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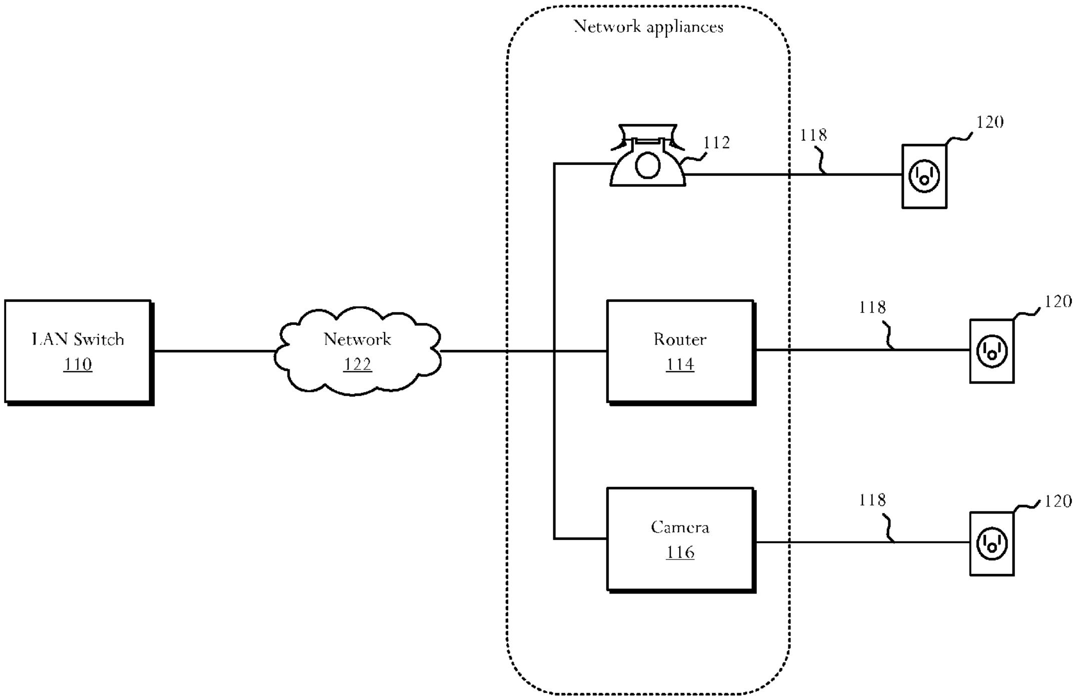

(57) Abstract: In a network device 300, a connector module 302 comprises a network connector 304 coupled to the connector module 302 in a configuration that transfers power and communication signals and an application connector 306 that comprises serial media independent interface (SMII) pins 308 and power pins 310. A Power-over-Ethernet (PoE) circuit 312 is coupled between the network connector 304 and the application connector 306.

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ETHERNET MODULE

BACKGROUND

[0001] Many networks such as local and wide area networks (LAN/WAN) structures are used to carry and distribute data communication signals between devices. Various network elements include hubs, switches, routers, and bridges, peripheral devices, such as, but not limited to, printers, data servers, desktop personal computers (PCs), portable PCs and personal data assistants (PDAs) equipped with network interface cards. Devices that connect to the network structure use power to enable operation. Power of the devices may be supplied by either an internal or an external power supply such as batteries or an AC power via a connection to an electrical outlet.

[0002] Some network solutions can distribute power over the network in combination with data communications. Power distribution over a network consolidates power and data communications over a single network connection to reduce installation costs, ensures power to network elements in the event of a traditional power failure, and enables reduction in the number of power cables, AC to DC adapters, and/or AC power supplies which may create fire and physical hazards. Additionally, power distributed over a network such as an Ethernet network may function as an uninterruptible power supply (UPS) to components or devices that normally would be powered using a dedicated UPS.

[0003] Additionally, network appliances, for example voice-over-Internet-Protocol (VOIP) telephones and other devices, are increasingly deployed and consume power. When compared to traditional counterparts, network appliances use an additional power feed. One drawback of VOIP telephony is that in the event of a power failure the ability to contact emergency services via an independently powered telephone is removed. The ability to distribute power to network appliances or circuits enable network appliances such as a VOIP telephone to operate in a fashion similar to ordinary analog telephone networks currently in use.

[0004] Distribution of power over Ethernet (PoE) network connections is in part governed by the Institute of Electrical and Electronics Engineers (IEEE) Standard 802.3 and other relevant standards, standards that are incorporated herein by reference. However, power distribution schemes within a network environment typically employ cumbersome, real estate intensive, magnetic transformers. Additionally, power-over-

Ethernet (PoE) specifications under the IEEE 802.3 standard are stringent and often limit allowable power.

[0005] Many limitations are associated with use of magnetic transformers. Transformer core saturation can limit current that can be sent to a power device, possibly further limiting communication channel performance. Cost and board space associated with the transformer comprise approximately 10 percent of printed circuit board (PCB) space within a modern switch. Additionally, failures associated with transformers often account for a significant number of field returns. Magnetic fields associated with the transformers can result in lower electromagnetic interference (EMI) performance.

[0006] However, magnetic transformers also perform several important functions such as supplying DC isolation and signal transfer in network systems. Thus, an improved approach to distributing power in a network environment may be sought that addresses limitations imposed by magnetic transformers while maintaining transformer benefits.

[0007] Various devices can only communicate with a network through an intermediate connection with a computer or similar system. Devices such as cameras, cam-corders, iPods™, storage devices, RFID tag readers, and many others cannot communicate directly with a network.

SUMMARY

[0008] According to an embodiment of a network device, a connector module comprises a network connector coupled to the connector module in a configuration that transfers power and communication signals and an application connector that comprises serial media independent interface (SMII) pins and power pins. A Power-over-Ethernet (PoE) circuit is coupled between the network connector and the application connector.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Embodiments of the invention relating to both structure and method of operation may best be understood by referring to the following description and accompanying drawings:

FIGUREs 1A and **1B** are schematic block diagrams that respectively illustrate a high level example embodiments of client devices in which power is supplied separately to network attached client devices, and a switch that is a power supply equipment (PSE)-capable power-over Ethernet (PoE) enabled LAN switch that supplies both data and power signals to the client devices;

FIGURE 2 is a functional block diagram illustrating a network interface including a network powered device (PD) interface and a network power supply equipment (PSE) interface, each implementing a non-magnetic transformer and choke circuitry;

FIGURE 3 is a schematic block and circuit diagram depicting an embodiment of a network device in the form of a connector module that is highly suitable for usage in supplying a power feed on multiple pairs;

FIGURE 4A is a schematic block and circuit diagram showing an embodiment of a network device configured as a connector module with a non-magnetic transformer that enables an integrated single-chip implementation;

FIGURE 4B is a schematic block and circuit diagram illustrating an embodiment of a network device configured as a connector module that includes a T-Less Connect™ solid-state transformer;

FIGURE 5 is a schematic circuit and block diagram depicting an embodiment of a network device configured as a connector module for usage with power sourcing equipment (PSE);

FIGURE 6 is a schematic circuit and block diagram showing an embodiment of a network device configured as a connector module for usage with an integrated power sourcing equipment (iPSE) that implements a non-magnetic transformer;

FIGURE 7 is a schematic circuit and block diagram that depicts an embodiment of a network device configured for usage as a midspan power sourcing equipment (PSE) connector module;

FIGUREs 8A, **8B**, and **8C** are schematic circuit and block diagrams illustrating embodiments of a network device in configurations of network attached appliances;

FIGUREs 9A, **9B**, and **9C** are schematic circuit and block diagrams showing embodiments of network devices in configurations of power sourcing equipment (PSE) switch modules;

FIGUREs 10A and **10B** are schematic circuit and block diagrams illustrating embodiments of a network device arranged as a network interface module;

FIGURE 11 is a schematic block diagram showing an embodiment of a powered network device, for example an enterprise VoIP phone;

FIGURE 12 is a schematic block diagram showing an embodiment of a network device in a configuration of a network attached appliance including a power sourcing equipment (PSE) device;

FIGUREs 13A and **13B** are schematic block diagrams showing embodiments of a network device configured as an Ethernet bridge module;

FIGURE 14 is a schematic block diagram depicting an embodiment of a network device in a configuration of an Ethernet bridge module that includes a magnetic transformer; and

FIGURE 15 is a schematic block diagram showing an embodiment of a network device configured as an Ethernet bridge module contained within a housing.

DETAILED DESCRIPTION

[0010] In various embodiments, an Ethernet module can support a power feed on multiple signal pairs. Some embodiments can be in the form of a connector, such as a Registered Jack (RJ)-45 connector, which include an integrated powered device / power sourcing equipment (PD/PSE) controller, a DC-DC controller for a PD implementation, and an Ethernet transformer. Other embodiments can be in the form of a connector, such as a Registered Jack (RJ)-45 connector, which include an integrated powered device / power sourcing equipment (PD/PSE) controller, a DC-DC controller for a PD implementation, and a solid-state transformer, such as a T-connect or T-Less Connect™ solid-state transformer.

[0011] Configurations can be implemented which include or exclude an Ethernet Physical Layer (PHY). Configurations can be implemented which include or exclude isolation.

[0012] The various modules and structures can be configured with any suitable footprint. In an illustrative embodiment, a standard footprint can be defined to specify an interface size of twenty (20) pins including, for example, eight (8) input RJ-45 pins, six (6) serial media independent interface (SMII) pins including reference clock signal pins, four (4) Management Data Input/Output (MDIO) pins which include two pins for opto-coupling, and two (2) power pins. MDIO is a standard-driven, dedicated-bus arrangement specified in Institute of Electrical and Electronics Engineers (IEEE) RFC802.3. The MDIO interface is implemented by two pins, and MDIO pin and a Management Data Clock (MDC) pin. MDIO is defined in relation to access and modification of registers within physical layer (PHY) devices, and to connection to media access controllers (MACs) in Ethernet systems. A smaller footprint can be defined or configured which can eliminate the two reference clock pins of the SMII interface and/or the two opto-coupling pins of the MDIO.

[0013] Referring to **FIGURE 3**, a schematic block and circuit diagram illustrates an embodiment of a network device **300** in the form of a connector module **302** that is highly suitable for usage in supplying a power feed on multiple pairs. The connector module **302** comprises a network connector **304** that transfers power and communication signals and an application connector **306** arranged to include serial media independent interface (SMII) pins **308** and power pins **310**. The connector module **302** further comprises a Power-over-Ethernet (PoE) circuit **312** coupled between the network connector **304** and the application connector **306**.

[0014] In a particular embodiment, the network connector **304** can be an eight-pin Registered Jack (RJ) 45 physical interface. The application connector **306** can be an arrangement that includes the SMII signal interface **308**, a Management Data Input/Output (MDIO) interface **314**, and a two-pin power interface **310**. In various configurations, the SMII signal interface **308** can be a four-pin signal interface or can be a six-pin interface including both signal pins and reference pins. The MDIO interface **314**, if included in the connector module **302**, can be either a two-pin interface including data and clock lines or a four-pin interface with data, clock or strobe, and opto-coupling lines.

[0015] The network device embodiment **300** shown in **FIGURE 3**, the Ethernet PHY **318** is connected to the application interface **306** by a SMII interface **308** and a Management Data Input/Output (MDIO) interface **314** which in combination make up a non-isolated interface.

[0016] In the illustrative network device **300**, the Power-over-Ethernet (PoE) circuit **312** comprises a magnetic transformer **316**, an Ethernet physical layer (PHY) **318**, a Powered Ethernet Device (PD) controller **320**, and a Direct Current-Direct Current (DC-DC) power converter **322**. The magnetic transformer **316** connects to communication signal pins **304S** of the network interface **304**. The Ethernet physical layer (PHY) **318** is connected between the magnetic transformer **316** and the application interface **306** and is coupled to the application interface **306** by a SMII interface **308**. The Powered Ethernet Device (PD) controller **320** is connected to power pins **304P** of the network interface **304**. In an example arrangement, the Powered Ethernet Device (PD) controller **320** can comprise a power switch circuit **326** and a signature and classification circuit **328**. The Direct Current-Direct Current (DC-DC) power converter **322** in connected between the PD controller **320** and power pins **310** of the application interface **306**.

[0017] The illustrative configuration whereby the transformer **316**, PD controller **320**, and the Ethernet PHY **318** are contained within the connector module **302**, and the Ethernet PHY **318** couples to the application connector **306** via the SMII interface **310** enables a compact connector module **302** with reduced pin count by exploiting the internal transformer **316** to supply power out and the PD controller **320** to generate a supply voltage, such as 48 volts. Combining the PD controller **320** and transformer **316** inside the connector module **302** enables operation switching to take place internal to the module without reserving pins for passing control signals.

[0018] Some arrangements of the Power-over-Ethernet (PoE) circuit **312** can include a diode bridge **324** connected between power pins **304P** of the network interface **304**

and the PD controller **320**. The diode bridge **324** can be integrated enabling implementation of the module components in a compact package, or even a single-chip package.

[0019] The particular connector module **302** can be constructed as an RJ-45 connector with a transformer-based 10/100 Powered Ethernet (PD) device with an application interface **306** including SMII and power pins. The RJ-45 connector has eight pins arranged in four pairs.

[0020] Referring to **FIGURE 4A**, a schematic block and circuit diagram illustrates an embodiment of a network device **400** configured as a connector module **402** with a non-magnetic transformer. The non-magnetic transformer can be integrated so that the module components can be implemented, if desired, in an integrated, single-chip arrangement. The connector module **402** comprises a Power-over-Ethernet (PoE) circuit **412** coupled between a network connector **404** and an application connector **406**. The illustrative Power-over-Ethernet (PoE) circuit **412** comprises a non-magnetic transformer and choke circuit **416**, an Ethernet physical layer (PHY) **418**, a Powered Ethernet Device (PD) controller **420**, and a Direct Current-Direct Current (DC-DC) power converter **422**. The non-magnetic transformer and choke circuit **416** is integrated into the iPED **430** and connected to communication signal pins **404S** of the network interface **404**. The Ethernet physical layer (PHY) **418** is integrated into the iPED **430** and connected between the non-magnetic transformer and choke circuit **416** and the application interface **406**. The illustrative Ethernet PHY **418** is connected to the application interface **406** by a SMII interface **408** and a Management Data Input/Output (MDIO) interface **414**. The Powered Ethernet Device (PD) controller **420** is integrated into the iPED **430** and connected to power pins **404P** of the network interface **404**. The Direct Current-Direct Current (DC-DC) power converter **422** is integrated into the iPED **430** and connected between the PD controller **420** and power pins **410** of the application interface **406**.

[0021] The Powered Ethernet Device (PD) controller **420** is depicted as an integrated device integrated into the IPED **430** and further comprising integrated circuit elements including a diode bridge **424** connected to power pins **404P** of the network interface **404**, a power switch circuit **426** connected to the diode bridge **424**, and a signature and classification circuit **428** connected to the diode bridge **424** and the power switch circuit **426**. The particular connector module **442** can be constructed as an RJ-45 connector with a transformer-less based 10/100 Powered Ethernet (PD) device with an application interface **406** including SMII and power pins.

[0022] Referring to **FIGURE 4B**, a schematic block and circuit diagram illustrates an embodiment of a network device **400** configured as a connector module **402** that includes a T-Less Connect™ solid-state transformer **432**. The integrated Powered Ethernet Device (iPED) **430** can be implemented to incorporate a T-Less Connect™ solid-state transformer **432** that separates Ethernet signals from power signals. The T-Less Connect™ solid-state transformer **432** can separate the signal and power signals by floating ground potential of the Ethernet PHY relative to earth ground. The T-Less Connect™ transformer **432** is described more fully in the discussion of **FIGURE 2**.

[0023] Referring to **FIGURE 5**, a schematic circuit and block diagram depicts an embodiment of a network device **500** configured as a connector module **502** for usage with power sourcing equipment (PSE). The connector module **502** comprises an application connector **506** and a network connector **504** coupled by a Power-over-Ethernet (PoE) circuit **512**. The illustrative Power-over-Ethernet (PoE) circuit **512** comprises a magnetic transformer **516**, an Ethernet physical layer (PHY) **518**, and a Power Sourcing Equipment (PSE) controller **520**. The magnetic transformer **516** is connected to communication signal pins **504S** of the network interface **504**. The Ethernet physical layer (PHY) **518** is connected between the magnetic transformer **516** and the application interface **506**. The Ethernet PHY **518** is connected to the application interface **506** by a SMII interface **508** and a Management Data Input/Output (MDIO) interface **514**. The Power Sourcing Equipment (PSE) controller **520** is connected between power pins **504P** of the network interface **504** and power feed pins **510** of the application interface **506**.

[0024] In some embodiments, a multi-port switch **536** can be connected to the application interface **506**, for example on the exterior side of the application interface **506** with respect to the connector module **502** so that the multi-port switch **536** is coupled to the PoE circuit **512** via the application interface **506**.

[0025] The depicted connector module **502** is configured as a RJ-45 PSE module including the Ethernet PHY **518**.

[0026] Referring to **FIGURE 6**, a schematic circuit and block diagram depicts an embodiment of a network device **600** configured as a connector module **602** for usage with an integrated power sourcing equipment (iPSE) that implements a non-magnetic transformer and facilitates an integrated single-chip implementation. A power sourcing equipment module **602** has an isolated interface. The connector module **602** comprises an application connector **606** and a network connector **504** coupled by a Power-over-Ethernet (PoE) circuit **612**. The Power-over-Ethernet (PoE) circuit **612** has an integrated

Powered Ethernet Source (iPES) **630** that comprises a non-magnetic power supply circuit **616**, an Ethernet physical layer (PHY) **618**, and a Power Sourcing Equipment (PSE) controller **620**. The non-magnetic power supply circuit **616** is integrated into the iPES **630** and is connected to communication signal pins **604S** and power pins **604P** of the network interface **604**. The Ethernet physical layer (PHY) **618** is integrated into the iPES **630** and connected between the non-magnetic power supply circuit **616** and the application interface **606**. The Ethernet PHY **618** is connected to the application interface **606** by a SMII interface **608** and a Management Data Input/Output (MDIO) interface **614**. The SMII standard specifies support for either direct current (DC) or alternating current (AC) operation. The Power Sourcing Equipment (PSE) controller **620** is connected between the non-magnetic power supply circuit **616** and power feed pins **610** of the application interface **606**.

[0027] In the illustrative connector module **602**, the iPES **630** is isolated from application resources by isolation capacitors **638** that are connected between the Ethernet PHY **618** and the application interface **606** and one or more optical couplers **640** connected between the PSE controller **620** and the application interface **606**. For example, in an AC implementation, suitable isolation capacitors **638** may be 0.01 µF or any suitable capacitance to supply power supply isolation. Isolation for the MDIO can be supplied by any suitable component such as capacitors or opto-couplers.

[0028] In some embodiments, a multi-port switch **636** can be connected to the application interface **606**, for example on the exterior side of the application interface **606** with respect to the connector module **602** so that the multi-port switch **636** is coupled to the PoE circuit **612** via the application interface **606**.

[0029] Referring to **FIGURE 7**, a schematic circuit and block diagram depicts an embodiment of a network device **700** configured for usage as a midspan power sourcing equipment (PSE) connector module **702**. The midspan arrangement **702** can be implemented including a network connector **704**, such as an RJ-45 connector, with four pairs. The signal can be carried on two pairs and power carried on the other two pairs. The midspan arrangement is a single package that has input connections to a switch supplying an Ethernet signal and to power supplied from exterior to the connector. The midspan connector **702** supplies output power and signal lines.

