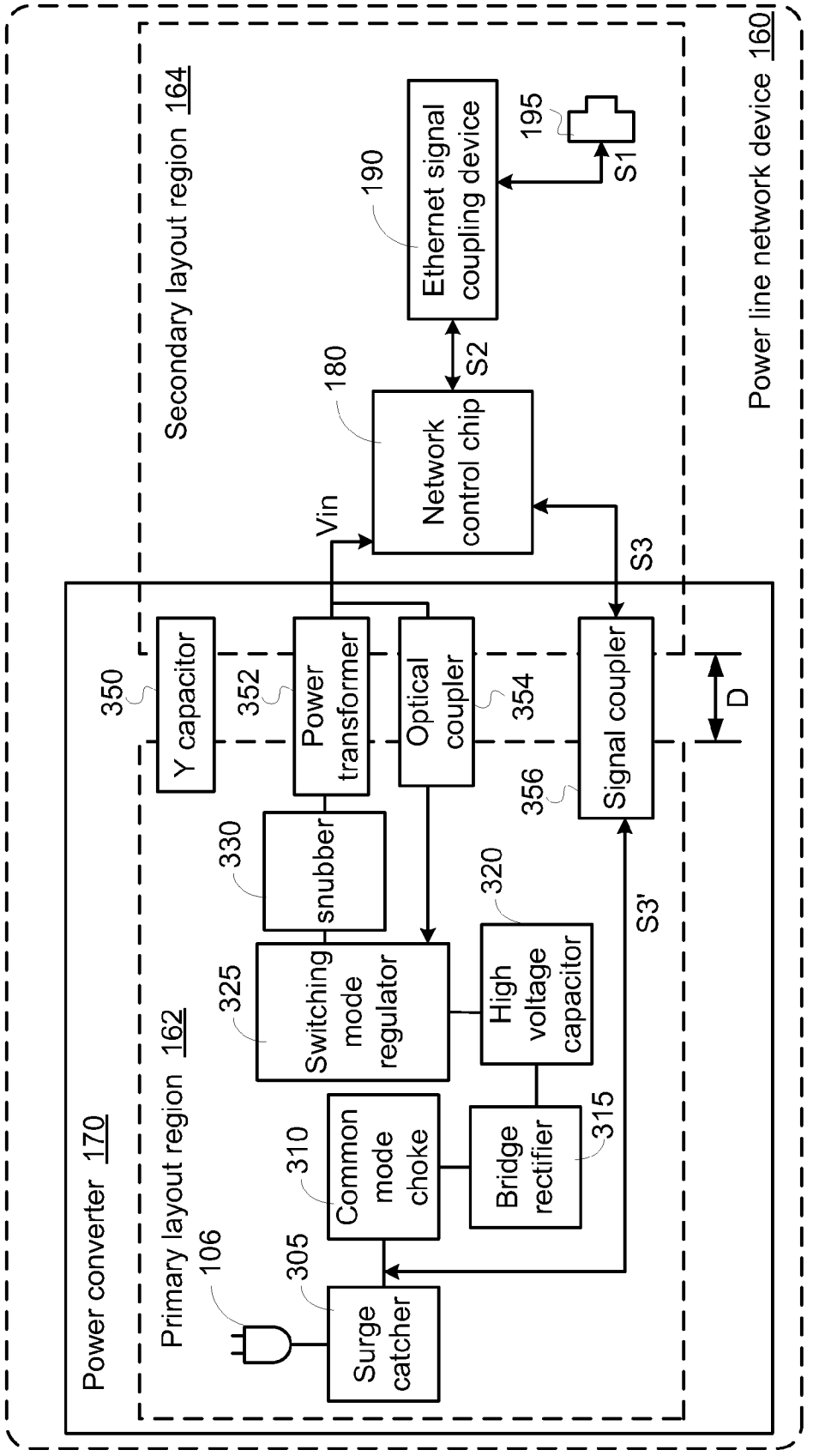

Power line network device 160
Secondary layout region 164
Power converter 170
Primary layout region 162
106
305
Surge catcher
310
Common mode choke
315
Bridge rectifier
320
High voltage capacitor
325
Switching mode regulator
330
snubber
350
Y capacitor
352
Power transformer
354
Optical coupler
356
Signal coupler
D
S3'
Vin
180
Network control chip
S3
190
Ethernet signal coupling device
S2
195
S1