[0030] Typically, the midspan can be configured as a power injector that links basic Ethernet switches to the end power device. A midspan is typically used to deploy installations of powered terminals such as Wireless Local Area Network (WLAN) access points, network security cameras and Internet Protocol (IP) phones.

[0031] One of the limitations of a conventional midspan arrangement is handling of power and signal in high-speed Ethernet applications. For example, in typical 10/100 Ethernet signal can be placed on two of four pairs and power placed on the remaining two pairs. However, in gigabit Ethernet, all four pairs carry signal so no lines are available for carrying power. Accordingly, conventional midspans cannot easily handle power and signal for gigabit Ethernet.

[0032] In contrast, the various connector arrangements disclosed herein enable efficient usage of Ethernet pathways even for gigabit Ethernet. The midspan connector **702** can include signal conditioning functional elements, for example that filter the communication signals and separate signal and power with little or no signal interference. Signals are distributed using a multi-port switch **736**.

[0033] The midspan Power Sourcing Equipment (PSE) module **702** comprises a Power-over-Ethernet (PoE) circuit **712** connected between a network connector **704** and an application connector **706**. The Power-over-Ethernet (PoE) circuit comprises a non-magnetic power supply circuit **716** and a Power Sourcing Equipment (PSE) controller **720**. The non-magnetic power supply circuit **716** is integrated into the midspan PSE module **702** and connected between the network connector **704** and the application connector **706**. A Power Sourcing Equipment (PSE) controller **720** is connected between the non-magnetic power supply circuit **716** and power feed pins **710** of the application interface **706**.

[0034] In some embodiments, a multi-port switch **736** can be connected to the application interface **706** so that the multi-port switch **736** is coupled to the PoE circuit **712** via the application interface **706**.

[0035] The application connector **706** can be capacitively-coupled to the multi-port switch **736**. In various embodiments, the multi-port switch **736** may be internal or external to the midspan connector **702**.

[0036] Referring to **FIGURE 8A**, a schematic circuit and block diagram depicts an embodiment of a network device **800A** in the configuration of a network attached appliance **850**. The network attached appliance **850** is an example implementation that incorporates a connector module **802**. The illustrative network attached appliance **850** comprises a housing **852** and an application processor **854** contained within the housing **852**. A connector module **802** is contained within the housing **852** and configured to connect the application processor **854** to a network **856**. The connector module **802** comprises a network connector **804**, an application connector **806**, and a Power-over-Ethernet (PoE) circuit **812**. The network connector **804** is coupled to the connector module **802** in a configuration that transfers power and communication signals. The application connector **806** is coupled to the connector module **802** and has serial media independent interface (SMII) pins **808** and power pins **810**. The Power-over-Ethernet (PoE) circuit **812** is connected between the network connector **804** and the application connector **806**.

[0037] In the illustrative embodiment, the Power-over-Ethernet (PoE) circuit **812** includes an integrated Powered Ethernet Device (iPED) **832**. The integrated Powered Ethernet Device (iPED) **832** comprises a non-magnetic transformer and choke circuit **816**, an Ethernet physical layer (PHY) **818**, a Powered Ethernet Device (PD) controller **820**, and a Direct Current-Direct Current (DC-DC) power converter **822**. The non-magnetic transformer and choke circuit **816** is integrated into the iPED **832** and connected to communication signal pins **804S** of the network interface **804**. The Ethernet physical layer (PHY) **818** is integrated into the iPED **832** and connected between the non-magnetic transformer and choke circuit **816** and the application interface **806**. The Ethernet PHY **818** is connected to the application interface **806** by a SMII interface **808** and a Management Data Input/Output (MDIO) interface **814**. The Powered Ethernet Device (PD) controller **820** is integrated into the iPED **832** and connected to power pins **804P** of the network interface **804**. The Direct Current-Direct Current (DC-DC) power converter **822** is integrated into the iPED **832** and connected between the PD controller **820** and power pins **804P** of the application interface **804**.

[0038] Referring to **FIGURE 8B**, a schematic circuit and block diagram depicts an embodiment of a network device **800B** in the configuration of a network attached appliance **850**. The network attached appliance **850** is an example implementation that incorporates a connector module **802**. The illustrative network attached appliance **850** comprises a housing **852** and an application processor **854** contained within the housing **852**. A connector module **802** is contained within the housing **852** and configured to connect the application processor **854** to a network **856**. The connector module **802** comprises a network connector **804**, an application connector **806**, and a Power-over-Ethernet (PoE) circuit **812**. The network connector **804** is coupled to the connector module **802** in a configuration that transfers power and communication signals. The application connector **806** is coupled to the connector module **802** and configured for coupling to the application processor **854**. The Power-over-Ethernet (PoE) circuit **812** is coupled between the network connector **804** and the application connector **806**.

[0039] In the illustrative embodiment, the Power-over-Ethernet (PoE) circuit **812** includes an integrated Powered Ethernet Device (iPED) **832**. The integrated Powered Ethernet Device (iPED) **832** comprises a non-magnetic transformer and choke circuit

816, a Powered Ethernet Device (PD) controller **820**, and a Direct Current-Direct Current (DC-DC) power converter **822**. The non-magnetic transformer and choke circuit **816** is integrated into the iPED **832** and coupled between communication signal pins **804S** of the network interface **804** and the application interface **804**. The Powered Ethernet Device (PD) controller **820** is integrated into the iPED **832** and connected to power pins **804P** of the network interface **804**. The Direct Current-Direct Current (DC-DC) power converter **822** is integrated into the iPED **832** and connected between the PD controller **820** and power pins **804P** of the application interface **804**.

[0040] In the illustrative embodiment, the connector module **802** further comprises isolation capacitors **838** and at least one optical coupler **840**. The isolation capacitors **838** are coupled between the non-magnetic transformer and choke circuit **816** and the application interface **806**. The optical coupler **840** is connected between the Powered Ethernet Device (PD) **820** and the application interface **806**.

[0041] The network attached appliance **850** can further comprise an Ethernet physical layer (PHY) **818** coupled between the application interface **806** and the application processor **854**. The Ethernet PHY **818** is coupled to the application processor **854** by a SMII interface **808** and a Management Data Input/Output (MDIO) interface **814**.

[0042] Referring to **FIGURE 8C**, a schematic circuit and block diagram depicts an embodiment of a network device **800C** in the configuration of a network attached appliance **850** incorporating a connector module **802** with a Power-over-Ethernet (PoE) circuit **812**. In the illustrative embodiment, the Power-over-Ethernet (PoE) circuit **812** includes an integrated Powered Ethernet Device (iPED) **832**. The integrated Powered Ethernet Device (iPED) **832** comprises an isolated Ethernet physical layer (PHY) **818C**, a Powered Ethernet Device (PD) controller **820**, and an isolated Direct Current-Direct Current (DC-DC) power converter **822C**. The isolated Ethernet physical layer (PHY) **818C** is integrated into the iPED **832** and coupled to the application interface **806** by a SMII interface **808** and a Management Data Input/Output (MDIO) interface **814**. The Powered Ethernet Device (PD) controller **820** is integrated into the iPED **832** and connected to power pins **804P** of the network interface **804**. The isolated Direct Current-Direct Current (DC-DC) power converter **822** is integrated into the iPED **832** and connected between the PD controller **820** and power pins **804P** of the application interface **806**.

[0043] In some embodiments, the integrated Powered Ethernet Device (iPED) **832** can further comprise an autotransformer **816C** that is integrated into the iPED **832** and coupled between communication signal pins of the network interface **804** and the application interface **806**. Isolation capacitors can be coupled to the autotransformer **816C** and integrated into the iPED **832** coupled between communication signal pins of the network interface **804** and the application interface **806**.

[0044] The isolated Ethernet physical layer (PHY) **818C** can have internal isolation, for example by including isolation capacitors **838** coupled to the SMII interface **808** and the MDIO interface **814**.

[0045] An isolation barrier is formed by isolating components and/or devices in the isolated Ethernet physical layer (PHY) **818C** the isolated Direct Current-Direct Current (DC-DC) power converter **822C**, thereby isolating the network interface **804** from the application interface **806**.

[0046] Referring to **FIGURE 9A**, a schematic circuit and block diagram depicts an embodiment of a network device **900** in the configuration of a power sourcing equipment (PSE) switch module **950**. The PSE switch module **950** may be termed a power sourcing equipment appliance and can comprise a housing **952** and an Ethernet switch **958** and an isolated power supply contained within the housing **952**. The PSE switch module **950** further comprises a connector module **902** contained within the housing **952** and configured to couple the Ethernet switch **958** and the isolated power supply **960** to a network **956**. The connector module comprises a network connector **904**, an application connector **906**, and a Power-over-Ethernet (PoE) circuit **912**. The network connector **904** is connected to the connector module **902** in a configuration that transfers power and communication signals. The application connector **906** is connected to the connector module **902** and comprises serial media independent interface (SMII) pins **908** and power pins **910**. The Power-over-Ethernet (PoE) circuit **912** is connected between the network connector **904** and the application connector **906**.

[0047] In the illustrative embodiment, the Power-over-Ethernet (PoE) circuit **912** can include an integrated Powered Ethernet Source (iPES) **930**. The integrated Powered Ethernet Source (iPES) **930** comprises a non-magnetic transformer and choke circuit **912**, an Ethernet physical layer (PHY) **918**, and a Power Sourcing Equipment (PSE) controller **920**. The non-magnetic transformer and choke circuit **912** is integrated into the iPES **930** and is connected to communication signal pins **904S** and power pins **904P** of the network interface **904**. The Ethernet physical layer (PHY) **918** is integrated into the iPES **930** and connected between the non-magnetic transformer and choke circuit **916** and the application interface **906**. The Ethernet PHY **918** is connected to the application interface **906** by a SMII interface **908** and a Management Data Input/Output (MDIO) interface **914**. The Power Sourcing Equipment (PSE) controller **920** is connected between the non-magnetic transformer and choke circuit **916** and power feed pins **910** of the application interface **906**.

[0048] In the illustrative PSE switch module **950**, the iPES **930** is isolated from the Ethernet switch **958** and the isolated power supply **960** by isolation capacitors **938** that are connected between the Ethernet PHY **918** and the application interface **906** and one or more optical couplers **940** connected between the PSE controller **920** and the application interface **906**.

[0049] Referring to **FIGURE 9B**, a schematic circuit and block diagram depicts an embodiment of a network device **900** in the configuration of a power sourcing equipment (PSE) switch module **970** or power sourcing equipment appliance with an Ethernet physical layer (PHY) **918** exterior to an integrated Powered Ethernet Source (iPES) **930**. The power sourcing equipment appliance **970** comprises the Ethernet physical layer (PHY) **981** coupling an Ethernet switch **958** and an isolated power supply **960** to an application interface **906**. The Power-over-Ethernet (PoE) circuit **912** comprises an integrated Powered Ethernet Source (iPES) **930** and a Power Sourcing Equipment (PSE) controller **920**. The integrated Powered Ethernet Source (iPES) **930** comprises a non-magnetic transformer and choke circuit **916** integrated into the iPES **930** and connected to communication signal pins **904S** and power pins **904P** of the network interface **904**. The Power Sourcing Equipment (PSE) controller **920** is connected between the non-magnetic transformer and choke circuit **916** and power feed pins **910** of the application interface **906**.

[0050] The iPES **930** can be isolated from the Ethernet switch **958** and the isolated power supply **960** by isolation capacitors **938** that are connected between the Ethernet PHY **918** and the application interface **906** and one or more optical couplers **940** connected between the PSE controller **920** and the application interface **906**.

[0051] PSE switch modules **950** and **970** in **FIGUREs 9A** and **9B** respectively show example isolation structures.

[0052] Referring to **FIGURE 9C**, a schematic circuit and block diagram depicts an embodiment of a network device **900C** in the configuration of a power sourcing equipment (PSE) switch module **950**. The PSE switch module **950** may be termed a power sourcing equipment appliance and can comprise a housing **952** and an Ethernet switch **958** and an isolated power supply contained within the housing **952**. The PSE switch module **950** further comprises a connector module **902** contained within the housing **952** and configured to couple the Ethernet switch **958** and the isolated power supply **960** to a network **956**. The connector module comprises a network connector **904**, an application connector **906**, and a Power-over-Ethernet (PoE) circuit **912**. The network connector **904** is connected to the connector module **902** in a configuration that transfers power and communication signals. The application connector **906** is connected to the connector module **902** and comprises serial media independent interface (SMII) pins **908** and power pins **910**. The Power-over-Ethernet (PoE) circuit **912** is connected between the network connector **904** and the application connector **906**.

[0053] In the illustrative embodiment, the Power-over-Ethernet (PoE) circuit **912** can include an integrated Powered Ethernet Source (iPES) **930**. The integrated Powered Ethernet Source (iPES) **930** comprises an isolated Ethernet physical layer (PHY) **918C**, and a Power Sourcing Equipment (PSE) controller **920**. The isolated Ethernet physical layer (PHY) **918C** is integrated into the iPES **930** and connected to the application interface **906** by a SMII interface **908** and a Management Data Input/Output (MDIO) interface **914**. The Power Sourcing Equipment (PSE) controller **920** is to power feed pins **910** of the application interface **906**.

[0054] In some embodiments, the integrated Powered Ethernet Source (iPES) **930** can further comprise an autotransformer **916C** that is integrated into the iPES **930** and coupled between communication signal pins of the network interface **904** and the application interface **906**. Isolation capacitors can be coupled to the autotransformer **916C** and integrated into the iPES **930** coupled between communication signal pins of the network interface **904** and the application interface **906**.

[0055] The isolated Ethernet physical layer (PHY) **918C** can have internal isolation, for example by including isolation capacitors **938** coupled to the SMII interface **908** and the MDIO interface **914**.

[0056] A Buck converter **962** can be integrated into the integrated Powered Ethernet Source (iPES) **930** and coupled to a power line supplying the isolated Ethernet physical layer (PHY) **918C** from the isolated power supply **960**.

[0057] An isolation barrier is formed by isolating components and/or devices in the isolated Ethernet physical layer (PHY) **918C**, thereby isolating the network interface **904** from the application interface **906**.

[0058] Referring to **FIGURE 10A**, a schematic circuit and block diagram illustrates an embodiment of a network device **1000A** arranged as a network interface module **1002**. The network interface module **1002** comprises a network connector **1004** connected to the network interface module **1002** in a configuration that transfers power and communication signals and an application connector **1006**. A Power-over-Ethernet

(PoE) circuit **1012** is connected between the network connector **1004** and the application connector **1006**. The PoE circuit **1012** comprises a transformer **1016** connected to communication signal pins **1004S** of the network interface **1004** and an Ethernet physical layer (PHY) **1018** connected between the transformer **1016** and the application interface **1006**. The Power-over-Ethernet (PoE) circuit **1012** can further comprise a Powered Ethernet Device (PD) controller **1020** coupled to power pins **1004P** of the network interface **1004**, and a Direct Current-Direct Current (DC-DC) power converter **1022** connected between the PD controller **1020** and power pins **1010** of the application interface **1006**.

[0059] The illustrative network interface module **1002** is depicted as a powered device module. In a different application, the network interface module can be configured for usage as a power sourcing equipment interface module, for example in an implementation such as that shown in **FIGURE 5** where a Power-over-Ethernet (PoE) circuit can comprise a Power Sourcing Equipment (PSE) controller coupled between power pins of the network interface and power feed pins of the application interface.

[0060] Referring to **FIGURE 10B**, a schematic circuit and block diagram illustrates an embodiment of a network device **1000B** arranged as a network interface module **1002**. The network interface module **1002** comprises a network connector **1004** connected to the network interface module **1002** in a configuration that transfers power and communication signals and an application connector **1006**. A Power-over-Ethernet (PoE) circuit **1012** is connected between the network connector **1004** and the application connector **1006** coupled to the network interface module **1002**. The PoE circuit **1012** comprises a transformer **1016** connected to communication signal pins **1004S** of the network interface **1004**.

[0061] An Ethernet physical layer (PHY) **1018** external to the network interface module **1002** can be coupled to the transformer **1016** through the application interface **1006**.

[0062] The Power-over-Ethernet (PoE) circuit **1012** can further comprise a Powered Ethernet Device (PD) controller **1020** coupled to power pins **1004P** of the network interface **1004**.

[0063] In some embodiments, the Power-over-Ethernet (PoE) circuit **1012** can further comprise a Direct Current-Direct Current (DC-DC) power converter **1022** connected between the PD controller **1020** and power pins **1010** of the application interface **1006**.

[0064] Referring to **FIGURE 11**, a schematic block diagram shows an embodiment of a powered network device, for example a network attached appliance **1192**. In this case, the network attached appliance is a VOIP telephone. Network connector **1132** takes form of an Ethernet network connector, such as RJ45 connector, and passes Ethernet signals to power feed circuitry **1162** and PD controller **1140**. Non-magnetic transformer and choke power feed circuitry **1162** separates the data signal and power signal. The data signal is provided to network physical layer **1136**. Network physical layer **1136** couples to a network MAC to execute the network hardware layer. An application specific processor, such as VOIP processor **1194** or related processors, couples to the network MAC. Additionally, the VOIP telephone processors and related circuitry (display **1196** and memory **1198** and **1199**) may be powered by power converter **1138** using power fed and separated from the network signal by non-magnetic transformer and choke power feed circuitry **1162**. In other embodiments, other network appliances, such as cameras, routers, printers and other like devices are envisioned.

[0065] In some embodiments, a network device **1192** can be configured to receive multiple power signals and data signals through a coupled network **1122**. The network device **1192** comprises a network connector **1132** configured to physically couple the network device **1192** to the network **1122** and receive four twisted pairs that carry the power signals including, for example a first power signal and a second power signal. The network device **1192** further comprises an integrated circuit (IC) coupled to the network connector **1132** which comprises an Ethernet physical layer (PHY) module **1136**, a power management module **1138**. Isolation capacitors can be coupled between the Ethernet PHY module **1136** and an application device **1194** and an optical coupler can be coupled between the power management module **1140** and the application device **1194**. A direct connection module is coupled to the network connector **1132** and operative to pass the received data signal(s) to the Ethernet PHY **1136**, sense a current associated with the twisted pairs, actively balance current associated with the twisted pairs, and pass the received plurality of power signals to the power management module **1140** wherein the power management module is operative to at least partially power the network device **1192** from the received plurality of power signals.

[0066] Referring to **FIGURE 12**, a schematic functional block diagram illustrates an embodiment of a network device in a configuration of a network attached appliance **1292** including a power sourcing equipment (PSE) device. The network attached appliance is shown as a VoIP telephone. Network connector **1232** takes form of an Ethernet network connector, such as RJ45 connector, and passes Ethernet signals to power feed circuitry **1262** and PD controller **1240**. Non-magnetic transformer and choke power feed circuitry

1262 separates the data signal and power signal. An optional connection to an external isolated power supply allows the network attached device to be powered when insufficient power is available or when more power is required than can be provided over the Ethernet connection. The data signal is provided to network physical layer **1236**. Network physical layer **1236** couples to a network MAC to execute the network hardware layer. An application specific processor, such as VoIP processor **1294** or related processors, couples to the network MAC. Additionally, the VoIP telephone processors and related circuitry (display **1296** and memory **1298** and **1299**) may be powered by power converter **1238** using power fed and separated from the network signal by non-magnetic transformer and choke power feed circuitry **1262**. In other embodiments, other network appliances, such as cameras, routers, printers and other like devices are envisioned.

[0067] **FIGURE 12** is a functional block diagram of a specific network attached PSE device **1293**. In this embodiment, PSE network device **1293** is an Ethernet router. Network connector **1232** may take the form of Ethernet network connector such as an RJ-45 connector, and is operable to distribute Ethernet signals that include both power and data as combined by the integrated circuits within PSE **1293**. PSE **1293** includes an integrated circuit **1266** which serves as a nonmagnetic transformer and choke circuit.

[0068] The 1500 volt isolation between earth ground and the PSE network device may be achieved through various means. The data connections may be capacitively isolated, optically isolated or isolated using a transformer. The power connection is isolated using one or more isolated power supplies. Capacitors **1215**, **1216** and optocoupler **1217** in **FIGURE 12** are one example of this isolation.

[0069] The PSE devices may be a single port or multi-port. As a single port this device can also be applied to a mid-span application. Data is provided to Ethernet physical layer **1254** either from network devices attached to network connector **1232** or data received from an external network via internet switch **1258** and an uplink. Ethernet switch **1258** could be an application specific processor or related processors that are operable to couple PSE **1293** via an uplink to an external network.

[0070] PSE devices may be integrated into various switches and routers for enterprise switching applications. However, in non-standard networks e.g. automotive etc., these PSE devices may be integrated into controller for the attached devices. In the case of multimedia or content distribution, these PSE devices may be incorporated into a controller/set-top box that distributes content and power to attached devices.

[0071] Nonmagnetic transformer and choke circuitry **1266** receives data from Ethernet physical layer **1254**. Additionally, power is supplied to the nonmagnetic transformer and choke circuitry **1266** from isolated power supply **1297**. In one embodiment this is a 48-volt power supply. However, this power distribution system may be applied to other power distribution systems, such as 110 volt systems as well. PSE controller **1256** receives the power signal from isolated power supply **1297** and is operable to govern the power signal content within the Ethernet signal supplied by nonmagnetic transformer and choke circuitry **1266**. For example, PSE controller **1256** may limit the Ethernet power produced by nonmagnetic transformer and choke circuitry **1266** based on the requirements of an attached PD. Thus PSE controller **1256** is operable to ensure that attached network PDs are not overloaded and are given a proper power signal. Power supply **1297** also supplies as shown a power signal to Ethernet PHY **1254**, Ethernet switch **1258**.

[0072] Isolated power supply **1297** may be attached to an AC power supply or other internal or external power supply in order to provide a power signal to be distributed to network-attached devices that couple to PSE **1293**. PSE controller **1256** may determine, in accordance with IEEE standard 802.3af, whether or not a network-attached device, in the case of an Ethernet-attached device, is a device operable to receive power from power supply equipment. When it is determined that an 802.3af compliant PD is attached to the network, PSE controller **1256** may supply power from power supply **1297** to nonmagnetic transformer and choke circuitry **1266**, which is then provided to the downstream network-attached device through network connectors **1232**.

[0073] The 802.3af Standard is intended to be fully compliant with all existing non-line powered Ethernet systems. As a result, the PSE network device is required to detect via a well defined procedure whether or not the far end network attached device is POE compliant and classify the amount of needed power prior to applying power to the system. Maximum allowed voltage is 57 volts to stay within the SELV (Safety Extra Low Voltage) limits.

[0074] In order to be backward compatible with non-powered systems the DC voltage applied will begin at a very low voltage and only begin to deliver power after confirmation that a POE device is present. During classification the PSE network device applies a voltage between 14.5V and 20.5V, and measures the current to determine the power class of the device.

[0075] The PSE network device enters a normal power supply mode after determining that the PD is ready to receive power. At this point the 48V supply is connected to the Ethernet cable. During the normal power supply mode, a maintain power signature is sensed by the PSE to continue supplying power. The maximum current allowed is limited by the power class of the network attached device.

[0076] In some embodiments, a power source equipment (PSE) network device **1293** operative to distribute a network power signal and a network data signal through a coupled network and comprises a network connector **1232** configured to physically couple the PSE network device **1293** to the network, and an integrated circuit (IC) coupled to the network connector **1232** that further comprises a power feed circuit **1242** which exchanges data signals with a network physical layer (PHY) module **1216**, an Ethernet switch **1282**, and the network connector **1232**. The integrated circuit also isolates the network PHY module **1216** from the Ethernet switch **1282,** and passes the power signal to the network connector **1232** as directed by a power source equipment (PSE) controller. The power signal is received from an isolated power supply.

[0077] In some embodiments, power can be supplied from a power source equipment (PSE) network device **1293** with an Ethernet power signal fed through an Ethernet network connection by producing the Ethernet power signal from power supplied by an isolated power supply **1297** in an integrated circuit (IC) within the PSE network device **1293**. The PSE network device **1293** is physically coupled to the isolated power supply and physically coupled to an Ethernet network. An Ethernet data signal and the Ethernet power signal are combined within the IC to produce an Ethernet signal. Ground isolation is provided for the Ethernet data signal and the Ethernet power signal. The Ethernet signal is exchanged with at least one Ethernet network power device (PD) which is physically coupled to the Ethernet network **1222** within the PSE network device **1293**. The IC is isolated from the one or more Ethernet network power devices.

[0078] In various embodiments, a power source equipment (PSE) network device **1293** can be operative to distribute an Ethernet power signal and an Ethernet data signal through a coupled Ethernet network. The illustrative PSE network device **1293** comprises an Ethernet network connector **1232** configured to physically couple the PSE network device **1293** to the Ethernet network, a PSE controller, an Ethernet physical layer (PHY) module **1216** configured to couple the PSE network device **1293** to a multiport switch **1282** at an isolated interface **1225**, **1226**; and an integrated circuit (IC). The IC is coupled to the Ethernet network connector **1232** that further comprises a power feed circuit **1242** which is configured to exchange Ethernet data signals with the Ethernet PHY module **1216** and the Ethernet connector **1232**, supply a power signal from a power supply to the PSE network device **1293**, and produce and pass the Ethernet power signal to the Ethernet connector **1232** as directed by the PSE controller.

[0079] A bridge circuit can bridge from Ethernet to legacy interfaces including interfaces to devices that are not typically Ethernet-enabled. For example, the bridge circuit enables interfacing to Universal Serial Bus (USB), Firewire (i.Link or IEEE 1394), Recommended Standard (RS)-232 serial binary data, RS-485 high-speed serial, Peripheral Component Interconnect (PCI), CompactPCI (cPCI), other PCI variant, or other suitable digital interfaces.

[0080] In some embodiments, at a fundamental primary level the bridge circuit can comprise a transformer-less power over Ethernet interface in combination with a Media Access Control (MAC) element, a processor to form various tasks for usage by the bridge interface, and digital drivers for usage by legacy interfaces.

[0081] In further embodiments, the bridge circuit can extend to a further level by adding an analog interface with an analog transceiver so that information on the internet can communicate to the analog domain. For example, analog transceivers enable direct internet communication with devices such as a Home Phoneline Networking Alliance (HPNA), home personal connections, Institute of Electrical and Electronics Engineers (IEEE) 802.11 wireless standard, Wi-Fi standard, Radio Frequency Identification (RFID) tag ID readers, scanners, and other analog devices.

[0082] In various embodiments, an Ethernet bridge can support a power feed on multiple signal pairs. Some embodiments can be in the form of a connector, such as a Registered Jack (RJ)-45 connector, which include an integrated powered device (PD) controller, a DC-DC controller, and an Ethernet transformer. Other embodiments can be in the form of a connector, such as a Registered Jack (RJ)-45 connector, which include an integrated powered device (PD) controller, a DC-DC controller, and a solid-state transformer, such as a T-connect or T-Less Connect™ solid-state transformer.

[0083] The Ethernet bridge can be constructed with a T-LessConnect™ solid-state transformer or a magnetic transformer, and may be implemented as a single-chip application-based appliance. In some configurations, the Ethernet bridge circuit can be integrated onto one chip.

[0084] Referring to FIGURE 13A, a schematic block diagram illustrates an embodiment of a network device 1300 configured as an Ethernet bridge module 1302. The Ethernet bridge module 1302 can be integrated onto a single-chip integrated circuit. The Ethernet bridge module 1302 comprises a network connector 1304 coupled to the integrated Ethernet bridge module 1302 in a configuration that transfers power and communication signals. The Ethernet bridge module 1302 further comprises one or more drivers 1306 and/or one or more transceivers 1308 integrated onto the Ethernet bridge module 1302 and configured to interface to one or more devices 1310 external to the Ethernet bridge module 1302. The Ethernet bridge module 1302 further comprises a Power-over-Ethernet (PoE) circuit 1312 integrated onto the Ethernet bridge module 1302 and coupled between the network connector 1304 and the drivers 1306 and/or transceivers 1308.

[0085] In some embodiments, the network connector 1302 can be a Registered Jack (RJ) 45 physical interface and the drivers 1306 and/or transceivers 1308 can comprise a digital driver with one or more digital interfaces and/or an analog transceiver with one or more analog interfaces. Various embodiments can include one or more digital interfaces such as a digital driver for Universal Serial Bus (USB), a FireWire Institute of Electrical and Electronics Engineers (IEEE) 1394 serial bus interface standard driver, a Recommended Standard (RS)-232 serial binary data interface driver, a RS-485 high-speed serial interface driver, a Peripheral Component Interconnect (PCI) standard interface driver, a PCI variant interface driver, or other suitable digital interfaces. Various embodiments can include one or more analog interfaces such as a Home Phoneline Networking Alliance (HPNA) interface driver, an Institute of Electrical and Electronics Engineers (IEEE) 802.11 wireless standard interface driver, a Wi-Fi standard interface driver, a Radio Frequency Identification (RFID) reader interface driver, a scanner interface driver, or other suitable analog interfaces.

[0086] In an early phase implementation, analog transceivers 1308 can be a CompactPCI interface, a USB interface, or other standard interface rather than an integrated transceiver. In a later phase, analog transceivers 1308 can be integrated on one integrated circuit chip as a single-chip bridge appliance.

[0087] The illustrative network device 1300 comprises a processor 1314 integrated onto the Ethernet bridge module 1302 that has functional programming for interfacing to memory, for example a dynamic random access memory (DRAM) interface, a flash memory interface, and the like, and for interfacing to the drivers 1306 and/or transceivers 1308. The processor 1314 can include various programming to facilitate bridge interfacing such as stack processing, packet processing, forwarding, scheduling, rule-based processing, interface task monitoring, and the like.

[0088] The Ethernet bridge module 1302 further can comprise a Media Access Control (MAC) layer 1316 which is communicatively coupled to the processor 1314 and functions as a controller to determine access to physical media. The MAC layer 1316 executes various operations such as 802.3 MAC functions or modifications to HPNA, HPNA MAC, 802.11, 802.11 MAC, Ethernet, Ethernet MAC, and the like according to the particular application executed.

[0089] In typical embodiments, the processor 1314 can be a microprocessor, a central processing unit (CPU), a digital signal processor, computational logic, state machine, and the like. The processor 1314 can include functional programming selected from among functional modules such as a Transmission Control Protocol / Internet Protocol (TCP/IP) stack processing module, a packet processing module adapted for packet forwarding and scheduling, a rule based processing module, a monitoring and event scheduling module, a drivers module, and others.

[0090] The MAC layer 1316 can include functional programming selected from among modules such as an Institute of Electrical and Electronics Engineers (IEEE) 802.3 physical layer and data link layer module, a IEEE 802.11 wireless module, a Home Phoneline Networking Alliance (HPNA) module, a Residential Internet (RI) module, and the like.

[0091] In some network device embodiments, a Management Data Input/Output (MDIO) and/or an Inter-Integrated Circuit (I2C) interface 1318 can be integrated onto the Ethernet bridge module 1302.

[0092] In the illustrative network device 1302, the Power-over-Ethernet (PoE) circuit 1312 comprises an integrated Powered Ethernet Device (iPED) 1334. The iPED 1334 comprises a non-magnetic transformer and choke circuit 1320 that is integrated into the iPED 1334 and coupled to communication signal pins of the network interface 1304. The iPED 1334 can further comprise an Ethernet physical layer (PHY) 1322 that is integrated into the iPED 1334 and coupled between the non-magnetic transformer and choke circuit 1320 and the processor, a Powered Ethernet Device (PD) controller 1324 integrated into the iPED 1334 and coupled to power pins of the network interface 1304, and a Direct Current-Direct Current (DC-DC) power converter 1326 that is integrated into the iPED 1334 and coupled between the PD controller 1324 and the processor 1314.

[0093] In some arrangements and configurations, the non-magnetic transformer and choke circuit 1320 can be a T-Less Connect™ solid-state transformer. The T-Less Connect™ solid-state transformer separates Ethernet signals from power signals.

[0094] In some embodiments the T-Less Connect™ solid-state transformer can function by floating ground potential of the Ethernet PHY relative to earth ground.

[0095] Referring to FIGURE 13B, a schematic block diagram illustrates an embodiment of a network device 1300 configured as an Ethernet bridge module 1302 that may be constructed as a single integrated circuit chip, multiple integrated circuits, a circuit board with multiple components and devices, or any other suitable arrangement. The illustrative Ethernet bridge module 1302 comprises a network connector 1304 in a configuration that transfers power and communication signals, one or more drivers 1306 and/or transceivers 1308 configured to interface to one or more devices 1310 external to the Ethernet bridge module 1302, and a Power-over-Ethernet (PoE) circuit 1312 coupled between the network connector 1304 and drivers 1306 and/or transceivers 1308 and comprising an integrated Powered Ethernet Device (iPED) 1334.

[0096] In the illustrative arrangement, the iPED 1334 comprises a non-magnetic transformer and choke circuit 1320, an Ethernet physical layer (PHY) 1322, a Powered Ethernet Device (PD) controller 1324, and a Direct Current-Direct Current (DC-DC) power converter 1326. The non-magnetic transformer and choke circuit 1320 is a non-magnetic transformer and choke circuit 1320 integrated into the iPED 1334 and connected to communication signal pins of the network interface 1304. The Ethernet physical layer (PHY) 1322 is integrated into the iPED 1334 and connected to the non-magnetic transformer and choke circuit 1320. The Powered Ethernet Device (PD) controller 1324 is integrated into the iPED 1334 and connected to power pins of the network interface 1304. The Direct Current-Direct Current (DC-DC) power converter 1326 integrated into the iPED 1334 and connected to the PD controller 1324.

[0097] FIGURE 13B shows the Powered Ethernet Device (PD) controller 1324 in greater detail. The illustrative PD controller 1324 comprises a diode bridge 1328 coupled to power pins of the network interface 1304, a power switch circuit 1330 coupled to the diode bridge 1328, and a signature and classification circuit 1332 coupled to the diode bridge 1328 and the power switch circuit 1330.

[0098] The non-magnetic transformer and choke circuit 1320 depicted in FIGURE 13B can also be a T-Less Connect™ solid-state transformer that separates Ethernet signals from power signals and/or that operates by floating ground potential of the Ethernet PHY relative to earth ground.

[0099] Referring to FIGURE 14, a schematic block diagram depicts an embodiment of a network device 1400 in a configuration of an Ethernet bridge module 1402 that includes a magnetic transformer 1420. The illustrative Ethernet bridge module 1402 comprises a network connector 1404 in a configuration that transfers power and communication signals, one or more drivers 1406 and/or transceivers 1408 configured to interface to devices 1410 external to the Ethernet bridge module 1402, and a Power-over-Ethernet (PoE) circuit **1412** coupled between the network connector **1404** and drivers **1406** and/or transceivers **1408**. The illustrative POE circuit **1412** comprises a magnetic transformer **1420** coupled to communication signal pins of the network interface **1404**, an Ethernet physical layer (PHY) **1422** coupled to the magnetic transformer **1420**, a Powered Ethernet Device (PD) controller **1424** coupled to power pins of the network interface **1404**, and a Direct Current-Direct Current (DC-DC) power converter **1426** coupled to the PD controller **1424**.

[0100] An illustrative Power-over-Ethernet (PoE) circuit **1412** comprises a magnetic transformer **1420** coupled to communication signal pins of a network interface **1404**. An Ethernet physical layer (PHY) **1422** is coupled between the magnetic transformer **1420** and a processor **1414**. A Powered Ethernet Device (PD) controller **1424** can be coupled to power pins of the network interface **1404**. The PoE circuit **1412** also can have a Direct Current-Direct Current (DC-DC) power converter **1426** coupled between the PD controller **1424** and the processor **1414**.

[0101] In the illustrative network device **1400**, the Power-over-Ethernet (PoE) circuit **1412** further comprises a diode bridge **1428** coupled between power pins of the network interface **1404** and the PD controller **1424**.

[0102] The Powered Ethernet Device (PD) controller **1424** can comprise a power switch circuit **1430** and a signature and classification circuit **1432**.

[0103] In some embodiments, the Ethernet bridge module **1402** can be integrated onto a single-chip integrated circuit.

[0104] Referring to **FIGURE 15**, a schematic block diagram shows an embodiment of a network device **1500** configured as an Ethernet bridge module **1502** that comprises a housing **1540**, a network connector **1304** coupled to the housing **1540** and configured to transfers power and communication signals, and one or more drivers **1306** and/or transceivers **1308**. The drivers **1306** and/or transceivers **1308** are contained in the housing **1540** and configured to interface to devices external to the Ethernet bridge module **1502**. The devices are selectable from among Ethernet-enabled devices and Ethernet non-enabled devices. The Ethernet bridge module **1502** further comprises a Power-over-Ethernet (PoE) circuit **1312** contained in the housing **1540** and coupled between the network connector **1304** and the drivers **1306** and/or transceivers **1308**.

[0105] The illustrative Ethernet bridge arrangement **1502** enables internet communication with various standard and legacy interfaces and/or devices that may or may not be Ethernet enabled. For example, the Ethernet bridge **1502** enables direct connection from the internet to a USB interface – a local interface that connects to common devices such as computers, printers, scanners, cameras, cam-corders, and the like. The Ethernet bridge **1502** enables image and other data from a camera or cam-corder to pass directly from the device onto a network by email or other technique by either wired or wireless Ethernet transmission. The Ethernet bridge **1502** enables a device such as a digital camera to mount essentially directly on the Ethernet interface, for example via the USB interface, and send data simply and seamlessly across to a selected receiver on the network.

[0106] In another example, one device that has a USB interface but not direct Ethernet connection, for example an iPod™, can also be connected directly to Ethernet without passing through a computer through usage of the Ethernet bridge **1502**. Accordingly, if a network is available, the Ethernet bridge **1502** can be used to plug the iPod into the network so that anyone with access to the network can listen to music played on the iPod. The music can be piped essentially to any location via the network.

[0107] Similarly, the Ethernet bridge **1502** can have a Firewire (IEEE 1394) analog transceiver **1308** that enables connection of a cam-corder to Ethernet and communication via a streaming protocol. The Ethernet connection formed by the Ethernet bridge **1502** extends the communication distance for Firewire transmission.