FIG. 3A

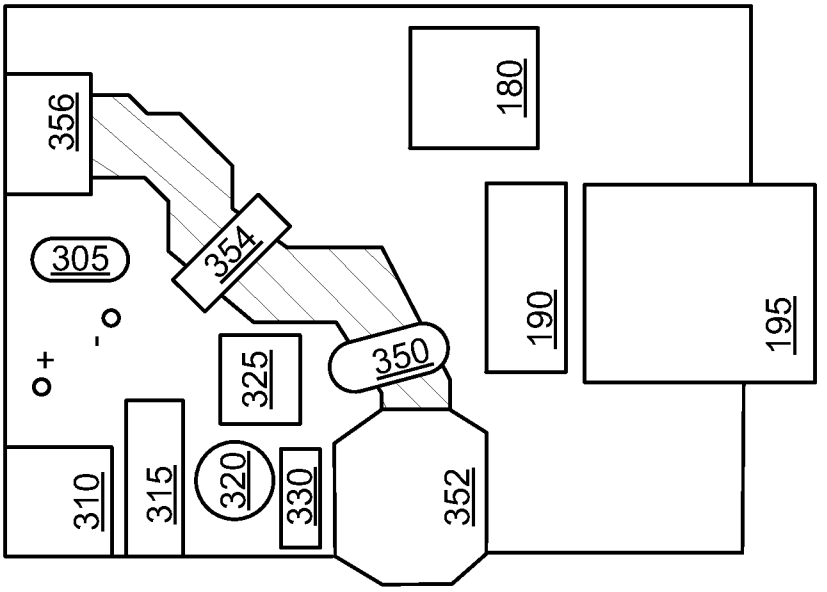

356
180
305
354
190
195
350
325
310
315
320
330
352

FIG. 3C

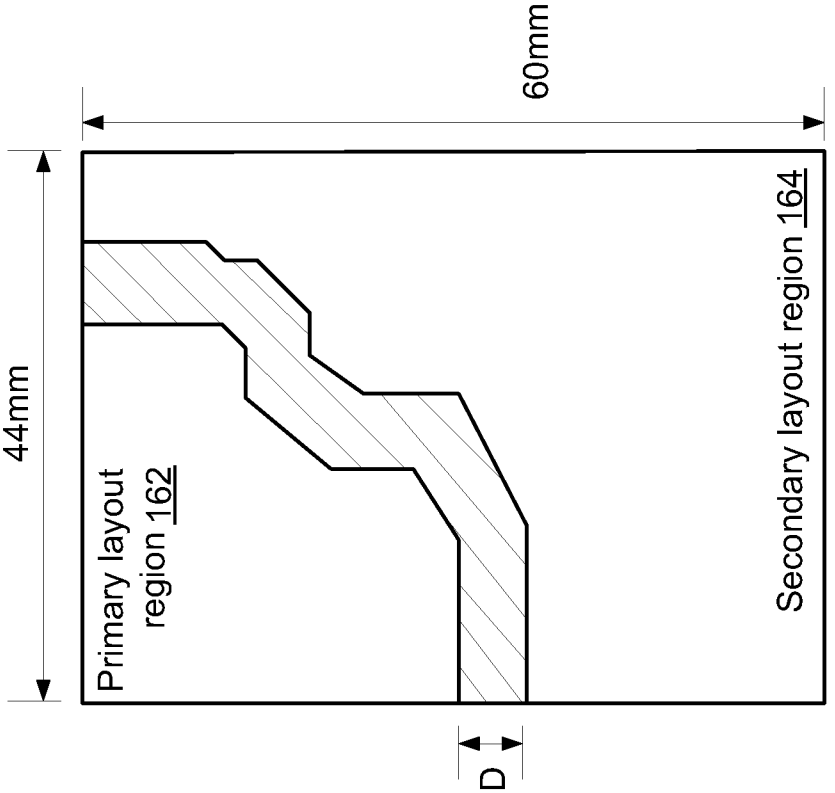

60mm
44mm
Primary layout region 162
Secondary layout region 164
D

FIG. 3B

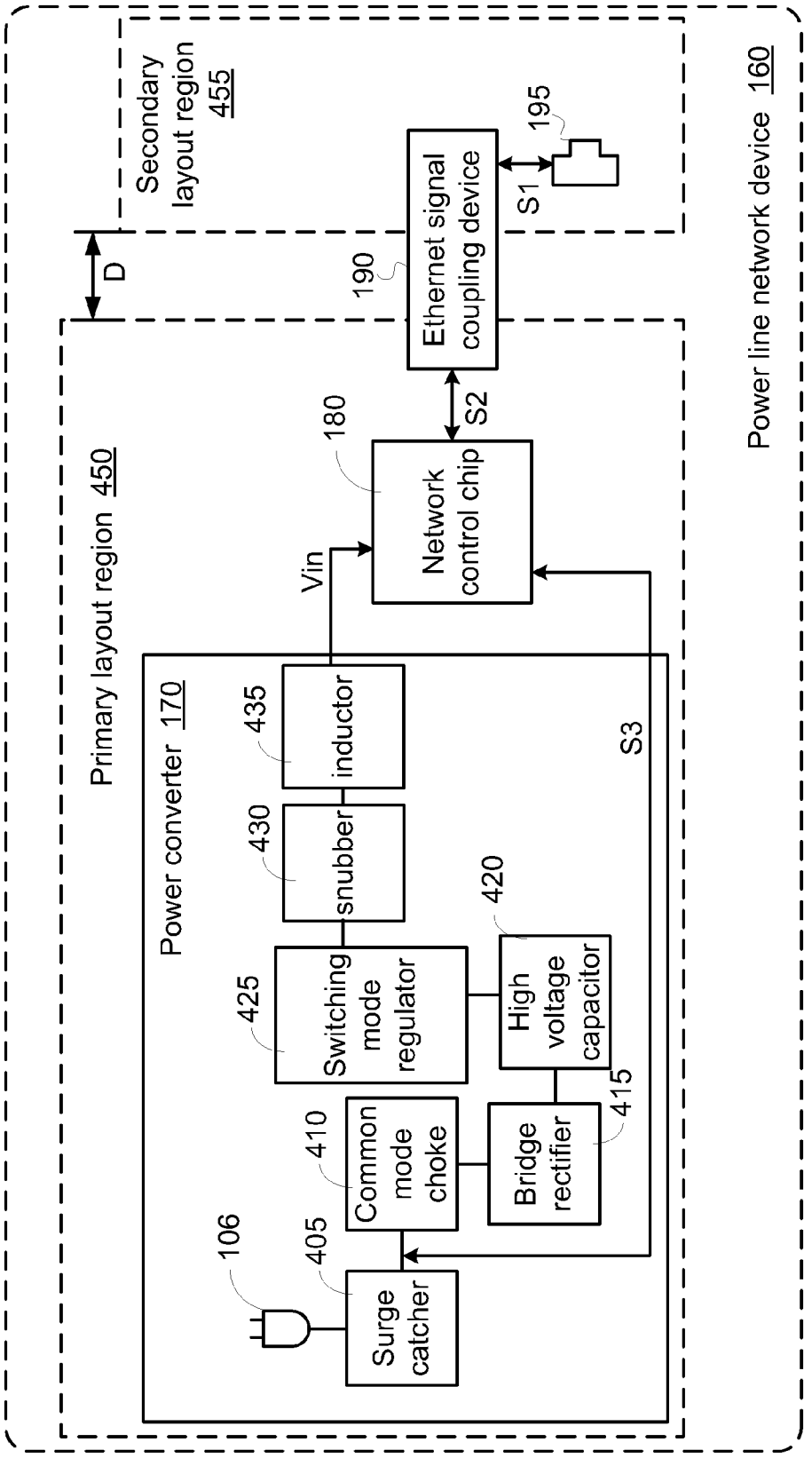

Power line network device 160
Secondary layout region 455
D
195
S1
190
Ethernet signal coupling device
S2
180
Network control chip
Vin
Primary layout region 450
Power converter 170
435
inductor
430
snubber
420
425
Switching mode regulator
High voltage capacitor
415
410
Common mode choke
Bridge rectifier
106
405
Surge catcher
S3