[0108] The Ethernet bridge **1502** further enables direct connection of an RS-232 interface to an Ethernet connection box so that data can pass directly from a source to the internet without requiring passage through an intervening computer. Accordingly, the Ethernet bridge **1502**, by enabling direct connection of RS-232 to Ethernet, greatly facilitates network connectivity by virtue of the ubiquitous availability of RS-232 interfaces.

[0109] In an illustrative embodiment, the housing **1540** can be configured as a very small dongle containing a small integrated circuit chip embodying the Ethernet bridge circuit **1502**. The housing **1540** can be positioned at one end of an Ethernet cable with the opposing end configured as an RJ-45 male jack **1304**. Information passes through the Ethernet bridge **1502** from the network connector **1304** to, for example, a USB port, RS-232 port, or the like. The network device **1500** enables direct connection of various legacy devices to the network for monitoring and communication of information to virtually any location.

[0110] Although the description herein may focus and describe a system and method for coupling high bandwidth data signals and power distribution between the integrated circuit and cable that uses transformer-less ICs with particular detail to the IEEE 802.3af

Ethernet standard, the concepts may be applied in non-Ethernet applications and non-IEEE 802.3af applications. Also, the concepts may be applied in subsequent standards that supersede or complement the IEEE 802.3af standard.

[0111] Various embodiments of the depicted system may support solid state, and thus non-magnetic, transformer circuits operable to couple high bandwidth data signals and power signals with new mixed-signal IC technology, enabling elimination of cumbersome, real-estate intensive magnetic-based transformers.

[0112] Typical conventional communication systems use transformers to perform common mode signal blocking, 1500 volt isolation, and AC coupling of a differential signature as well as residual lightning or electromagnetic shock protection. The functions are replaced by a solid state or other similar circuits in accordance with embodiments of circuits and systems described herein whereby the circuit may couple directly to the line and provide high differential impedance and low common mode impedance. High differential impedance enables separation of the physical layer (PHY) signal from the power signal. Low common mode impedance enables elimination of a choke, allowing power to be tapped from the line. The local ground plane may float to eliminate a requirement for 1500 volt isolation. Additionally, through a combination of circuit techniques and lightning protection circuitry, voltage spike or lightning protection can be supplied to the network attached device, eliminating another function performed by transformers in traditional systems or arrangements. The disclosed technology may be applied anywhere transformers are used and is not limited to Ethernet applications.

[0113] Specific embodiments of the circuits and systems disclosed herein may be applied to various powered network attached devices or Ethernet network appliances. Such appliances include, but are not limited to VoIP telephones, routers, printers, and other similar devices.

[0114] The IEEE 802.3 Ethernet Standard, which is incorporated herein by reference, addresses loop powering of remote Ethernet devices (802.3af). Power over Ethernet (PoE) standard and other similar standards support standardization of power delivery over Ethernet network cables to power remote client devices through the network connection. The side of link that supplies power is called Powered Supply Equipment (PSE). The side of link that receives power is the Powered device (PD). Other implementations may supply power to network attached devices over alternative networks such as, for example, Home Phoneline Networking alliance (HomePNA) local area networks and other similar networks. HomePNA uses existing telephone wires to share a single network connection within a home or building. In other examples, devices may support communication of network data signals over power lines.

[0115] In various configurations described herein, a magnetic transformer of conventional systems may be eliminated while transformer functionality is maintained. Techniques enabling replacement of the transformer may be implemented in the form of integrated circuits (ICs) or discrete components.

[0116] **FIGURE 1A** is a schematic block diagram that illustrates a high level example embodiment of devices in which power is supplied separately to network attached client devices **112** through **116** that may benefit from receiving power and data via the network connection. The devices are serviced by a local area network (LAN) switch **110** for data. Individual client devices **112** through **116** have separate power connections **118** to electrical outlets **120**. **FIGURE 1B** is a schematic block diagram that depicts a high level example embodiment of devices wherein a switch **110** is a power supply equipment (PSE)-capable power-over Ethernet (PoE) enabled LAN switch that supplies both data and power signals to client devices **112** through **116**. Network attached devices may include a Voice Over Internet Protocol (VOIP) telephone **112**, access points, routers, gateways **114** and/or security cameras **116**, as well as other known network appliances. Network supplied power enables client devices **112** through **116** to eliminate power connections **118** to electrical outlets **120** as shown in **FIGURE 1A**. Eliminating the second connection enables the network attached device to have greater reliability when attached to the network with reduced cost and facilitated deployment.

[0117] Referring to **FIGURE 2**, a functional block diagram depicts an embodiment of a network device **200** including a T-Less Connect™ solid-state transformer. The illustrative network device comprises a power potential rectifier **202** adapted to conductively couple a network connector **232** to an integrated circuit **270**, **272** that rectifies and passes a power signal and data signal received from the network connector **232**. The power potential rectifier **202** regulates a received power and/or data signal to ensure proper signal polarity is applied to the integrated circuit **270**, **272**.

[0118] The network device **200** is shown with the power sourcing switch **270** sourcing power through lines 1 and 2 of the network connector **232** in combination with lines 3 and 6.

[0119] In some embodiments, the power potential rectifier **202** is configured to couple directly to lines of the network connector **232** and regulate the power signal whereby the power potential rectifier **202** passes the data signal with substantially no degradation.

[0120] In some configuration embodiments, the network connector **232** receives multiple twisted pair conductors **204**, for example twisted 22-26 gauge wire. Any one of a subset of the twisted pair conductors **204** can forward bias to deliver current and the power potential rectifier **202** can forward bias a return current path via a remaining conductor of the subset.

[0121] **FIGURE 2** illustrates the network interface **200** including a network powered device (PD) interface and a network power supply equipment (PSE) interface, each implementing a non-magnetic transformer and choke circuitry. A powered end station **272** is a network interface that includes a network connector **232**, non-magnetic transformer and choke power feed circuitry **262**, a network physical layer **236**, and a power converter **238**. Functionality of a magnetic transformer is replaced by circuitry **262**. In the context of an Ethernet network interface, network connector **232** may be a RJ45 connector that is operable to receive multiple twisted wire pairs. Protection and conditioning circuitry may be located between network connector **232** and non-magnetic transformer and choke power feed circuitry **262** to attain surge protection in the form of voltage spike protection, lighting protection, external shock protection or other similar active functions. Conditioning circuitry may be a diode bridge or other rectifying component or device. A bridge or rectifier may couple to individual conductive lines 1-8 contained within the RJ45 connector. The circuits may be discrete components or an integrated circuit within non-magnetic transformer and choke power feed circuitry **262**.

[0122] In an Ethernet application, the IEEE 802.3af standard (PoE standard) enables delivery of power over Ethernet cables to remotely power devices. The portion of the connection that receives the power may be referred to as the powered device (PD). The side of the link that supplies power is called the power sourcing equipment (PSE).

[0123] In the powered end station **272**, conductors 1 through 8 of the network connector **232** couple to non-magnetic transformer and choke power feed circuitry **262**. Non-magnetic transformer and choke power feed circuitry **262** may use the power feed circuit and separate the data signal portion from the power signal portion. The data signal portion may then be passed to the network physical layer (PHY) **236** while the power signal passes to power converter **238**.

[0124] If the powered end station **272** is used to couple the network attached device or PD to an Ethernet network, network physical layer **236** may be operable to implement the 10 Mbps, 100 Mbps, and/or 1 Gbps physical layer functions as well as other Ethernet data protocols that may arise. The Ethernet PHY **236** may additionally couple to an Ethernet media access controller (MAC). The Ethernet PHY **236** and Ethernet MAC when coupled are operable to implement the hardware layers of an Ethernet protocol stack. The architecture may also be applied to other networks. If a power signal is not received but a traditional, non-power Ethernet signal is received the nonmagnetic power feed circuitry **262** still passes the data signal to the network PHY.

[0125] The power signal separated from the network signal within non-magnetic transformer and choke power feed circuit **262** by the power feed circuit is supplied to power converter **238**. Typically the power signal received does not exceed 57 volts SELV (Safety Extra Low Voltage). Typical voltage in an Ethernet application is 48-volt power. Power converter **238** may then further transform the power as a DC to DC converter to provide 1.8 to 3.3 volts, or other voltages specified by many Ethernet network attached devices.

[0126] Power-sourcing switch **270** includes a network connector **232**, Ethernet or network physical layer **254**, PSE controller **256**, non-magnetic transformer and choke power supply circuitry **266**, and possibly a multiple-port switch. Transformer functionality is supplied by non-magnetic transformer and choke power supply circuitry **266**. Power-sourcing switch **270** may be used to supply power to network attached devices. Powered end station **272** and power sourcing switch **270** may be applied to an Ethernet application or other network-based applications such as, but not limited to, a vehicle-based network such as those found in an automobile, aircraft, mass transit system, or other like vehicle. Examples of specific vehicle-based networks may include a local interconnect network (LIN), a controller area network (CAN), or a flex ray network. All may be applied specifically to automotive networks for the distribution of power and data within the automobile to various monitoring circuits or for the distribution and powering of entertainment devices, such as entertainment systems, video and audio entertainment systems often found in today's vehicles. Other networks may include a high speed data network, low speed data network, time-triggered communication on CAN (TTCAN) network, a J1939-compliant network, ISO11898-compliant network, an ISO11519-2-compliant network, as well as other similar networks. Other embodiments may supply power to network attached devices over alternative networks such as but not limited to a HomePNA local area network and other similar networks. HomePNA uses existing telephone wires to share a single network connection within a home or building. Alternatively, embodiments may be applied where network data signals are provided over power lines.

[0127] Non-magnetic transformer and choke power feed circuitry **262** and **266** enable elimination of magnetic transformers with integrated system solutions that enable an increase in system density by replacing magnetic transformers with solid state power feed circuitry in the form of an integrated circuit or discreet component.

[0128] In some embodiments, non-magnetic transformer and choke power feed circuitry **262**, network physical layer **236**, power distribution management circuitry **254**, and power converter **238** may be integrated into a single integrated circuit rather than discrete components at the printed circuit board level. Optional protection and power conditioning circuitry may be used to interface the integrated circuit to the network connector **232**.

[0129] The Ethernet PHY may support the 10/100/1000 Mbps data rate and other future data networks such as a 10000 Mbps Ethernet network. Non-magnetic transformer and choke power feed circuitry **262** supplies line power minus the insertion loss directly to power converter **238**, converting power first to a 12V supply then subsequently to lower supply levels. The circuit may be implemented in any appropriate process, for example a 0.18 or 0.13 micron process or any suitable size process.

[0130] Non-magnetic transformer and choke power feed circuitry **262** may implement functions including IEEE 802.3.af signaling and load compliance, local unregulated supply generation with surge current protection, and signal transfer between the line and integrated Ethernet PHY. Since devices are directly connected to the line, the circuit may be implemented to withstand a secondary lightning surge.

[0131] For the power over Ethernet (PoE) to be IEEE 802.3af standard compliant, the PoE may be configured to accept power with various power feeding schemes and handle power polarity reversal. A rectifier, such as a diode bridge, a switching network, or other circuit, may be implemented to ensure power signals having an appropriate polarity are delivered to nodes of the power feed circuit. Any one of the conductors 1, 4, 7 or 3 of the network RJ45 connection can forward bias to deliver current and any one of the return diodes connected can forward bias to form a return current path via one of the remaining conductors. Conductors 2, 5, 8 and 4 are connected similarly.

[0132] Non-magnetic transformer and choke power feed circuitry **262** applied to PSE may take the form of a single or multiple port switch to supply power to single or multiple devices attached to the network. Power sourcing switch **270** may be operable to receive power and data signals and combine to communicate power signals which are then distributed via an attached network. If power sourcing switch **270** is a gateway or router, a high-speed uplink couples to a network such as an Ethernet network or other network. The data signal is relayed via network PHY **254** and supplied to non-magnetic transformer and choke power feed circuitry **266**. PSE switch **270** may be attached to an

AC power supply or other internal or external power supply to supply a power signal to be distributed to network-attached devices that couple to power sourcing switch **270**. Power controller **256** within or coupled to non-magnetic transformer and choke power feed circuitry **266** may determine, in accordance with IEEE standard 802.3af, whether a network-attached device in the case of an Ethernet network-attached device is a device operable to receive power from power supply equipment. When determined that an IEEE 802.3af compliant powered device (PD) is attached to the network, power controller **256** may supply power from power supply to non-magnetic transformer and choke power feed circuitry **266**, which is sent to the downstream network-attached device through network connectors, which in the case of the Ethernet network may be an RJ45 receptacle and cable.

[0133] IEEE 802.3af Standard is to fully comply with existing non-line powered Ethernet network systems. Accordingly, PSE detects via a well-defined procedure whether the far end is PoE compliant and classify sufficient power prior to applying power to the system. Maximum allowed voltage is 57 volts for compliance with SELV (Safety Extra Low Voltage) limits.

[0134] For backward compatibility with non-powered systems, applied DC voltage begins at a very low voltage and only begins to deliver power after confirmation that a PoE device is present. In the classification phase, the PSE applies a voltage between 14.5V and 20.5V, measures the current and determines the power class of the device. In one embodiment the current signature is applied for voltages above 12.5V and below 23 Volts. Current signature range is 0-44mA.

[0135] The normal powering mode is switched on when the PSE voltage crosses 42 Volts where power MOSFETs are enabled and the large bypass capacitor begins to charge.

[0136] A maintain power signature is applied in the PoE signature block – a minimum of 10mA and a maximum of 23.5kohms may be applied for the PSE to continue to feed power. The maximum current allowed is limited by the power class of the device (class 0-3 are defined). For class 0, 12.95W is the maximum power dissipation allowed and 400ma is the maximum peak current. Once activated, the PoE will shut down if the applied voltage falls below 30V and disconnect the power MOSFETs from the line.

[0137] Power feed devices in normal power mode provide a differential open circuit at the Ethernet signal frequencies and a differential short at lower frequencies. The common mode circuit presents the capacitive and power management load at frequencies determined by the gate control circuit.

[0138] Terms “substantially”, “essentially”, or “approximately”, that may be used herein, relate to an industry-accepted tolerance to the corresponding term. Such an industry-accepted tolerance ranges from less than one percent to twenty percent and corresponds to, but is not limited to, component values, integrated circuit process variations, temperature variations, rise and fall times, and/or thermal noise. The term “coupled”, as may be used herein, includes direct coupling and indirect coupling via another component, element, circuit, or module where, for indirect coupling, the intervening component, element, circuit, or module does not modify the information of a signal but may adjust its current level, voltage level, and/or power level. Inferred coupling, for example where one element is coupled to another element by inference, includes direct and indirect coupling between two elements in the same manner as “coupled”.

[0139] While the present disclosure describes various embodiments, these embodiments are to be understood as illustrative and do not limit the claim scope. Many variations, modifications, additions and improvements of the described embodiments are possible. For example, those having ordinary skill in the art will readily implement the steps necessary to provide the structures and methods disclosed herein, and will understand that the process parameters, materials, and dimensions are given by way of example only. The parameters, materials, and dimensions can be varied to achieve the desired structure as well as modifications, which are within the scope of the claims. Variations and modifications of the embodiments disclosed herein may also be made while remaining within the scope of the following claims. For example, various aspects or portions of a network interface are described including several optional implementations for particular portions. Any suitable combination or permutation of the disclosed designs may be implemented.

WHAT IS CLAIMED IS:

1. A network device **300** comprising:

a connector module **302** comprising:

a network connector **304** coupled to the connector module **302** in a configuration that transfers power and communication signals;

an application connector **306** coupled to the connector module **302** and comprising serial media independent interface (SMII) pins **308** and power pins **310**; and

a Power-over-Ethernet (PoE) circuit **312** coupled between the network connector **304** and the application connector **306**.

2. The network device **300** according to Claim 1 further comprising:

the network connector **304** comprising an eight-pin Registered Jack (RJ) 45 physical interface; and

the application connector **306** comprising a SMII signal interface **308**, a Management Data Input/Output (MDIO) interface **314**, and a two-pin power interface **310**.

3. The network device **300** according to Claim 2 further comprising:

the SMII signal interface **308** is a four-pin signal interface or a six-pin signal and reference clock interface; and

the MDIO interface **314** is a two-pin data and clock interface or a four-pin data, clock, and opto-coupling interface.

4. The network device **300** according to Claim 1 further comprising:

the Power-over-Ethernet (PoE) circuit **312** comprising:

a magnetic transformer **316** coupled to communication signal pins **304S** of the network interface **304**;

an Ethernet physical layer (PHY) **318** coupled between the magnetic transformer **316** and the application interface **306**, the Ethernet PHY **308** coupled to the application interface by a SMII interface **314**;

a Powered Ethernet Device (PD) controller **320** coupled to power pins **310** of the network interface **304**; and a Direct Current-Direct Current (DC-DC) power converter **322** coupled between the PD controller **320** and power pins **310** of the application interface **306**.

5. The network device **300** according to Claim 4 further comprising: the Power-over-Ethernet (PoE) circuit **312** further comprising:

a diode bridge **324** coupled between power pins **310** of the network interface **304** and the PD controller **320**.

6. The network device **300** according to Claim 4 further comprising: the Ethernet PHY **318** coupled to the application interface **306** by a SMII interface **308** and a Management Data Input/Output (MDIO) interface **314**.

7. The network device **300** according to Claim 4 further comprising: the Powered Ethernet Device (PD) controller **320** comprising a power switch circuit **326** and a signature and classification circuit **328**.

8. The network device **400** according to Claim 1 further comprising: the Power-over-Ethernet (PoE) circuit **412** comprising:

an integrated Powered Ethernet Device (iPED) **430** comprising:

a non-magnetic transformer and choke circuit **416** integrated into the iPED **430** and coupled to communication signal pins of the network interface;

an Ethernet physical layer (PHY) **418** integrated into the iPED **430** and coupled between the non-magnetic transformer and choke circuit **416** and the application interface, the Ethernet PHY **418** coupled to the application interface by a SMII interface **408** and a Management Data Input/Output (MDIO) interface **414**;

a Powered Ethernet Device (PD) controller **420** integrated into the iPED **430** and coupled to power pins of the network interface; and

a Direct Current-Direct Current (DC-DC) power converter **422** integrated into the iPED **430** and coupled between the PD controller **420** and power pins of the application interface.

9. The network device **400** according to Claim 8 further comprising:
the Powered Ethernet Device (PD) controller **420** comprising:
a diode bridge **424** coupled to power pins of the network interface;
a power switch circuit **426** coupled to the diode bridge **424**; and
a signature and classification circuit **428** coupled to the diode bridge **424** and the power switch circuit **428**.

10. The network device **400** according to Claim 8 further comprising:
the integrated Powered Ethernet Device (iPED) **430** further comprises a T-Less Connect™ solid-state transformer **432** that separates Ethernet signals from power signals.

11. The network device **400** according to Claim 8 further comprising:
the integrated Powered Ethernet Device (iPED) **430** further comprises a T-Less Connect™ solid-state transformer **432** that floats ground potential of the Ethernet PHY relative to earth ground.

12. The network device **500** according to Claim 1 further comprising:
the Power-over-Ethernet (PoE) circuit **512** comprising:
a magnetic transformer **516** coupled to communication signal pins of the network interface;
an Ethernet physical layer (PHY) **518** coupled between the magnetic transformer **516** and the application interface, the Ethernet PHY coupled to the application interface by a SMII interface **508** and a Management Data Input/Output (MDIO) interface **514**;
a Power Sourcing Equipment (PSE) controller **520** coupled between power pins of the network interface and power feed pins of the application interface.

13. The network device **500** according to Claim 12 further comprising:
a multi-port switch **536** coupled to the PoE circuit **512** via the application interface.

14. The network device **600** according to Claim 1 further comprising:
the Power-over-Ethernet (PoE) circuit **612** comprising:
an integrated Powered Ethernet Source (iPES) **630** comprising:

a non-magnetic power supply circuit **616** integrated into the iPES **630** and coupled to communication signal pins and power pins of the network interface;

an Ethernet physical layer (PHY) **618** integrated into the iPES **630** and coupled between the non-magnetic power supply circuit **616** and the application interface, the Ethernet PHY **618** coupled to the application interface by a SMII interface **608** and a Management Data Input/Output (MDIO) interface **614**; and

a Power Sourcing Equipment (PSE) controller **620** coupled between the non-magnetic power supply circuit **616** and power feed pins of the application interface.

15. The network device **600** according to Claim 14 further comprising:

isolation capacitors **638** coupled between the Ethernet PHY **618** and the application interface; and

at least one optical coupler **640** coupled between the PSE controller **620** and the application interface.

16. The network device **600** according to Claim 14 further comprising:

a multi-port switch **636** coupled to the PoE circuit **612** via the application interface.

17. The network device **700** according to Claim 1 further comprising:

a midspan Power Sourcing Equipment (PSE) module **702** comprising:

the Power-over-Ethernet (PoE) circuit **712** comprising:

a non-magnetic power supply circuit **716** integrated into the midspan PSE module **702** and coupled between the network connector and the application connector; and

a Power Sourcing Equipment (PSE) controller **720** coupled between the non-magnetic power supply circuit **716** and power feed pins of the application interface.

18. The network device **700** according to Claim 17 further comprising:

a multi-port switch **736** coupled to the PoE circuit **712** via the application interface.

19. A network device **800A** comprising:

a network attached appliance **850** comprising:

a housing **852**;

an application processor **854** contained within the housing **852**; and

a connector module **802** contained within the housing **852** and configured to couple the application processor **854** to a network **856**, the connector module **802** comprising:

a network connector **804** coupled to the connector module **802** in a configuration that transfers power and communication signals;

an application connector **806** coupled to the connector module **802** and comprising serial media independent interface (SMII) pins **808** and power pins **810**; and

a Power-over-Ethernet (PoE) circuit **812** coupled between the network connector **804** and the application connector **806**.

20. The network device **800A** according to Claim 19 further comprising:

the Power-over-Ethernet (PoE) circuit **812** comprising:

an integrated Powered Ethernet Device (iPED) comprising:

a non-magnetic transformer and choke circuit **816** integrated into the iPED and coupled to communication signal pins of the network interface;

an Ethernet physical layer (PHY) **818** integrated into the iPED and coupled between the non-magnetic transformer and choke circuit **816** and the application interface, the Ethernet PHY **818** coupled to the application interface by a SMII interface **808** and a Management Data Input/Output (MDIO) interface **814**;

a Powered Ethernet Device (PD) controller **820** integrated into the iPED and coupled to power pins of the network interface; and

a Direct Current-Direct Current (DC-DC) power converter **822** integrated into the iPED and coupled between the PD controller **820** and power pins **810** of the application interface.

21. A network device **900A** comprising:
a power sourcing equipment appliance **950** comprising:
a housing **952**;
an Ethernet switch **958** contained within the housing **952**;
an isolated power supply **960** contained within the housing **952**; and
a connector module **902** contained within the housing **952** and configured to couple the Ethernet switch **958** and the isolated power supply **960** to a network **956**, the connector module **902** comprising:
a network connector **904** coupled to the connector module **902** in a configuration that transfers power and communication signals;
an application connector **906** coupled to the connector module **902** and comprising serial media independent interface (SMII) pins **908** and power pins **910**; and
a Power-over-Ethernet (PoE) circuit **912** coupled between the network connector **904** and the application connector **906**.

22. The network device **900** according to Claim 21 further comprising:
the Power-over-Ethernet (PoE) circuit **912** comprising:
an integrated Powered Ethernet Source (iPES) comprising:
a non-magnetic transformer and choke circuit **916** integrated into the iPES and coupled to communication signal pins and power pins of the network interface;
an Ethernet physical layer (PHY) **918** integrated into the iPES and coupled between the non-magnetic transformer and choke circuit **916** and the application interface, the Ethernet PHY **918** coupled to the application interface by a SMII interface **908** and a Management Data Input/Output (MDIO) interface **914**; and
a Power Sourcing Equipment (PSE) controller **920** coupled between the non-magnetic transformer and choke circuit **916** and power feed pins of the application interface.

23. The network device **900** according to Claim 22 further comprising:
isolation capacitors **938** coupled between the Ethernet PHY **918** and the application interface; and

at least one optical coupler **940** coupled between the PSE controller **920** and the application interface.

24. The network device **900** according to Claim 21 further comprising:
the power sourcing equipment appliance **950** further comprising:
an Ethernet physical layer (PHY) **918** coupling the Ethernet switch **958** and the isolated power supply **960** to the application interface; and
the Power-over-Ethernet (PoE) circuit **912** comprising:
an integrated Powered Ethernet Source (iPES) comprising:
a non-magnetic transformer and choke circuit **916** integrated into the iPES and coupled to communication signal pins and power pins of the network interface; and
a Power Sourcing Equipment (PSE) controller **920** coupled between the non-magnetic transformer and choke circuit **916** and power feed pins of the application interface.

25. The network device **900** according to Claim 24 further comprising:
isolation capacitors **938** coupled between the non-magnetic transformer and choke circuit **916** and the application interface; and
at least one optical coupler **940** coupled between the PSE controller **920** and the application interface.

26. A network device **1000A** comprising:
a network interface module **1002** comprising:
a network connector **1004** coupled to the network interface module **1002** in a configuration that transfers power and communication signals;
an application connector **1006** coupled to the network interface module **1002**; and
a Power-over-Ethernet (PoE) circuit **1012** coupled between the network connector **1004** and the application connector **1006**, the PoE circuit **1012** comprising:
a transformer **1016** coupled to communication signal pins of the network interface; and
an Ethernet physical layer (PHY) **1018** coupled between the transformer **916** and the application interface.

27. The network device **1000A** according to Claim 26 further comprising: the Power-over-Ethernet (PoE) circuit **1012** further comprising:

a Powered Ethernet Device (PD) controller **1020** coupled to power pins **1010** of the network interface.

28. The network device **1000A** according to Claim 26 further comprising: the Power-over-Ethernet (PoE) circuit **1012** further comprising:

a Direct Current-Direct Current (DC-DC) power converter **1022** coupled between the PD controller **1020** and power pins of the application interface.

29. The network device according to Claim 26 further comprising: the Power-over-Ethernet (PoE) circuit further comprising:

a Power Sourcing Equipment (PSE) controller coupled between power pins of the network interface and power feed pins of the application interface.

30. A network device **800B** comprising:

a network attached appliance **850** comprising:

a housing **852**;

an application processor **854** contained within the housing **852**; and

a connector module **802** contained within the housing **852** and configured to couple the application processor **854** to a network **856**, the connector module **802** comprising:

a network connector **804** coupled to the connector module **802** in a configuration that transfers power and communication signals;

an application connector **806** coupled to the connector module **802** and configured for coupling to the application processor **854**; and

a Power-over-Ethernet (PoE) circuit **812** coupled between the network connector **804** and the application connector **806**.

31. The network device **800B** according to Claim 30 further comprising: the Power-over-Ethernet (PoE) circuit **812** comprising:

an integrated Powered Ethernet Device (iPED) comprising:

a non-magnetic transformer and choke circuit **816** integrated into the iPED and coupled between communication signal pins of the network interface and the application interface;

a Powered Ethernet Device (PD) controller **820** integrated into the iPED and coupled to power pins of the network interface; and

a Direct Current-Direct Current (DC-DC) power converter **822** integrated into the iPED and coupled between the PD controller **820** and power pins of the application interface.

32. The network device **800B** according to Claim 31 further comprising: the integrated Powered Ethernet Device (iPED) further comprising:

isolation capacitors **838** coupled between the non-magnetic transformer and choke circuit **816** and the application interface; and

at least one optical coupler **840** coupled between the Powered Ethernet Device (PD) controller **820** and the application interface.

33. The network device **800B** according to Claim 30 further comprising: the network attached appliance **850** further comprising:

an Ethernet physical layer (PHY) **818** coupled between the application interface and the application processor **854**, the Ethernet PHY **818** coupled to the application processor **854** by a SMII interface and a Management Data Input/Output (MDIO) interface.

34. The network device **800B** according to Claim 30 further comprising: the Power-over-Ethernet (PoE) circuit **812** comprising:

an integrated Powered Ethernet Device (iPED) comprising:

a non-magnetic transformer and choke circuit **816** integrated into the iPED and coupled between communication signal pins of the network interface and the application interface;

an Ethernet physical layer (PHY) **818** integrated into the iPED and coupled between the non-magnetic transformer and choke circuit **816** and the application interface, the Ethernet PHY **818** coupled to the application interface by a SMII interface and a Management Data Input/Output (MDIO) interface;

a Powered Ethernet Device (PD) controller **820** integrated into the iPED and coupled to power pins of the network interface; and

a Direct Current-Direct Current (DC-DC) power converter **822** integrated into the iPED and coupled between the PD controller **820** and power pins of the application interface.

35. The network device **800C** according to Claim 30 further comprising: the Power-over-Ethernet (PoE) circuit **812** comprising:

an integrated Powered Ethernet Device (iPED) comprising:

an isolated Ethernet physical layer (PHY) **818** integrated into the iPED and coupled to the application interface by a SMII interface and a Management Data Input/Output (MDIO) interface;

a Powered Ethernet Device (PD) controller **820** integrated into the iPED and coupled to power pins of the network interface; and

an isolated Direct Current-Direct Current (DC-DC) power converter **822** integrated into the iPED and coupled between the PD controller **820** and power pins of the application interface.

36. The network device **800C** according to Claim 35 further comprising: the Power-over-Ethernet (PoE) circuit comprising:

an integrated Powered Ethernet Device (iPED) further comprising:

an autotransformer **816C** integrated into the iPED and coupled between communication signal pins of the network interface and the application interface.

37. The network device **800C** according to Claim 36 further comprising: the Power-over-Ethernet (PoE) circuit **812** comprising:

an integrated Powered Ethernet Device (iPED) further comprising:

isolation capacitors **838** coupled to the autotransformer **816C** and integrated into the iPED coupled between communication signal pins of the network interface and the application interface.

38. The network device **800C** according to Claim 35 further comprising: the isolated Ethernet physical layer (PHY) **818** further comprising:
isolation capacitors **838** coupled to the SMII interface and the MDIO interface.

39. The network device **800C** according to Claim 35 further comprising: an isolation barrier formed by the isolated Ethernet physical layer (PHY) **818** and the isolated Direct Current-Direct Current (DC-DC) power converter **822** isolating the network interface and the application interface.

40. A network device **1000B** comprising:
a network interface module **1002** comprising:
a network connector **1004** coupled to the network interface module **1002** in a configuration that transfers power and communication signals;
an application connector **1006** coupled to the network interface module **1002**; and
a Power-over-Ethernet (PoE) circuit **1012** coupled between the network connector **1004** and the application connector **1006**, the PoE circuit **1012** comprising:
a transformer **1016** coupled to communication signal pins of the network interface module **1002**.

41. The network device **1000B** according to Claim 40 further comprising: an Ethernet physical layer (PHY) **1018** external to the network interface module **1002** coupled to the transformer **1016** through the application connector **1004**.

42. The network device **1000B** according to Claim 40 further comprising: the Power-over-Ethernet (PoE) circuit **1012** further comprising:
a Powered Ethernet Device (PD) controller **1020** coupled to power pins of the network interface module **1002**.

43. The network device **1000B** according to Claim 40 further comprising: the Power-over-Ethernet (PoE) circuit **1012** further comprising:
a Direct Current-Direct Current (DC-DC) power converter **1022** coupled between the PD controller **1020** and power pins of the application connector **1004**.

44. A network device **900C** comprising:

a power sourcing equipment appliance **950** comprising:

a housing **952**;

an Ethernet switch **958** contained within the housing **952**;

an isolated power supply **960** contained within the housing **952**; and

a connector module **902** contained within the housing **952** and configured to couple the Ethernet switch **958** and the isolated power supply **960** to a network **956**, the connector module **902** comprising:

a network connector **904** coupled to the connector module **902** in a configuration that transfers power and communication signals;

an application connector **906** coupled to the connector module **902** and comprising serial media independent interface (SMII) pins **908** and power pins **910**; and

a Power-over-Ethernet (PoE) circuit **912** coupled between the network connector **904** and the application connector **906** comprising:

an integrated Powered Ethernet Source (iPES) comprising:

an isolated Ethernet physical layer (PHY) **918** integrated into the iPES coupled to the application interface by a SMII interface **908** and a Management Data Input/Output (MDIO) interface **914**; and

a Power Sourcing Equipment (PSE) controller **920** coupled to power feed pins of the application connector **906**.

45. The network device **900C** according to Claim 44 further comprising:

the Power-over-Ethernet (PoE) circuit **912** comprising:

an integrated Powered Ethernet Source (iPES) further comprising:

an autotransformer **916C** integrated into the iPED and coupled between communication signal pins of the network connector **904** and the application connector **906**.

46. The network device **900C** according to Claim 45 further comprising:

the Power-over-Ethernet (PoE) circuit **912** comprising:

an integrated Powered Ethernet Source (iPES) further comprising:

isolation capacitors **938** coupled to the autotransformer **916C** and integrated into the iPES coupled between communication signal pins of the network connector **904** and the application connector **906**.

47. The network device **900C** according to Claim 44 further comprising:
the isolated Ethernet physical layer (PHY) **918** further comprising:
isolation capacitors **938** coupled to the SMII interface **908** and the MDIO interface **914**.

48. The network device **900C** according to Claim 44 further comprising:
a Buck converter **962** integrated into the integrated Powered Ethernet Source (iPES) and coupled to a power line supplying the isolated Ethernet physical layer (PHY) **918** from the isolated power supply **960**.

49. The network device **900C** according to Claim 44 further comprising:
an isolation barrier formed by the isolated Ethernet physical layer (PHY) **918** and the isolated Direct Current-Direct Current (DC-DC) power converter **922** isolating the network connector **904** and the application connector **906**.

50. A network device configured to receive a plurality of power signals and data signals through a coupled network **1122** comprising:
a network connector **1132** configured to physically couple the network device to the network **1122** and receive four twisted pairs that carry the plurality of power signals, wherein the plurality of power signals comprise a first power signal and a second power signal; and
an integrated circuit (IC) coupled to the network connector **1132** and comprising:
an Ethernet physical layer (PHY) module **1136**;
a power management module **1138**;
isolation capacitors coupled between the Ethernet PHY module **1136** and an application device;
an optical coupler coupled between the power management module and the application device; and
a direct connection module coupled to the network connector **1132** and operative to:
pass the received data signal(s) to the Ethernet PHY **1136**;
sense a current associated with the twisted pairs;

actively balance current associated with the twisted pairs; and

pass the received plurality of power signals to the power management module **1138** wherein the power management module is operative to at least partially power the network device from the received plurality of power signals.

51. A power source equipment (PSE) network device **1293** operative to distribute a network power signal and a network data signal through a coupled network comprising:

a network connector **1232** configured to physically couple the PSE network device **1293** to the network; and

an integrated circuit (IC) coupled to the network connector **1232** that further comprises a power feed circuit operative to:

exchange data signals with a network physical layer (PHY) module **1216**, Ethernet switch **1282**, and the network connector **1232**;

isolate the network PHY module **1216** from the Ethernet switch **1282**; and

pass the power signal to the network connector **1232** as directed by a power source equipment (PSE) controller, wherein the power signal is received from an isolated power supply.

52. A method for supplying power from a power source equipment (PSE) network device **1293** with an Ethernet power signal fed through an Ethernet network connection comprising:

producing the Ethernet power signal from power supplied by an isolated power supply **1297** in an integrated circuit (IC) within the PSE network device **1293**;

physically coupling the PSE network device **1293** to the isolated power supply **1297**;

physically coupling the PSE network device **1293** to an Ethernet network;

combining within the IC an Ethernet data signal and the Ethernet power signal to produce an Ethernet signal;

providing ground isolation for the Ethernet data signal and the Ethernet power signal;

exchanging the Ethernet signal with at least one Ethernet network power device (PD) physically coupled to the Ethernet network within the PSE network device **1293**; and isolating the IC from the at least one Ethernet network power device.

53. A power source equipment (PSE) network device **1293** operative to distribute an Ethernet power signal and an Ethernet data signal through a coupled Ethernet network comprising:

an Ethernet network connector **1232** configured to physically couple the PSE network device **1293** to the Ethernet network;

a PSE controller;

an Ethernet physical layer (PHY) module **1216** configured to couple the PSE network device **1293** to a multiport switch **1282** at an isolated interface; and

an integrated circuit (IC) coupled to the Ethernet network connector **1232** that further comprises a power feed circuit configured to:

exchange Ethernet data signals with the Ethernet PHY module **1216** and the Ethernet connector **1232**;

supply a power signal from a power supply to the PSE network device **1293**; and

produce and pass the Ethernet power signal to the Ethernet connector **1232** as directed by the PSE controller.

54. A network device **1300** comprising:

an Ethernet bridge module **1302** integrated onto a single-chip integrated circuit comprising:

a network connector **1304** coupled to an integrated Ethernet bridge module **1302** in a configuration that transfers power and communication signals;

at least one driver **1306** and/or transceiver **1308** integrated onto the Ethernet bridge module **1302** and configured to interface to at least one device **1310** external to the Ethernet bridge module **1302**; and

a Power-over-Ethernet (PoE) circuit **1312** integrated onto the Ethernet bridge module **1302** and coupled between the network connector **1304** and the at least one driver **1306** and/or transceiver **1308**.

55. The network device **1300** according to Claim 54 further comprising:

the network connector **1304** comprising a Registered Jack (RJ) 45 physical interface; and the at least one driver **1306** and/or transceiver **1308** comprising:

a digital driver **1306** comprising at least one digital interface; and

an analog transceiver **1308** comprising at least one analog interface.

56. The network device **1300** according to Claim 55 wherein the at least one digital interface is selected from a group of digital interfaces consisting of:

a digital driver for Universal Serial Bus (USB);

a FireWire Institute of Electrical and Electronics Engineers (IEEE) 1394 serial bus interface standard driver;

a Recommended Standard (RS)-232 serial binary data interface driver;

a RS-485 high-speed serial interface driver;

a Peripheral Component Interconnect (PCI) standard interface driver;

a PCI variant interface driver.

57. The network device **1300** according to Claim 55 wherein the at least one analog interface is selected from a group of analog interfaces consisting of:

a Home Phoneline Networking Alliance (HPNA) interface driver;

an Institute of Electrical and Electronics Engineers (IEEE) 802.11 wireless standard interface driver;

a Wi-Fi standard interface driver;

a Radio Frequency Identification (RFID) reader interface driver; and

a scanner interface driver.

58. The network device **1300** according to Claim 54 further comprising:

a processor **1314** integrated onto the Ethernet bridge module **1302** and comprising functional programming configured for interfacing to memory and for interfacing to the at least one driver **1306** and/or transceiver **1308**; and

a Media Access Control (MAC) layer **1316** communicatively coupled to the processor **1314** and comprising a controller to determine access to physical media.