FIG. 4A

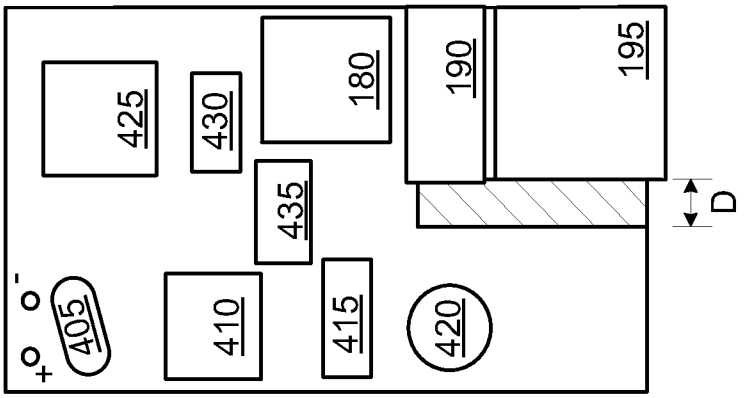

425
430
180
190
195
435
405
410
415
420
D

FIG. 4C

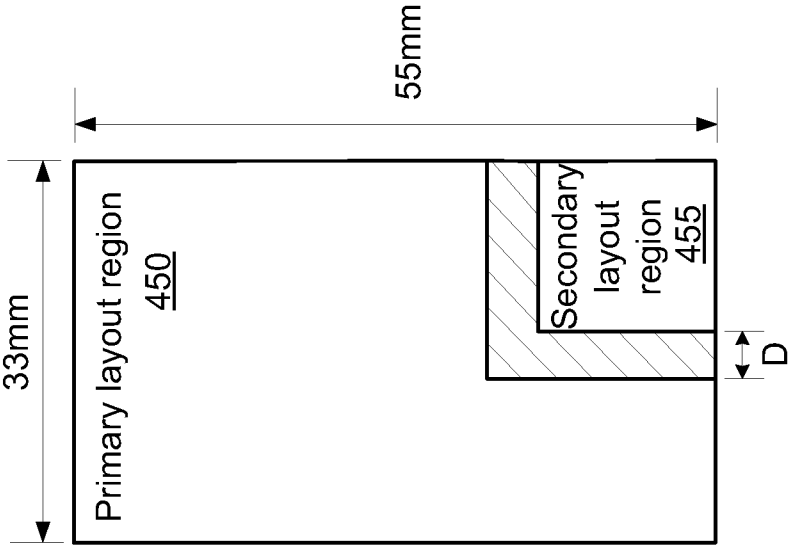

55mm
33mm
Primary layout region
450
Secondary
layout
region
455
D

FIG. 4B

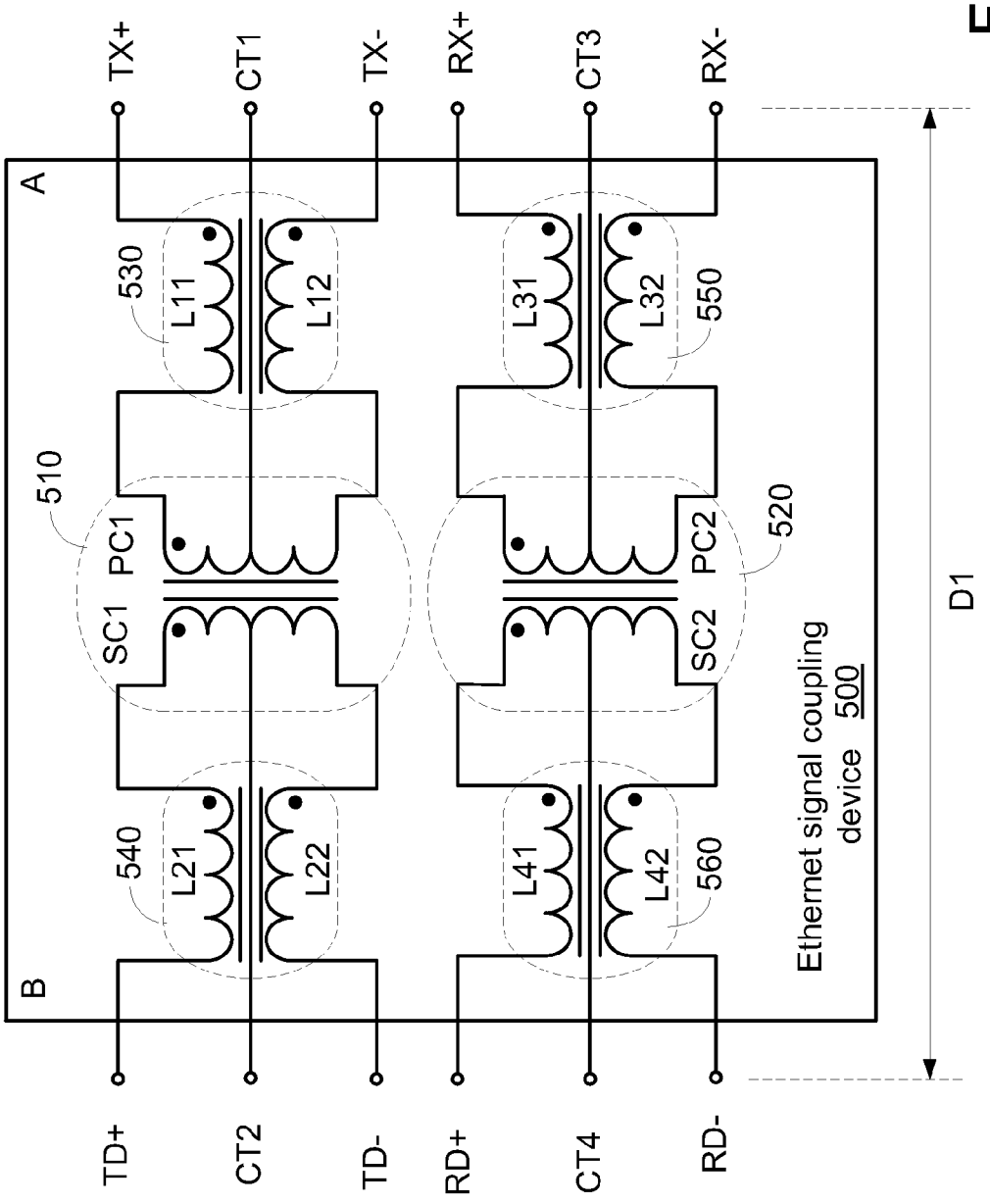

TX+
CT1
TX-
RX+
CT3
RX-
A
B
510
530
L11
L12
L31
L32
550
PC1
SC1
PC2
SC2
520
540
L21
L22
L41
L42
560
Ethernet signal coupling device 500
D1
TD+
CT2
TD-
RD+
CT4
RD-

FIG. 5

BROADBAND POWER LINE NETWORK DEVICE AND ETHERNET SIGNAL COUPLING DEVICE THEREOF

[0001] This is a divisional application of co-pending U.S. application Ser. No. 13/469,244, filed May 11, 2012, which claims the benefits of Taiwan Patent Application No. 101100517, filed Jan. 5, 2012, and Taiwan Patent Application No. 101200272, filed Jan. 5, 2012, the subject matters of which are incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to a broadband power line network device, and more particularly to a broadband power line network device with a non-isolated AC-DC power converter. The present invention also relates to an Ethernet signal coupling device of the broadband power line network device.

BACKGROUND OF THE INVENTION

[0003] With increasing development of science and technology, personal computers and networks are widely used in homes and become indispensable communication devices. For example, through network connection, personal computers in homes may be employed to exchange data, share data or print data. Nowadays, a power line communication (PLC) system is one of the most popular ways to connect many computers. In the PLC system, the electrical wires are utilized to connect these computers.

[0004] FIG. **1** schematically illustrates the architecture of a conventional broadband power line communication system. Generally, the home-use power outlets are found in many regions such as rooms, studies, living rooms, kitchens, or the like. These power outlets are connected with each other in parallel to provide AC power. In additions, the power outlets and the electric wires between these power outlets may be collectively employed to construct the broadband power line communication system. As shown in FIG. **1**, the plug **105** of the personal computer **100** may be inserted into a first power outlet **110** to provide electrical power to the personal computer **100**. The personal computer **100** may be in communication with another home-use computer (e.g. a notebook computer **200**) through corresponding electrical wires within the power outlets.

[0005] Generally, in the broadband power line communication system, several broadband power line network devices are employed to transmit Ethernet signals at a data transmission rate higher than 10 Mbps. The network system that does not transmit Ethernet signals and the network system that transmit Ethernet signals at the data transmission rate lower than 10 Mbps are not considered as the broadband power line communication system. For brevity, in this context, the power line network devices are broadband power line network devices.

[0006] Please refer to FIG. **1** again. The network line **115** of the personal computer **100** is connected to a first power line network device **120**, and the first power line network device **120** is plugged into a second power outlet **125**. Similarly, the network line **215** of the notebook computer **200** is connected to a second power line network device **220**, and the second power line network device **220** is plugged into a third power outlet **225**. In such way, the personal computer **100** and the notebook computer **200** are in communication with each other, and the broadband power line communication system is established.

[0007] As is well known, the power outlet can provide a high AC voltage such as 110V or 220V. Consequently, the trace layout of each power line network device should comply with stringent safety regulations in order to prevent any user from directly contacting with the high AC voltage at any situation.

[0008] Therefore, there is a need of proving a power line network device for complying with the safety regulations and meeting the requirements of reduced trace layout area and reduced fabricating cost.

SUMMARY OF THE INVENTION

[0009] The present invention provides a broadband power line network device with a non-isolated AC-DC power converter. The broadband power line network device uses an Ethernet signal coupling device to isolate the high voltage, thereby preventing from injuring the user. In addition, the volume and the fabrication cost of the broadband power line network device will be reduced.

[0010] An embodiment of the present invention provides a broadband power line network device. The broadband power line network device includes a printed circuit board, a power converter, a network control chip, a network connector, and an Ethernet signal coupling device. The printed circuit board includes a primary layout region and a secondary layout region. The primary layout region and the secondary layout region are separated from each other by a first distance. The power converter is disposed on the primary layout region of the printed circuit board, and includes a pair of power-receiving terminals for receiving an AC voltage, thereby converting the AC voltage into a DC voltage. The network control chip is disposed on the primary layout region of the printed circuit board for receiving the DC voltage. The network connector is disposed on the secondary layout region of the printed circuit board for transmitting or receiving an external network signal. The Ethernet signal coupling device is arranged between the primary layout region and the secondary layout region of the printed circuit board. If the external network signal from the secondary layout region is received by the Ethernet signal coupling device, the Ethernet signal coupling device generates an internal network signal to the primary layout region. Alternatively, if the internal network signal from the primary layout region is received by the Ethernet signal coupling device, the Ethernet signal coupling device generates the external network signal to the secondary layout region. After the internal network signal is received and modulated by the network control chip, the internal network signal is converted into a modulated network signal and the modulated network signal is outputted from the broadband power line network device through the power-receiving terminals. Alternatively, after the modulated network signal from the power-receiving terminals is received by the network control chip, the modulated network signal is converted into the internal network signal and the internal network signal is transmitted to the Ethernet signal coupling device.

[0011] Another embodiment of the present invention provides an Ethernet signal coupling device. The Ethernet signal coupling device includes a primary side, a secondary side, a first transformer, and a second transformer. The primary side includes a plurality of signal terminals, which at least include a TX+ signal terminal, a TX− signal terminal, a RX+ signal

terminal and a RX− signal terminal. The secondary side includes a plurality of signal terminals, which at least include a TD+ signal terminal, a TD− signal terminal, a RD+ signal terminal and a RD− signal terminal. The first transformer includes a primary coil coupled to the TX+ signal terminal and the TX− signal terminal and a secondary coil coupled to the TD+ signal terminal and the TD− signal terminal. The second transformer includes a primary coil coupled to the RX+ signal terminal and the RX− signal terminal and a secondary coil coupled to the RD+ signal terminal and the RD− signal terminal. The primary coil of the first transformer and the primary coil of the second transformer are wound by triple insulated wires, or the secondary coil of the first transformer and the secondary coil of the second transformer are wound by triple insulated wires.