59. The network device **1300** according to Claim 57 further comprising:

the processor functional programming comprising at least one functional module selected from a group consisting of a Transmission Control Protocol / Internet Protocol (TCP/IP) stack processing module, a packet processing module adapted for packet forwarding and scheduling, a rule based processing module, a monitoring and event scheduling module, and a drivers module; and

the MAC layer **1316** comprising at least one functional module selected from a group consisting of an Institute of Electrical and Electronics Engineers (IEEE) 802.3 physical layer and data link layer module, an IEEE 802.11 wireless module, a Home Phoneline Networking Alliance (HPNA) module, a Residential Internet (RI) module.

60. The network device **1300** according to Claim 58 further comprising:

a Management Data Input/Output (MDIO) and/or an Inter-Integrated Circuit (I^2C) interface integrated onto the Ethernet bridge module **1302**.

61. The network device **1400** according to Claim 54 further comprising:

the Power-over-Ethernet (PoE) circuit **1412** comprising:

a magnetic transformer **1420** coupled to communication signal pins of the network interface **1404**;

an Ethernet physical layer (PHY) **1422** coupled between the magnetic transformer **1420** and the processor **1414**;

a Powered Ethernet Device (PD) controller **1424** coupled to power pins of the network interface **1404**; and

a Direct Current-Direct Current (DC-DC) power converter **1426** coupled between the PD controller **1424** and the processor **1414**.

62. The network device **1400** according to Claim 61 further comprising:

the Power-over-Ethernet (PoE) circuit **1412** further comprising:

a diode bridge **1428** coupled between power pins of the network interface and the PD controller **1424**.

63. The network device **1400** according to Claim 61 further comprising:

the Powered Ethernet Device (PD) controller **1424** comprising a power switch circuit **1430** and a signature and classification circuit **1432**.

64. The network device **1300** according to Claim 54 further comprising:

the Power-over-Ethernet (PoE) circuit **1312** comprising:

an integrated Powered Ethernet Device (iPED) **1334** comprising:

a non-magnetic transformer and choke circuit **1320** integrated into the iPED **1334** and coupled to communication signal pins of the network interface;

an Ethernet physical layer (PHY) **1322** integrated into the iPED **1334** and coupled between the non-magnetic transformer and choke circuit **1320** and the processor **1314**;

a Powered Ethernet Device (PD) controller **1324** integrated into the iPED **1334** and coupled to power pins of the network interface; and

a Direct Current-Direct Current (DC-DC) power converter **1326** integrated into the iPED and coupled between the PD controller **1324** and power pins of the processor **1314**.

65. The network device **1300** according to Claim 64 further comprising:

the Powered Ethernet Device (PD) controller **1324** comprising:

a diode bridge **1328** coupled to power pins of the network interface;

a power switch circuit **1330** coupled to the diode bridge **1328**; and

a signature and classification circuit **1332** coupled to the diode bridge **1328** and the power switch circuit **1330**.

66. The network device **1300** according to Claim 64 further comprising:

the integrated Powered Ethernet Device (iPED) **1334** further comprises a T-Less Connect™ solid-state transformer **1320** that separates Ethernet signals from power signals.

67. The network device **1300** according to Claim 64 further comprising:

the integrated Powered Ethernet Device (iPED) **1334** further comprises a T-Less Connect™ solid-state transformer **1320** that floats ground potential of the Ethernet PHY **1322** relative to earth ground.

68. A network device **1400** comprising:

an Ethernet bridge module **1402** comprising:

a network connector **1404** in a configuration that transfers power and communication signals;

at least one driver **1406** and/or transceiver **1408** configured to interface to at least one device **1410** external to the Ethernet bridge module **1402**; and a Power-over-Ethernet (PoE) circuit **1412** coupled between the network connector **1404** and the at least one driver **1406** and/or transceiver **1408**, the POE circuit **1412** comprising:

a magnetic transformer **1420** coupled to communication signal pins of the network connector **1404**;

an Ethernet physical layer (PHY) **1422** coupled to the magnetic transformer **1420**;

a Powered Ethernet Device (PD) controller **1424** coupled to power pins of the network connector **1404**; and

a Direct Current-Direct Current (DC-DC) power converter **1426** coupled to the PD controller **1424**.

69. The network device **1400** according to Claim 68 further comprising:
the Power-over-Ethernet (PoE) circuit **1412** further comprising:

a diode bridge **1428** coupled between power pins of the network connector **1404** and the PD controller **1424**.

70. The network device **1400** according to Claim 68 further comprising:
the Powered Ethernet Device (PD) controller **1424** comprising a power switch circuit **1430** and a signature and classification circuit **1432**.

71. The network device **1400** according to Claim 68 further comprising:
the Ethernet bridge module **1402** integrated onto a single-chip integrated circuit.

72. A network device **1300** comprising:
an Ethernet bridge module **1302** comprising:

a network connector **1304** in a configuration that transfers power and communication signals;

at least one driver **1306** and/or transceiver **1308** configured to interface to at least one device external to the Ethernet bridge module **1302**; and

a Power-over-Ethernet (PoE) circuit **1312** coupled between the network connector **1304** and the at least one driver **1306** and/or transceiver **1308**, the POE circuit **1312** comprising:

an integrated Powered Ethernet Device (iPED) **1334** comprising:

a non-magnetic transformer and choke circuit **1320** integrated into the iPED **1334** and coupled to communication signal pins of the network connector **1304**;

an Ethernet physical layer (PHY) **1322** integrated into the iPED **1334** and coupled to the non-magnetic transformer and choke circuit **1320**;

a Powered Ethernet Device (PD) controller **1324** integrated into the iPED **1334** and coupled to power pins of the network connector **1304**; and

a Direct Current-Direct Current (DC-DC) power converter **1326** integrated into the iPED **1334** and coupled to the PD controller **1324**.

73. The network device **1300** according to Claim 72 further comprising:

the Powered Ethernet Device (PD) controller **1324** comprising:

a diode bridge **1328** coupled to power pins of the network connector **1304**;

a power switch circuit **1330** coupled to the diode bridge **1328**; and

a signature and classification circuit **1332** coupled to the diode bridge **1328** and the power switch circuit **1330**.

74. The network device **1300** according to Claim 72 further comprising:

the integrated Powered Ethernet Device (iPED) **1334** further comprises a T-Less Connect™ solid-state transformer that separates Ethernet signals from power signals.

75. The network device **1300** according to Claim 72 further comprising:

the integrated Powered Ethernet Device (iPED) **1334** further comprises a T-Less Connect™ solid-state transformer that floats ground potential of the Ethernet PHY relative to earth ground.

76. The network device **1300** according to Claim 72 further comprising:

the Ethernet bridge module **1302** integrated onto a single-chip integrated circuit.

77. A network device **1500** comprising:

an Ethernet bridge module **1302** comprising:

a housing **1540**;

a network connector **1304** coupled to the housing **1540** and configured to transfers power and communication signals;

at least one driver **1306** and/or transceiver **1308** contained in the housing **1540** and configured to interface to at least one device **1310** external to the Ethernet bridge module **1302**, the at least one device **1310** selectable from among Ethernet-enabled devices and Ethernet non-enabled devices; and

a Power-over-Ethernet (PoE) circuit **1312** contained in the housing **1540** and coupled between the network connector **1304** and the at least one driver **1306** and/or transceiver **1308**.

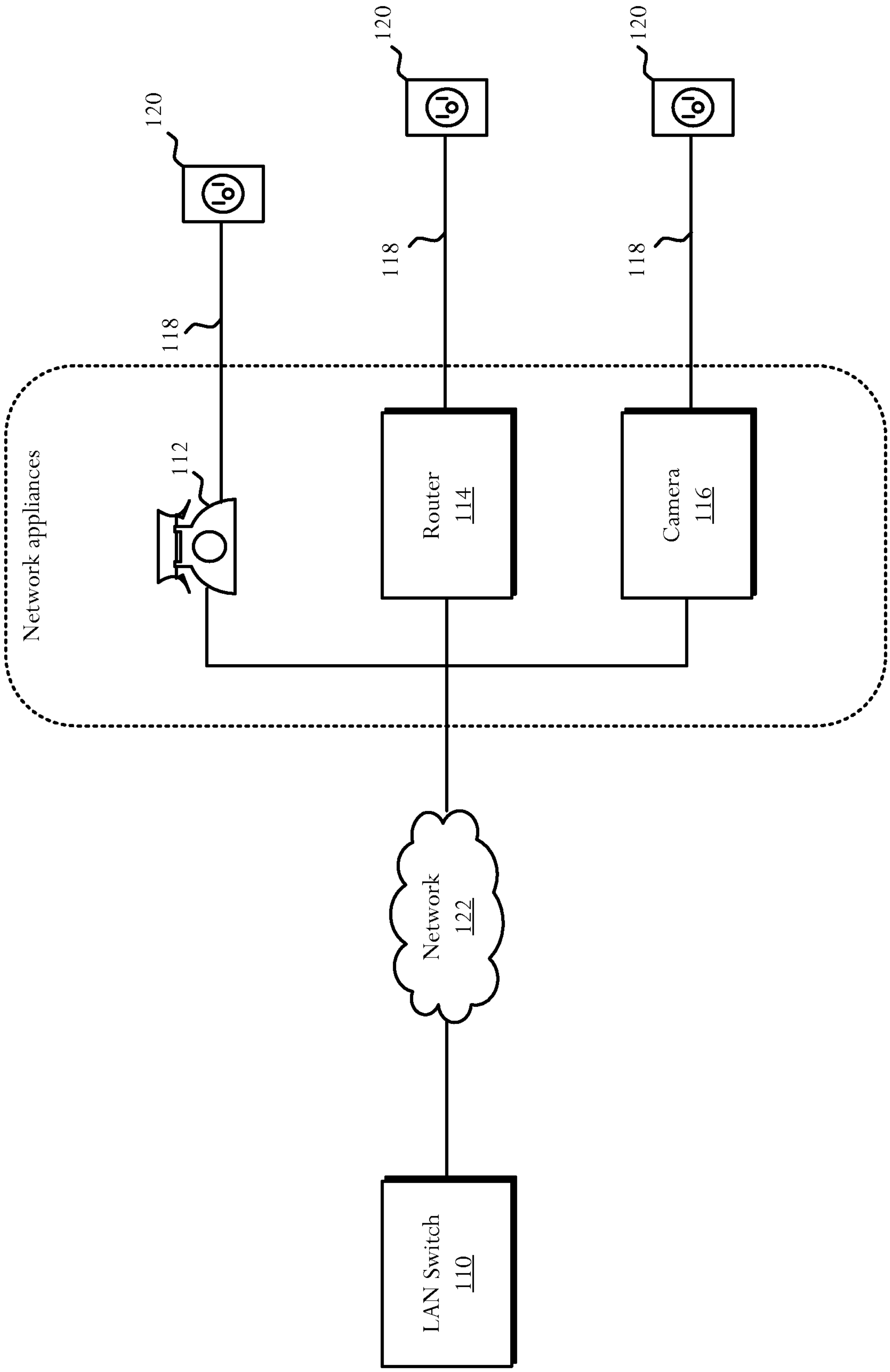

120
120
120
120
118
118
118
Network appliances
112
Router
114
Camera
116
Network
122
LAN Switch
110

FIG. 1A

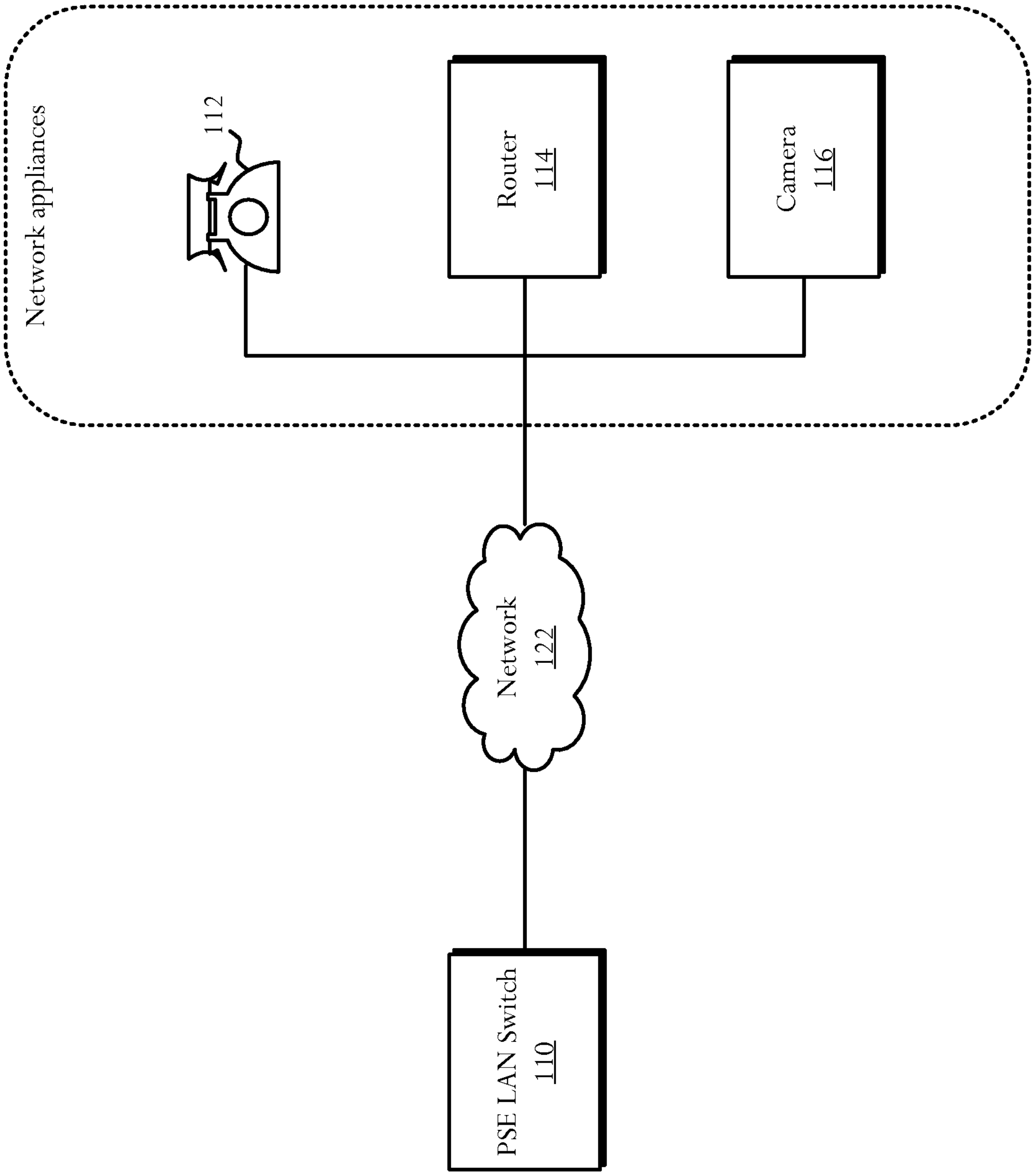

Network appliances
112
Router
114
Camera
116
Network
122
PSE LAN Switch
110

FIG. 1B

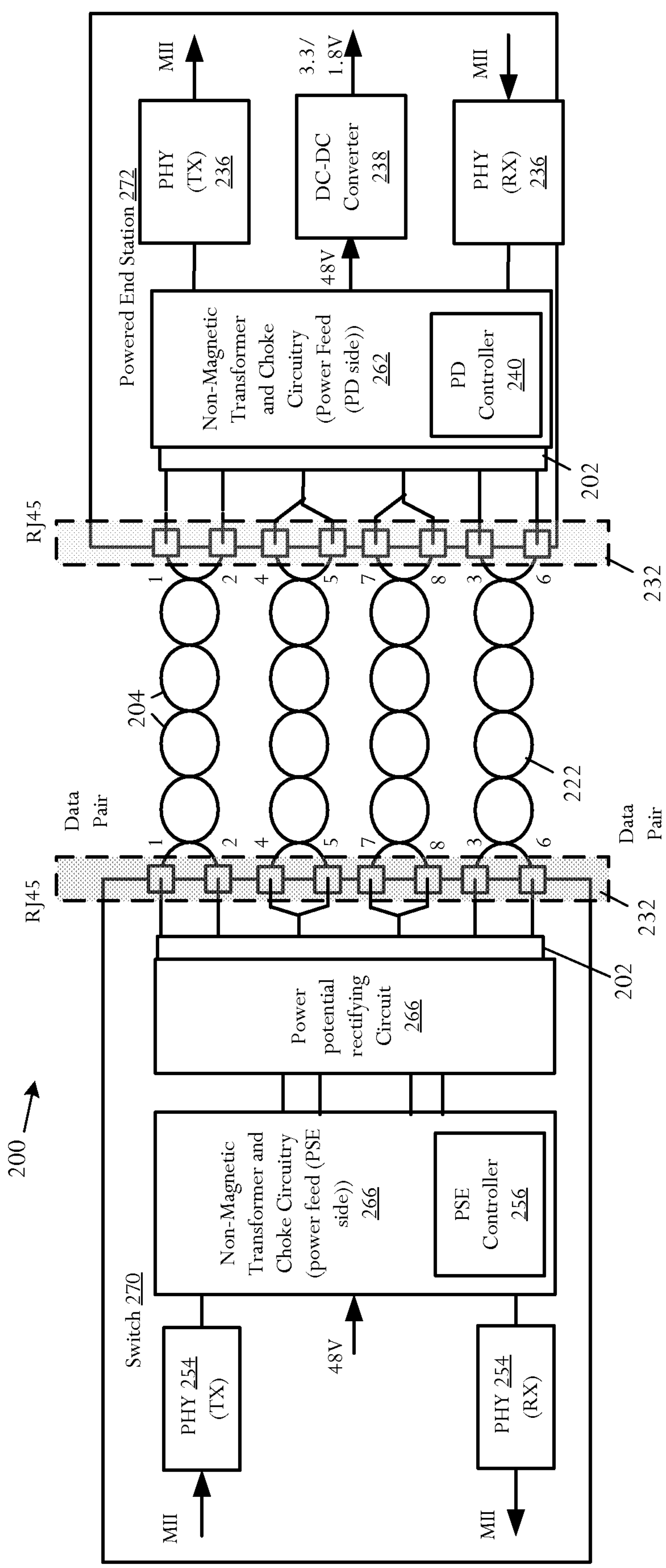

Powered End Station 272
MII
PHY (TX) 236
3.3/ 1.8V
DC-DC Converter 238
48V
MII
PHY (RX) 236
Non-Magnetic Transformer and Choke Circuitry (Power Feed (PD side)) 262
PD Controller 240
202
RJ45
232
1 2 4 5 7 8 3 6
204
222
Data Pair
Data Pair
RJ45
232
1 2 4 5 7 8 3 6
202
Power potential rectifying Circuit 266
200
Non-Magnetic Transformer and Choke Circuitry (power feed (PSE side)) 266
PSE Controller 256
Switch 270
48V
PHY 254 (TX)
PHY 254 (RX)
MII
MII