[0012] Numerous objects, features and advantages of the present invention will be readily apparent upon a reading of the following detailed description of embodiments of the present invention when taken in conjunction with the accompanying drawings. However, the drawings employed herein are for the purpose of descriptions and should not be regarded as limiting.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The above objects and advantages of the present invention will become more readily apparent to those ordinarily skilled in the art after reviewing the following detailed description and accompanying drawings, in which:

[0014] FIG. **1** (prior art) schematically illustrates the architecture of a conventional broadband power line communication system;

[0015] FIG. **2** is a schematic circuit block diagram illustrating a power line network device according to an embodiment of the present invention;

[0016] FIG. **3**A is a schematic circuit block diagram illustrating a power line network device with an isolated AC-DC power converter according to an embodiment of the present invention;

[0017] FIGS. **3**B and **3**C schematically illustrate the layout configuration of the printed circuit board and related components of the power line network device of FIG. **3**A;

[0018] FIG. **4**A is a schematic circuit block diagram illustrating a power line network device with a non-isolated AC-DC power converter according to an embodiment of the present invention;

[0019] FIGS. **4**B and **4**C schematically illustrate the layout configuration of the printed circuit board and related components of the power line network device of FIG. **4**A; and

[0020] FIG. **5** is a schematic circuit block diagram illustrating an Ethernet signal coupling device used in the power line network device according to an embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0021] FIG. **2** is a schematic circuit block diagram illustrating a power line network device according to an embodiment of the present invention. As shown in FIG. **2**, the power line network device **160** comprises a plug **106**, a power converter **170**, a network control chip **180**, an Ethernet signal coupling device **190**, and a network connector **195**. The network connector **195** of the power line network device **160** is for example a RJ45 connector. The network connector **195** may be connected to a personal computer (not shown) through a network line. During the data transmission process, an external network signal S**1** is transmitted from the personal computer to the Ethernet signal coupling device **190**. In response to the external network signal S**1**, the Ethernet signal coupling device **190** generates an internal network signal S**2** to the network control chip **180**.

[0022] Basically, the external network signal S**1** fails to be directly transmitted to the network control chip **180**. Consequently, after the external network signal S**1** is received by the Ethernet signal coupling device **190**, the internal network signal S**2** is induced and transmitted to the network control chip **180**. In an embodiment, the Ethernet signal coupling device **190** is a signal transformer for receiving the external network signal S**1** and generating the internal network signal S**2**.

[0023] After the internal network signal S**2** is modulated by the network control chip **180**, a modulated network signal S**3** is outputted from the network control chip **180**. The modulated network signal S**3** is transmitted to the power converter **170**, and then outputted to another power line network device (not shown) through the plug **106**.

[0024] On the other hand, after the modulated network signal S**3** from another power line network device (not shown) is received by the plug **106**, the modulated network signal S**3** is transmitted to the network control chip **180** through the power converter **170**. After the modulated network signal S**3** is demodulated by the network control chip **180**, the internal network signal S**2** is outputted from the network control chip **180**. In response to the internal network signal S**2**, the Ethernet signal coupling device **190** generates the external network signal S**1**. The external network signal S**1** is then transmitted to the personal computer (not shown).

[0025] In addition, the power converter **170** is connected to the plug **106** for receiving an external AC voltage and converting the external AC voltage into a DC voltage Vin. The DC voltage Vin is provided to the network control chip **180** for allowing normal operations of the network control chip **180**.

[0026] In addition, the power converter **170**, the network control chip **180** and the Ethernet signal coupling device **190** of the power line network device **160** are covered by an insulating housing (not shown). Consequently, only the plug **106** and the conductors (e.g. metal) of the network connector **195** may be touched by the user.

[0027] After the plug **106** of the power line network device **160** is inserted into a power outlet, only the conductor of the network connector **195** is possibly touched by the user. For protecting the user, the trace layout of the printed circuit board (PCB) of the power line network device **160** should comply with safety regulations. Consequently, even if the conductor of the network connector **195** is touched by the user, the user will not be injured. Generally, according to the safety regulations, the AC voltage higher than 42.4V or the DC voltage higher than 60V is defined as a dangerous voltage because the user may be injured by the AC voltage of 42.4V or the DC voltage of 60V.

[0028] For protecting the user, a first approach of the present invention utilizes an isolated AC-DC power converter. In the isolated AC-DC power converter, the high-voltage input terminal and the low-voltage output terminal are isolated from each other in order to maintain the safety of the output terminal. In an embodiment, a power transformer is used as the main coupling device of the isolated AC-DC power converter.

[0029] In the PCB trace layout of the power line network device **160**, the power converter **170** is disposed on a primary layout region (i.e. a high-voltage region) of the printed circuit board, and the network control chip **180**, the Ethernet signal coupling device **190** and the network connector **195** are disposed on a secondary layout region (i.e. a low-voltage region) of the printed circuit board. The primary layout region and the secondary layout region are not directly connected with each other. Whereas, a coupling device is used as the signal media between the primary layout region and the secondary layout region of the printed circuit board. The trace layout of the printed circuit board can prevent generation of the dangerous voltage at the secondary layout region.

[0030] FIG. **3**A is a schematic circuit block diagram illustrating a power line network device with an isolated AC-DC power converter according to an embodiment of the present invention. As shown in FIG. **3**A, the power line network device **160** is mounted on a single printed circuit board. In addition, the printed circuit board is divided into a primary layout region **162** (i.e. a high-voltage region) and a secondary layout region **164** (i.e. a low-voltage region). On the surface of the printed circuit board, the primary layout region **162** and the secondary layout region **164** are completely electrically isolated from each other. That is, there is no trace pattern between the primary layout region **162** and the secondary layout region **164**.

[0031] Moreover, coupling devices are used as the signal and power media between the primary layout region **162** and the secondary layout region **164**. In this embodiment, the coupling devices comprise a Y capacitor **350**, a power transformer **352**, an optical coupler **354**, and a signal coupler **356**.

[0032] Please refer to FIG. **3**A again. Except for the coupling devices, the other components of the power converter **170** are all disposed on the primary layout region **162**. A surge catcher **305**, a common mode choke **310**, a bridge rectifier **315**, a high voltage capacitor **320**, a switching mode regulator **325** and a snubber **330** are sequentially connected between the plug **106** and the power transformer **352**. Basically, the common mode choke **310** is used for eliminating the common mode electromagnetic interference. The bridge rectifier **315** and a high voltage capacitor **320** are used for achieving the functions of DC voltage conversion and voltage stabilization. The switching mode regulator **325** is used for voltage conversion. The converted voltage is transmitted to the power transformer **352** through the snubber **330**. Consequently, the power transformer **352** generates the DC voltage Vin to the network control chip **180**. According to a change of the DC voltage Vin, the optical coupler **354** generates a control signal to the switching mode regulator **325**. The modulated network signal S**3** generated by the network control chip **180** is processed by the signal coupler **356**, and thus an induced modulated network signal S**3'** is outputted from the signal coupler **356** to the plug **106** through the surge catcher **305**.

[0033] For allowing the printed circuit board to comply with the safety regulations, the primary layout region **162** and the secondary layout region **164** should be separated from each other by a safety distance D. For example, the safety distance is greater than 3 mm (e.g. 5 mm).

[0034] FIGS. **3**B and **3**C schematically illustrate the layout configuration of the printed circuit board and related components of the power line network device of FIG. **3**A. As shown in FIG. **3**B, the printed circuit board has a size of 44 mm×60 mm. In addition, the printed circuit board is divided into a primary layout region **162** and a secondary layout region **164**. There is no trace pattern between the primary layout region **162** and the secondary layout region **164**. The primary layout region **162** and the secondary layout region **164** should be separated from each other by a safety distance D.

[0035] As shown in FIG. **3**C, related components of the power line network device are mounted on the printed circuit board. The primary layout region **162** has a pair of power-receiving terminals (+, −), which are connected to the power outlet (not shown). Furthermore, the surge catcher **305**, the common mode choke **310**, the bridge rectifier **315**, the high voltage capacitor **320**, the switching mode regulator **325** and the snubber **330** are disposed on the primary layout region **162**. The network control chip **180**, the Ethernet signal coupling device **190** and the network connector **195** are disposed on the secondary layout region **164**. The Y capacitor **350**, the power transformer **352**, the optical coupler **354** and the signal coupler **356** are spanned across the primary layout region **162** and the secondary layout region **164**.

[0036] As shown in FIG. **3**C, the network connector **195** is disposed on the secondary layout region **164**. In addition, no dangerous voltage is generated in the secondary layout region **164**. Consequently, after the printed circuit board is covered by the insulating housing, even if the conductor (e.g. metal) of the network connector **195** is touched by the user, the user is not injured.

[0037] For further reducing the area of the printed circuit board, a second approach of the present invention utilizes a non-isolated AC-DC power converter. The use of the non-isolated AC-DC power converter can decrease the number of the coupling devices. However, since the high-voltage input terminal and the low-voltage output terminal of the non-isolated AC-DC power converter are not isolated from each other, the user is possibly injured.

[0038] For protecting the user, the printed circuit board is divided into a primary layout region and a secondary layout region. Both of a high voltage (e.g. a dangerous voltage) and a low voltage may be generated in the primary layout region. Whereas, only the low voltage may be generated in the secondary layout region. In the PCB trace layout of the power line network device **160**, the power converter **170** and the network control chip **180** are disposed on the primary layout region, and the network connector **195** is disposed on the secondary layout region. The primary layout region and the secondary layout region are not directly connected with each other. Whereas, the Ethernet signal coupling device **190** is used as the signal media between the primary layout region and the secondary layout region of the printed circuit board.

[0039] FIG. **4**A is a schematic circuit block diagram illustrating a power line network device with a non-isolated AC-DC power converter according to an embodiment of the present invention. As shown in FIG. **4**A, the power line network device **160** is mounted on a single printed circuit board. In addition, the printed circuit board is divided into a primary layout region **450** and a secondary layout region **455**. On the surface of the printed circuit board, the primary layout region **450** and the secondary layout region **455** are completely electrically isolated from each other. That is, there is no trace pattern between the primary layout region **450** and the secondary layout region **455**.

[0040] Moreover, only the Ethernet signal coupling device **190** is used as the signal media between the primary layout region **450** and the secondary layout region **455**. An example of the Ethernet signal coupling device **190** is a signal transformer.

[0041] Please refer to FIG. **4**A again. The power converter **170** and the network control chip **180** are both disposed on the primary layout region **450**. The power converter **170** comprises a surge catcher **405**, a common mode choke **410**, a bridge rectifier **415**, a high voltage capacitor **420**, a switching mode regulator **425**, a snubber **430** and an inductor **435**, which are sequentially connected between the plug **106** and the network control chip **180**. Basically, the common mode choke **410** is used for eliminating the common mode electromagnetic interference. The bridge rectifier **415** and a high voltage capacitor **420** are used for achieving the functions of DC voltage conversion and voltage stabilization. The switching mode regulator **425** is used for voltage conversion. The converted voltage is transmitted to the inductor **435** through the snubber **430**. Consequently, the inductor **435** generates the DC voltage Vin to the network control chip **180**. The modulated network signal S**3** generated by the network control chip **180** is transmitted to the plug **106** through the surge catcher **405**.

[0042] For allowing the printed circuit board to comply with the safety regulations, the primary layout region **450** and the secondary layout region **460** should be separated from each other by a safety distance D.

[0043] FIGS. **4**B and **4**C schematically illustrate the layout configuration of the printed circuit board and related components of the power line network device of FIG. **4**A. As shown in FIG. **4**B, the printed circuit board has a size of 33 mm×55 mm. In addition, the printed circuit board is divided into a primary layout region **450** and a secondary layout region **455**. There is no trace pattern between the primary layout region **450** and the secondary layout region **455**. The primary layout region **450** and the secondary layout region **455** should be separated from each other by a safety distance D.

[0044] As shown in FIG. **4**C, related components of the power line network device are mounted on the printed circuit board. The primary layout region **450** has a pair of power-receiving terminals (+, −), which are connected to the power outlet (not shown). Furthermore, the surge catcher **405**, the common mode choke **410**, the bridge rectifier **415**, the high voltage capacitor **420**, the switching mode regulator **425**, the snubber **430** and the inductor **435** of the power converter **170** and the network control chip **180** are all disposed on the primary layout region **450**. Only the network connector **195** is disposed on the secondary layout region **455**. The Ethernet signal coupling device **190** is spanned across the primary layout region **450** and the secondary layout region **455**.

[0045] As shown in FIG. **4**C, the network connector **195** is disposed on the secondary layout region **455**. In addition, no dangerous voltage is generated in the secondary layout region **455**. Consequently, after the printed circuit board is covered by the insulating housing, even if the conductor (e.g. metal) of the network connector **195** is touched by the user, the user is not injured.

[0046] From the above description, the present invention provides a broadband power line network device with a non-isolated AC-DC power converter. The broadband power line network device uses an Ethernet signal coupling device to isolate the high voltage, thereby preventing from injuring the user. In addition, the volume and the fabrication cost of the broadband power line network device will be reduced. Moreover, since the network control chip used in the power line network device of the present invention is capable of transmitting Ethernet signals at a data transmission rate higher than 10 Mbps, the power line network device is a high speed power line network device.

[0047] FIG. **5** is a schematic circuit block diagram illustrating an Ethernet signal coupling device used in the power line network device according to an embodiment of the present invention. The signal terminals at the primary side A of the Ethernet signal coupling device **500** at least comprise the signal terminals TX+, TX−, RX+ and RX−. The signal terminals at the secondary side B of the Ethernet signal coupling device **500** at least comprise the signal terminals TD+, TD−, RD+ or RD−. In addition to the above signal terminals, the Ethernet signal coupling device **500** may further comprise other signal terminals such as the common terminals (CT1~CT4).