FIG. 2

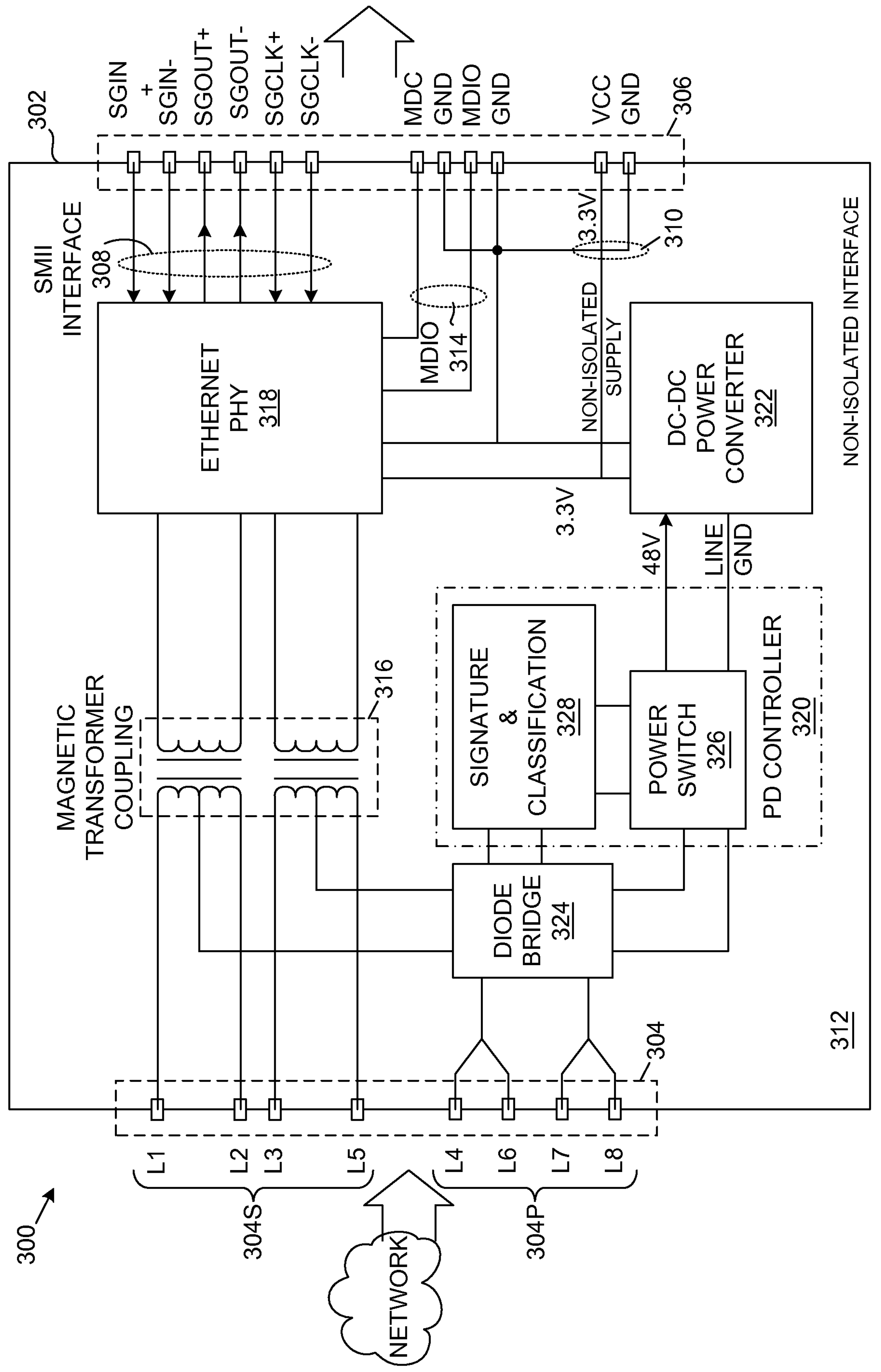
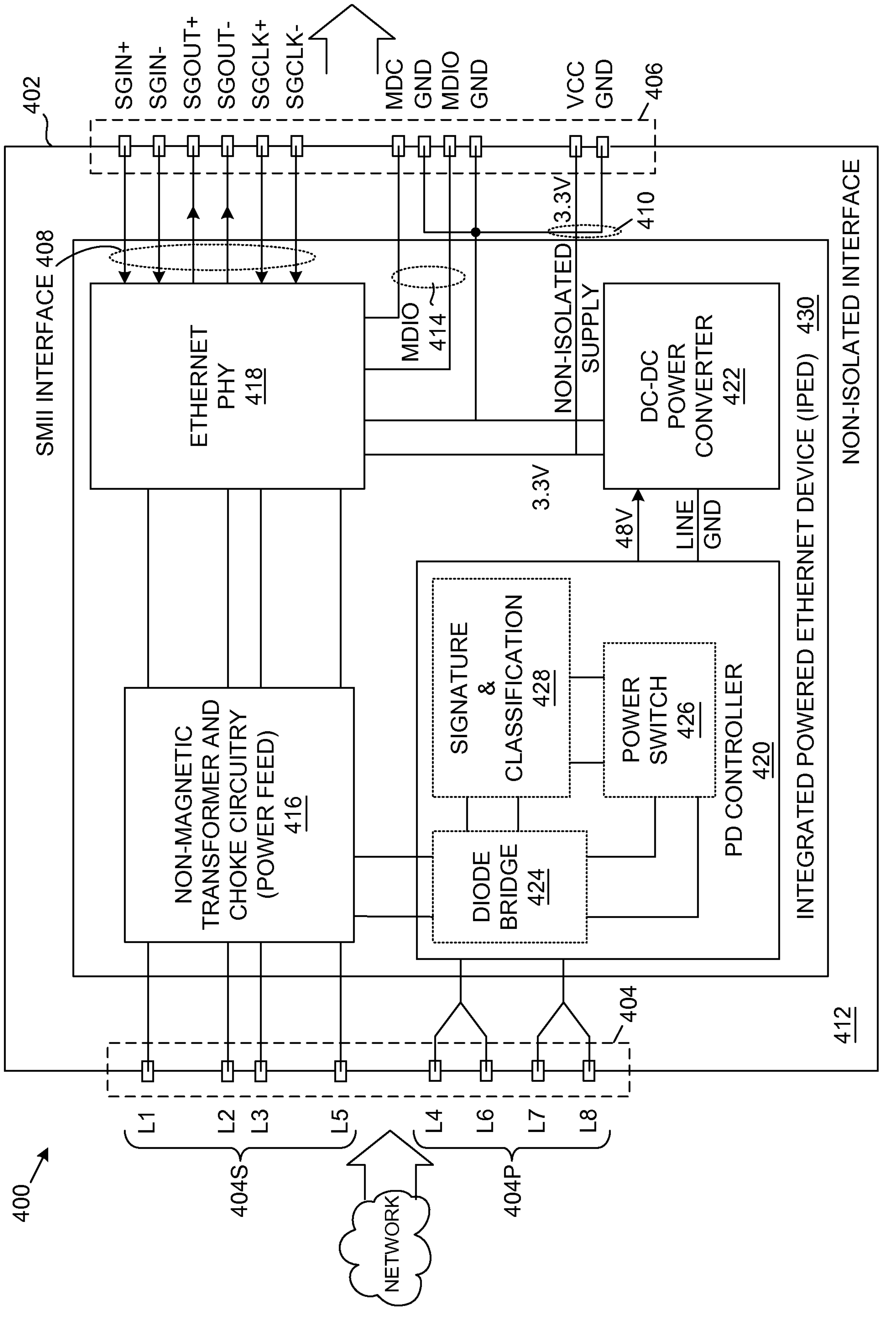

SGIN+
SGIN-
SGOUT+
SGOUT-
SGCLK+
SGCLK-
MDC
GND
MDIO
GND
VCC
GND
302
306
SMII INTERFACE
308
3.3V
310
MDIO
314
NON-ISOLATED SUPPLY
NON-ISOLATED INTERFACE
ETHERNET PHY 318
DC-DC POWER CONVERTER 322
3.3V
48V
LINE GND
MAGNETIC TRANSFORMER COUPLING
316
SIGNATURE & CLASSIFICATION 328
POWER SWITCH 326
PD CONTROLLER 320
DIODE BRIDGE 324
312
304
L1
L2
L3
L5
L4
L6
L7
L8
304S
304P
NETWORK
300

FIG. 3



SGIN+
SGIN-
SGOUT+
SGOUT-
SGCLK+
SGCLK-
MDC
GND
MDIO
GND
VCC
GND
402
406
410
3.3V
SMII INTERFACE 408
MDIO
414
NON-ISOLATED SUPPLY
ETHERNET PHY 418
DC-DC POWER CONVERTER 422
3.3V
48V
LINE GND
NON-MAGNETIC TRANSFORMER AND CHOKE CIRCUITRY (POWER FEED) 416
SIGNATURE & CLASSIFICATION 428
POWER SWITCH 426
DIODE BRIDGE 424
PD CONTROLLER 420
INTEGRATED POWERED ETHERNET DEVICE (IPED) 430
NON-ISOLATED INTERFACE
412
404
L1
L2
L3
L5
L4
L6
L7
L8
404S
404P
NETWORK
400

FIG. 4A

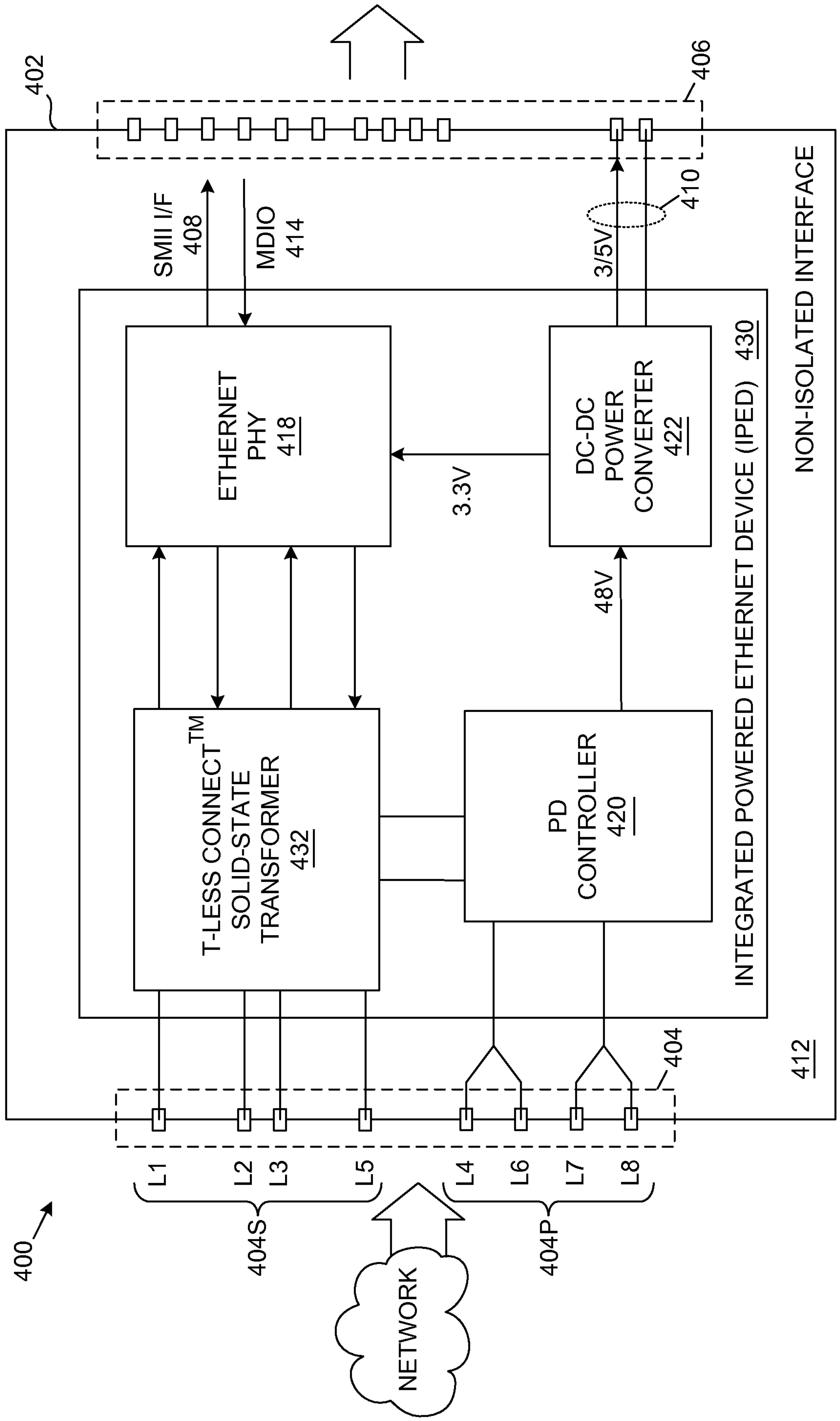

402
406
SMII I/F
408
MDIO
414
3/5V
410
ETHERNET
PHY
418
DC-DC
POWER
CONVERTER
422
3.3V
48V
T-LESS CONNECT™
SOLID-STATE
TRANSFORMER
432
PD
CONTROLLER
420
INTEGRATED POWERED ETHERNET DEVICE (IPED) 430
NON-ISOLATED INTERFACE
412
404
L1
L2
L3
L5
L4
L6
L7
L8
404S
404P
NETWORK
400

FIG. 4B

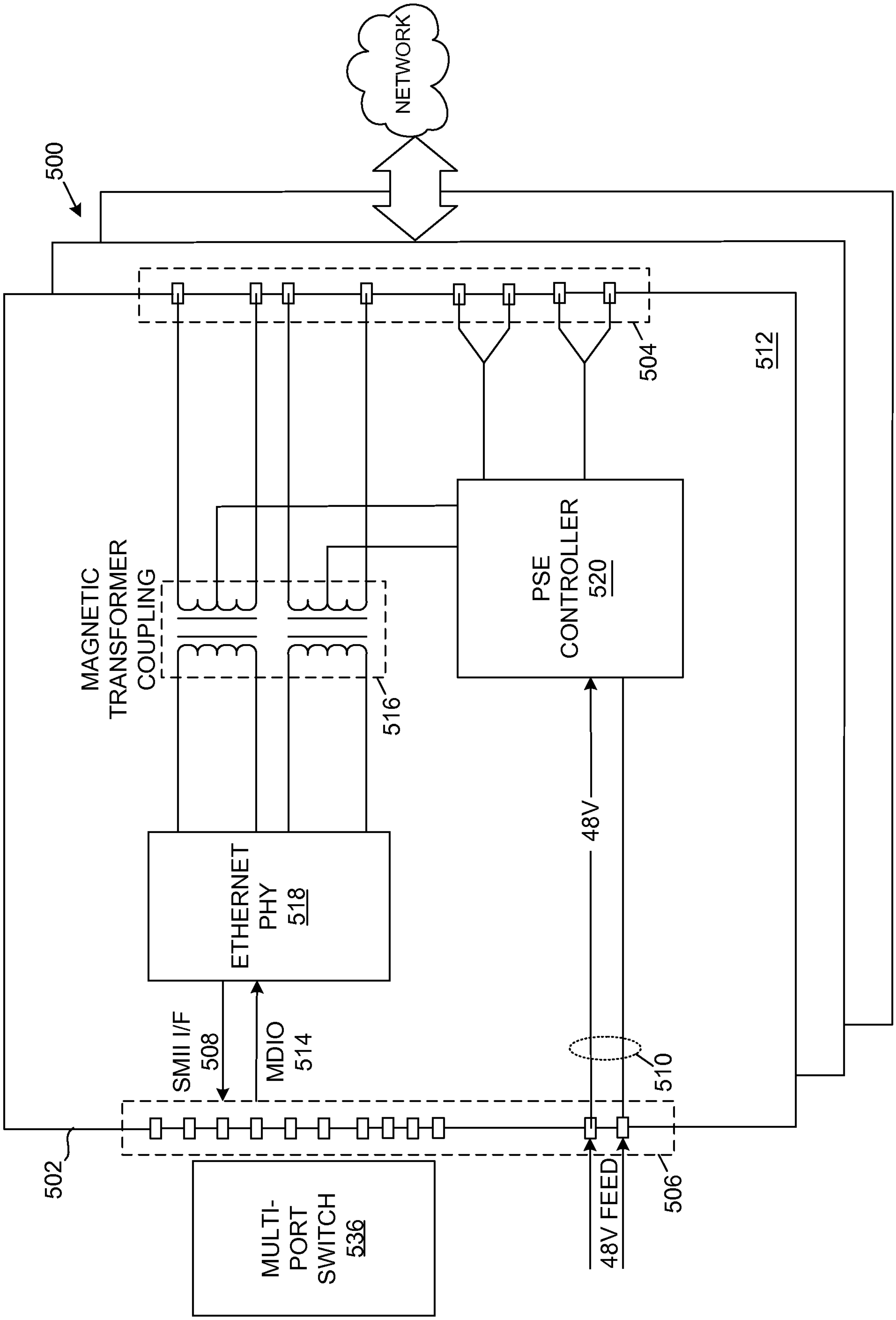
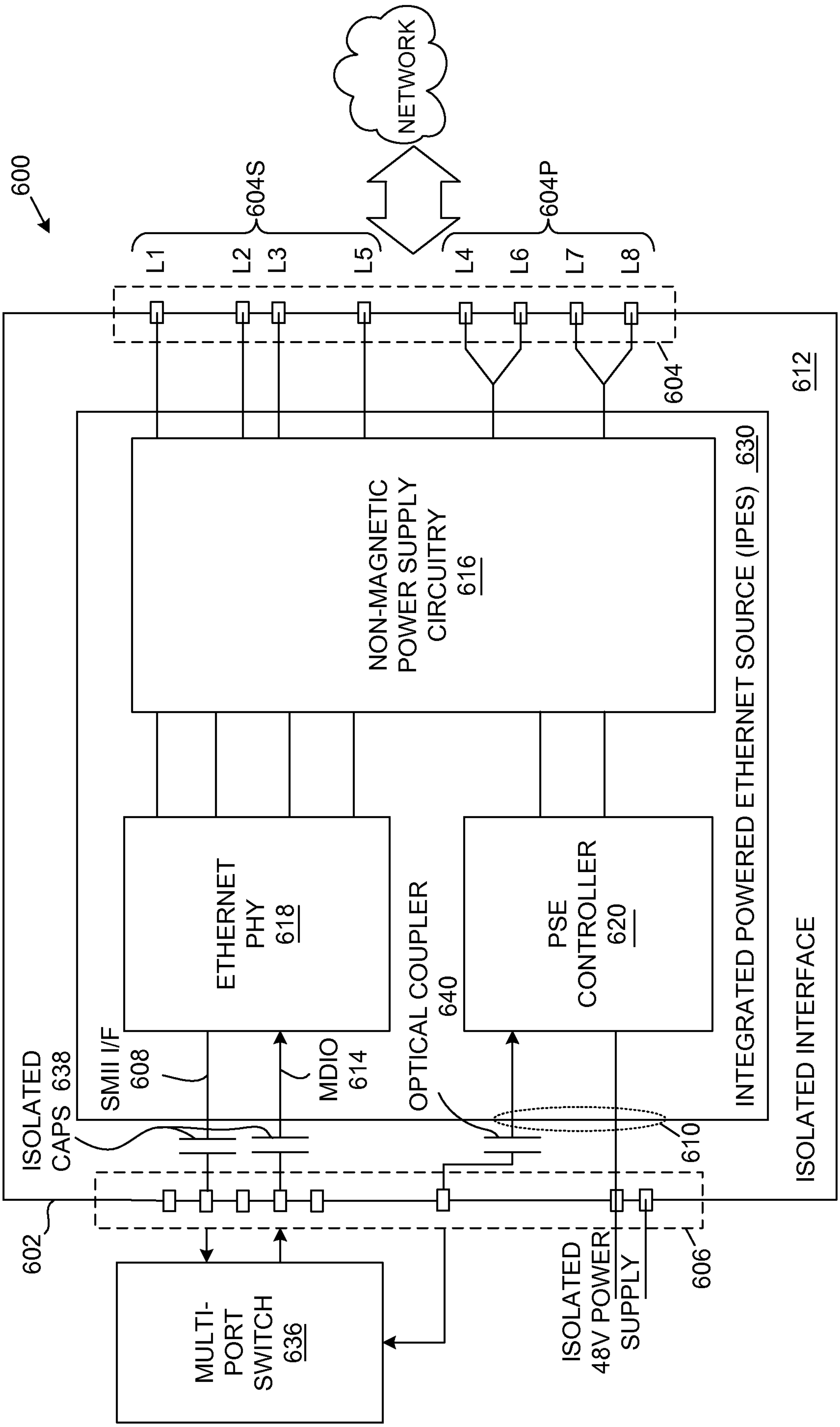