[0048] In an embodiment, the signal terminals at the primary side A receive the external network signal, and the signal terminals at the secondary side B receive the internal network signal. Alternatively, the signal terminals at the secondary side B receive the external network signal, and the signal terminals at the primary side A receive the internal network signal. The external network signal is a network signal transmitted between the power line network device and an external electronic device (e.g. a personal computer). The internal network signal is a network signal that is generated and transmitted within the power line network device. Furthermore, each of the internal network signal and the external network signal at least comprises a differential transmitting signal pair and differential receiving signal pair.

[0049] Please refer to FIG. **5** again. The Ethernet signal coupling device **500** comprises a first transformer **510**, a second transformer **520**, a first common mode choke **530**, a second common mode choke **540**, a third common mode choke **550**, and a fourth common mode choke **560**.

[0050] Both of the first transformer **510** and the second transformer **520** are central-tapped transformers. In the coil of each of the first transformer **510** and the second transformer **520**, one end of the coil with a dot denotes a first electrode terminal (e.g. a positive terminal), and the other end of the coil without the dot denotes a second electrode terminal (e.g. a negative terminal).

[0051] The TD+ signal terminal and the TD− signal terminal are used for transmitting the differential transmitting signal pair of the internal network signal. After the common mode noise contained in the differential transmitting signal pair of the internal network signal is eliminated by the second common mode choke **540**, the differential transmitting signal pair of the internal network signal is inputted into the first transformer **510**. Due to electromagnetic induction, the first transformer **510** generates a corresponding differential transmitting signal pair of the external network signal. After the common mode noise contained in the differential transmitting signal pair of the external network signal is eliminated by the first common mode choke **530**, the differential transmitting signal pair of the external network signal is outputted from the TX+ signal terminal and the TX− signal terminal.

[0052] As shown in FIG. **5**, the first electrode terminal of the first coil L**11** of the first common mode choke **530** is connected to the TX+ signal terminal, and the first electrode terminal of the second coil L**12** of the first common mode choke **530** is connected to the TX− signal terminal. The second electrode terminal of the first coil L**21** of the second common mode choke **540** is connected to the TD+ signal

terminal, and the second electrode terminal of the second coil L**22** of the second common mode choke **540** is connected to the TD− signal terminal.

[0053] The first electrode terminal of the primary coil PC**1** of the first transformer **510** is connected to the second electrode terminal of the first coil L**11** of the first common mode choke **530**. The second electrode terminal of the primary coil PC**1** of the first transformer **510** is connected to the second electrode terminal of the second coil L**12** of the first common mode choke **530**. The central tap of the primary coil PC**1** of the first transformer **510** is connected to the CT1 terminal. In addition, the first electrode terminal of the secondary coil SC**1** of the first transformer **510** is connected to the first electrode terminal of the first coil L**21** of the second common mode choke **540**. The second electrode terminal of the secondary coil SC**1** of the first transformer **510** is connected to the first electrode terminal of the second coil L**22** of the second common mode choke **540**. The central tap of the secondary coil SC**1** of the first transformer **510** is connected to the CT2 terminal.

[0054] The RX+ signal terminal and the RX− signal terminal are used for receiving the differential transmitting signal pair of the external network signal. After the common mode noise contained in the differential transmitting signal pair of the external network signal is eliminated by the third common mode choke **550**, the differential transmitting signal pair of the external network signal is inputted into the second transformer **520**. Due to electromagnetic induction, the second transformer **520** generates a corresponding differential receiving signal pair of the internal network signal. After the common mode noise contained in the differential receiving signal pair of the internal network signal is eliminated by the fourth common mode choke **560**, the differential receiving signal pair of the internal network signal is outputted from the RD+ signal terminal and the RD− signal terminal.

[0055] As shown in FIG. **5**, the first electrode terminal of the first coil L**31** of the third common mode choke **550** is connected to the RX+ signal terminal, and the first electrode terminal of the second coil L**32** of the third common mode choke **550** is connected to the RX− signal terminal. The second electrode terminal of the first coil L**41** of the fourth common mode choke **560** is connected to the RD+ signal terminal, and the second electrode terminal of the second coil L**42** of the fourth common mode choke **560** is connected to the RD− signal terminal.

[0056] The first electrode terminal of the primary coil PC**2** of the second transformer **520** is connected to the second electrode terminal of the first coil L**31** of the third common mode choke **550**. The second electrode terminal of the primary coil PC**2** of the second transformer **520** is connected to the second electrode terminal of the second coil L**32** of the third common mode choke **550**. The central tap of the primary coil PC**2** of the second transformer **520** is connected to the CT3 terminal. In addition, the first electrode terminal of the secondary coil SC**2** of the second transformer **520** is connected to the first electrode terminal of the first coil L**41** of the fourth common mode choke **560**. The second electrode terminal of the secondary coil SC**2** of the second transformer **520** is connected to the first electrode terminal of the second coil L**42** of the fourth common mode choke **560**. The central tap of the secondary coil SC**2** of the second transformer **520** is connected to the CT4 terminal.

[0057] As shown in FIG. **5**, the first transformer **510** and the second transformer **520** of the Ethernet signal coupling device **500** are used for receiving the external network signal and inducing the internal network signal, or receiving the internal network signal and inducing the external network signal.

[0058] Moreover, since the internal network signal and the external network signal are not electrically connected with each other, the high voltage of the power line network device can be effectively isolated.

[0059] Generally, the coils of the transformers and the common mode chokes are all produced by winding enameled wires. In practice, the degree of insulation of the enameled wire is usually insufficient to comply with the safety regulations. For increasing the insulating efficacy, the coils at the primary side A and/or the coils at the secondary side B are wound by triple insulated wires.

[0060] In an embodiment, the coils at the primary side A (e.g. including the primary coil PC**1** of the first transformer **510**, the primary coil PC**2** of the second transformer **520**, the first coil L**11** and the second coil L**12** of the first common mode choke **530**, and the first coil L**31** and the second coil L**32** of the third common mode choke **550**) are wound by enameled wires. Whereas, the coils at the secondary side B (e.g. including the secondary coil SC**1** of the first transformer **510**, the secondary coil SC**2** of the second transformer **520**, the first coil L**21** and the second coil L**22** of the second common mode choke **540**, and the first coil L**41** and the second coil L**42** of the fourth common mode choke **560**) are wound by triple insulated wires.

[0061] It is noted that, however, those skilled in the art will readily observe that numerous modifications and alterations may be made while retaining the teachings of the invention. For example, in some other embodiments, the coils at the primary side A are wound by triple insulated wires, and the coils at the secondary side B are wound by enameled wires. In such way, the Ethernet signal coupling device **500** can still comply with the safety regulations.

[0062] Since the triple insulated wires have better insulating efficacy, the insulating efficacy of the first transformer **510** and the second transformer **520** will be enhanced. That is, the uses of the triple insulated wires can effective isolate the high voltage and the network signal of the power line network device while complying with the safety regulations.

[0063] Please refer to FIG. **5** as well as FIG. **4**. The Ethernet signal coupling device **500** is fixed on two separate layout regions of the printed circuit board (PCB). In an embodiment, the signal terminals at the primary side A are fixed on the primary layout region of the printed circuit board, and the signal terminals at the secondary side B are fixed on the secondary layout region of the printed circuit board. For complying with the safety regulations, the primary layout region and the secondary layout region are separated from each other by a safety distance D1 in order to achieve effective isolation. Consequently, in the Ethernet signal coupling device **500**, the signal terminals at the primary side A and the signal terminals at the secondary side B are separated from each other by at least the safety distance D1. In an embodiment, the safety distance D1 is equal to or greater than 5 mm.

[0064] For achieving better insulating efficacy, in some other embodiments, the coils at the primary side A and the coils at the secondary side B are all wound by triple insulated wires.

[0065] From the above description, since the coils of the Ethernet signal coupling device of the present invention are wound by triple insulated wires, the insulating efficacy will be

enhanced. In other words, the uses of the triple insulated wires can effective isolate the high voltage and the network signal of the power line network device while complying with the safety regulations.

[0066] While the invention has been described in terms of what is presently considered to be the most practical and preferred embodiments, it is to be understood that the invention needs not be limited to the disclosed embodiment. On the contrary, it is intended to cover various modifications and similar arrangements included within the spirit and scope of the appended claims which are to be accorded with the broadest interpretation so as to encompass all such modifications and similar structures.

What is claimed is:

1. An Ethernet signal coupling device, comprising:

a primary side comprising a plurality of signal terminals, which at least include a TX+ signal terminal, a TX− signal terminal, a RX+ signal terminal and a RX− signal terminal;

a secondary side comprising a plurality of signal terminals, which at least include a TD+ signal terminal, a TD− signal terminal, a RD+ signal terminal and a RD− signal terminal;

a first transformer comprising a primary coil coupled to the TX+ signal terminal and the TX− signal terminal and a secondary coil coupled to the TD+ signal terminal and the TD− signal terminal; and

a second transformer comprising a primary coil coupled to the RX+ signal terminal and the RX− signal terminal and a secondary coil coupled to the RD+ signal terminal and the RD− signal terminal,

wherein the primary coil of the first transformer and the primary coil of the second transformer are wound by triple insulated wires, or the secondary coil of the first transformer and the secondary coil of the second transformer are wound by triple insulated wires.

2. The Ethernet signal coupling device as claimed in claim **1**, wherein the primary coil of the first transformer has a central tap connected to a CT1 terminal, the secondary coil of the first transformer has a central tap connected to a CT2 terminal, the primary coil of the second transformer has a central tap connected to a CT3 terminal, and the secondary coil of the second transformer has a central tap connected to a CT4 terminal.

3. The Ethernet signal coupling device as claimed in claim **1**, further comprising:

a first common mode choke comprising a first coil and a second coil, wherein a first electrode terminal of the first coil of the first common mode choke is connected to the TX+ signal terminal, and a first electrode terminal of the second coil of the first common mode choke is connected to the TX− signal terminal;

a second common mode choke comprising a first coil and a second coil, wherein a second electrode terminal of the first coil of the second common mode choke is connected to the TD+ signal terminal, and a second electrode terminal of the second coil of the second common mode choke is connected to the TD− signal terminal,

wherein the first electrode terminal of the primary coil of the first transformer is connected to the second electrode terminal of the first coil of the first common mode choke, the second electrode terminal of the primary coil of the first transformer is connected to the second electrode terminal of the second coil of the first common mode choke, the first electrode terminal of the secondary coil of the first transformer is connected to the first electrode terminal of the first coil of the second common mode choke, and the second electrode terminal of the secondary coil of the first transformer is connected to the first electrode terminal of the second coil of the second common mode choke.

4. The Ethernet signal coupling device as claimed in claim **3**, wherein the first coil and the second coil of the first common mode choke are wound by the triple insulated wires, or the first coil and the second coil of the second common mode choke are wound by the triple insulated wires.

5. The Ethernet signal coupling device as claimed in claim **1**, further comprising:

a third common mode choke comprising a first coil and a second coil, wherein a first electrode terminal of the first coil of the third common mode choke is connected to the RX+ signal terminal, and a first electrode terminal of the second coil of the third common mode choke is connected to the RX− signal terminal;

a fourth common mode choke comprising a first coil and a second coil, wherein a second electrode terminal of the first coil of the fourth common mode choke is connected to the RD+ signal terminal, and a second electrode terminal of the second coil of the fourth common mode choke is connected to the RD− signal terminal;

wherein the first electrode terminal of the primary coil of the second transformer is connected to the second electrode terminal of the first coil of the third common mode choke, the second electrode terminal of the primary coil of the second transformer is connected to the second electrode terminal of the second coil of the third common mode choke, the first electrode terminal of the secondary coil of the second transformer is connected to the first electrode terminal of the first coil of the fourth common mode choke, and the second electrode terminal of the secondary coil of the second transformer is connected to the first electrode terminal of the second coil of the fourth common mode choke.

6. The Ethernet signal coupling device as claimed in claim **5**, wherein the first coil and the second coil of the third common mode choke are wound by the triple insulated wires, or the first coil and the second coil of the fourth common mode choke are wound by the triple insulated wires.

7. The Ethernet signal coupling device as claimed in claim **1**, wherein the plurality of signal terminals at the primary side and the plurality of signal terminals at the secondary side are separated from each other by at least a first distance.

8. The Ethernet signal coupling device as claimed in claim **7**, wherein the first distance is a safety distance, and the safety distance is equal to or greater than 5 mm.

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