NETWORK
500
502
504
506
510
512
MAGNETIC
TRANSFORMER
COUPLING
516
PSE
CONTROLLER
520
ETHERNET
PHY
518
SMII I/F
508
MDIO
514
48V
48V FEED
MULTI-
PORT
SWITCH
536

FIG. 5



600
NETWORK
604S
604P
L1
L2
L3
L5
L4
L6
L7
L8
604
612
NON-MAGNETIC POWER SUPPLY CIRCUITRY 616
INTEGRATED POWERED ETHERNET SOURCE (IPES) 630
ETHERNET PHY 618
PSE CONTROLLER 620
OPTICAL COUPLER 640
SMII I/F 608
MDIO 614
ISOLATED CAPS 638
610
ISOLATED INTERFACE
602
606
MULTI-PORT SWITCH 636
ISOLATED 48V POWER SUPPLY

FIG. 6

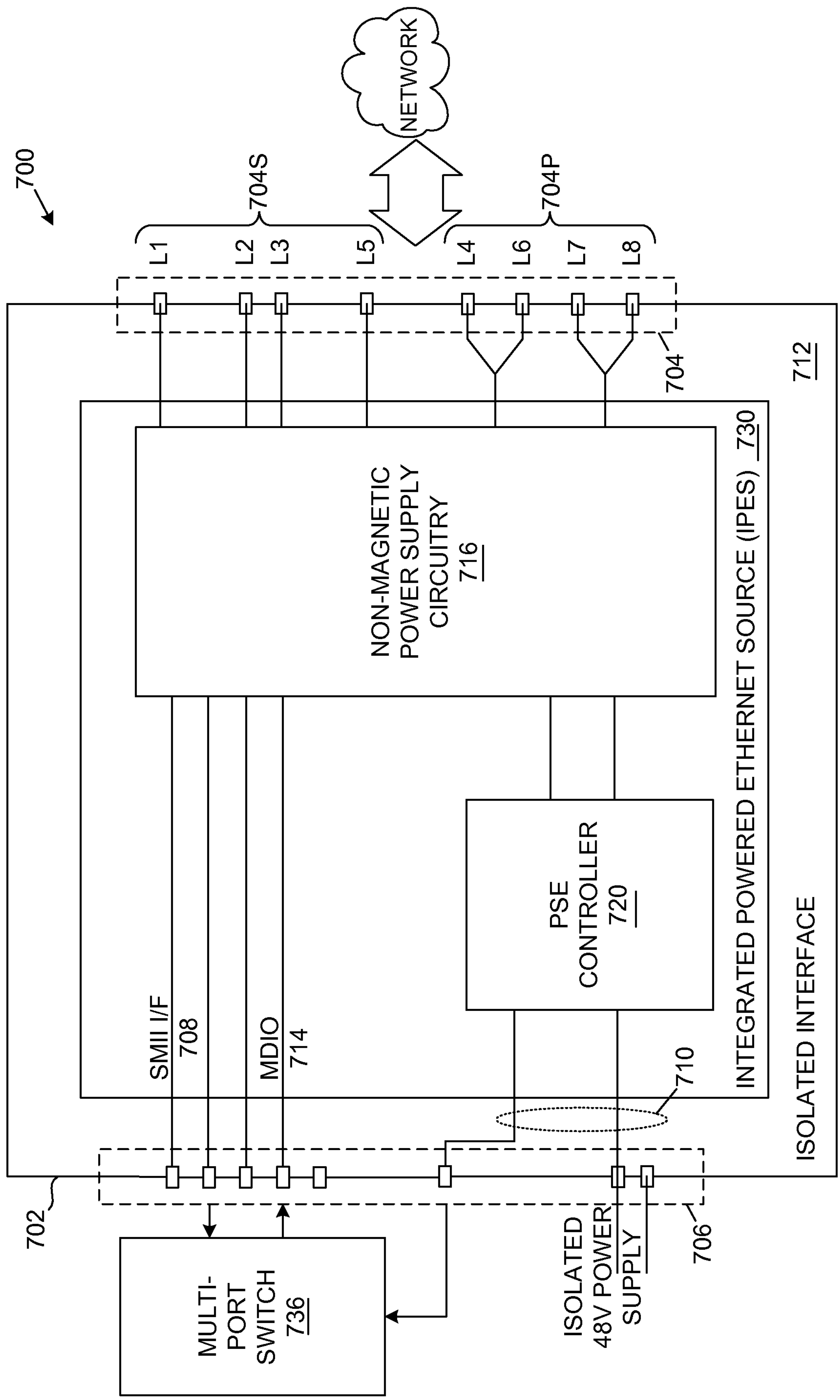

NETWORK
700
704S
704P
L1
L2
L3
L5
L4
L6
L7
L8
704
712
NON-MAGNETIC POWER SUPPLY CIRCUITRY 716
INTEGRATED POWERED ETHERNET SOURCE (IPES) 730
PSE CONTROLLER 720
SMII I/F 708
MDIO 714
710
ISOLATED INTERFACE
702
706
MULTI-PORT SWITCH 736
ISOLATED 48V POWER SUPPLY

FIG. 7

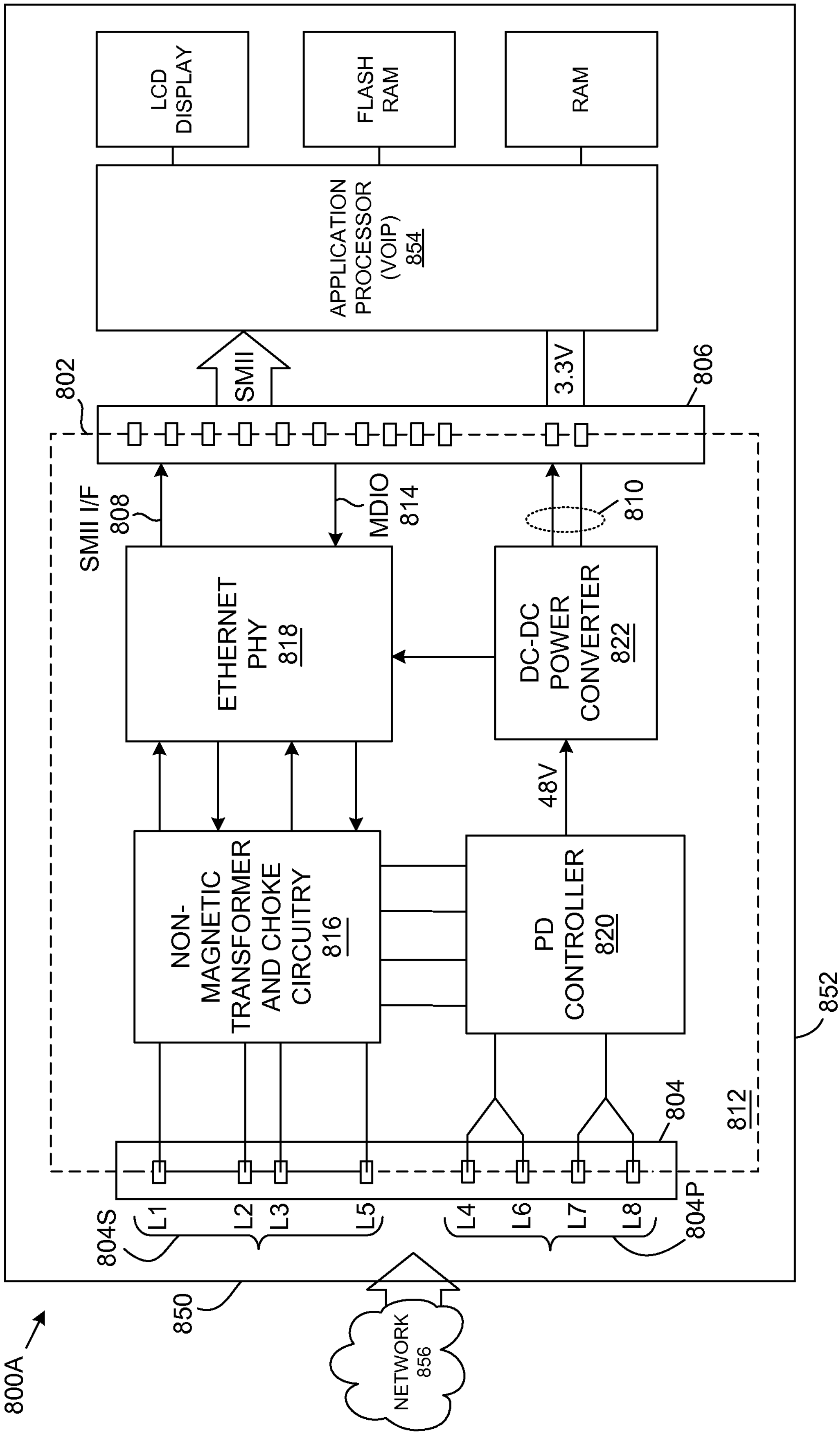

LCD DISPLAY
FLASH RAM
RAM
APPLICATION PROCESSOR (VOIP) 854
SMII
3.3V
802
806
SMII I/F 808
MDIO 814
810
ETHERNET PHY 818
DC-DC POWER CONVERTER 822
48V
NON-MAGNETIC TRANSFORMER AND CHOKE CIRCUITRY 816
PD CONTROLLER 820
852
804
812
L1
L2
L3
L5
L4
L6
L7
L8
804S
804P
850
NETWORK 856
800A

FIG. 8A

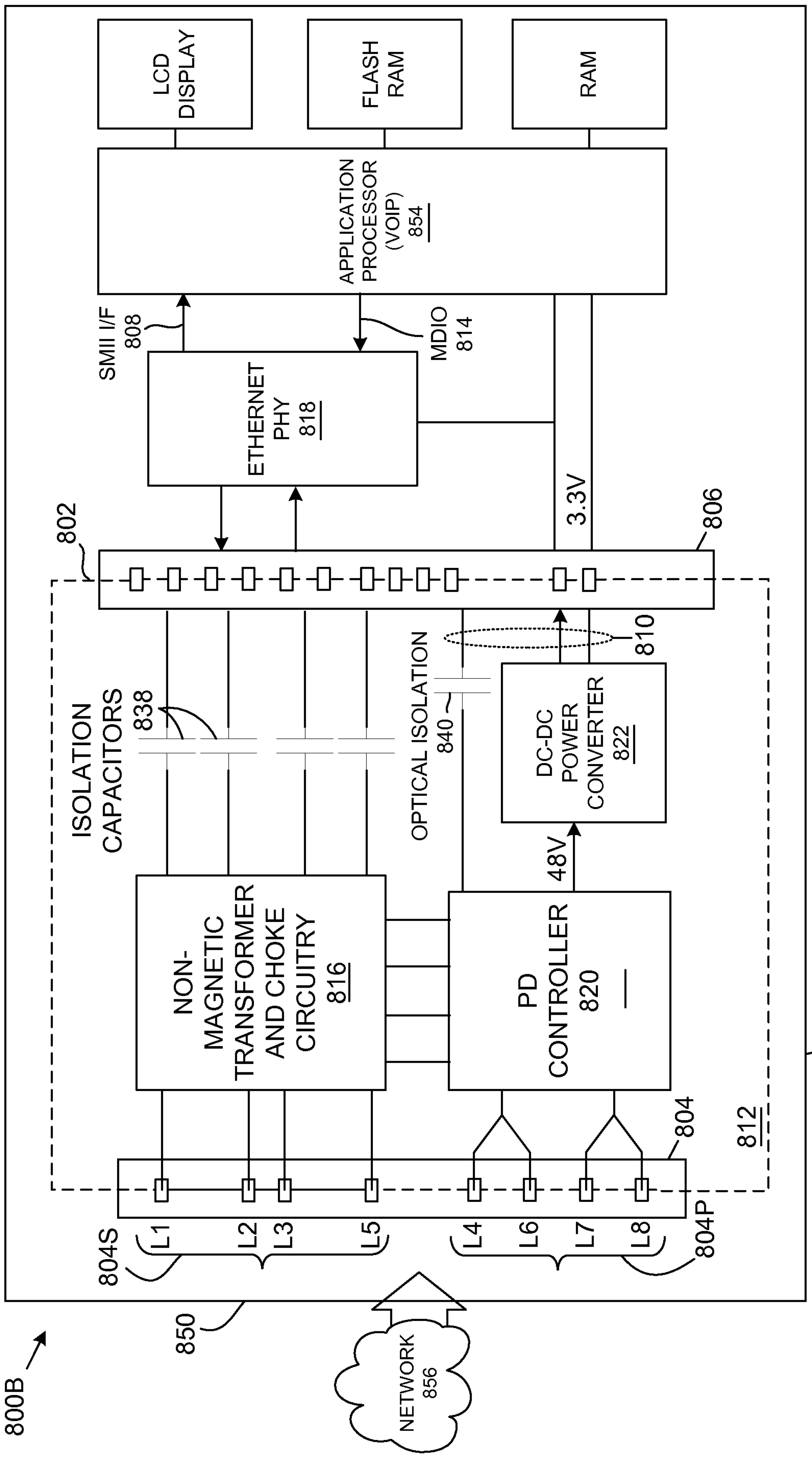

LCD DISPLAY
FLASH RAM
RAM
APPLICATION PROCESSOR (VOIP) 854
SMII I/F 808
MDIO 814
ETHERNET PHY 818
3.3V
802
806
ISOLATION CAPACITORS 838
OPTICAL ISOLATION 840
810
DC-DC POWER CONVERTER 822
48V
NON-MAGNETIC TRANSFORMER AND CHOKE CIRCUITRY 816
PD CONTROLLER 820
804
812
852
L1
L2
L3
L5
L4
L6
L7
L8
804S
804P
850
NETWORK 856
800B

FIG. 8B

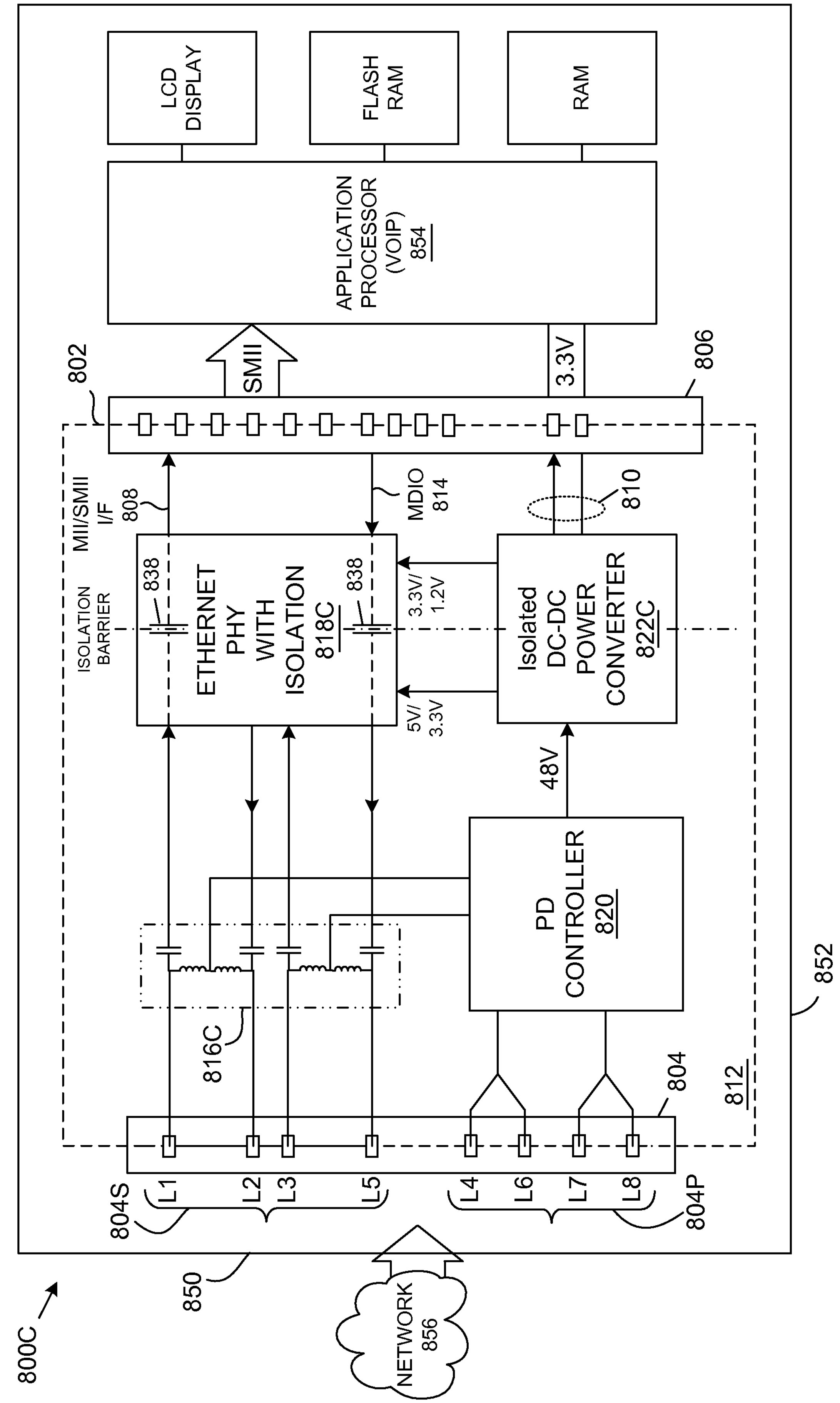

LCD DISPLAY
FLASH RAM
RAM
APPLICATION PROCESSOR (VOIP) 854
SMII
3.3V
802
806
MII/SMII I/F 808
MDIO 814
810
ISOLATION BARRIER
838
ETHERNET PHY WITH ISOLATION 818C
838
3.3V/ 1.2V
5V/ 3.3V
Isolated DC-DC POWER CONVERTER 822C
48V
PD CONTROLLER 820
816C
804
812
852
L1 L2 L3 L5 L4 L6 L7 L8
804S
804P
850
NETWORK 856
800C

FIG. 8C

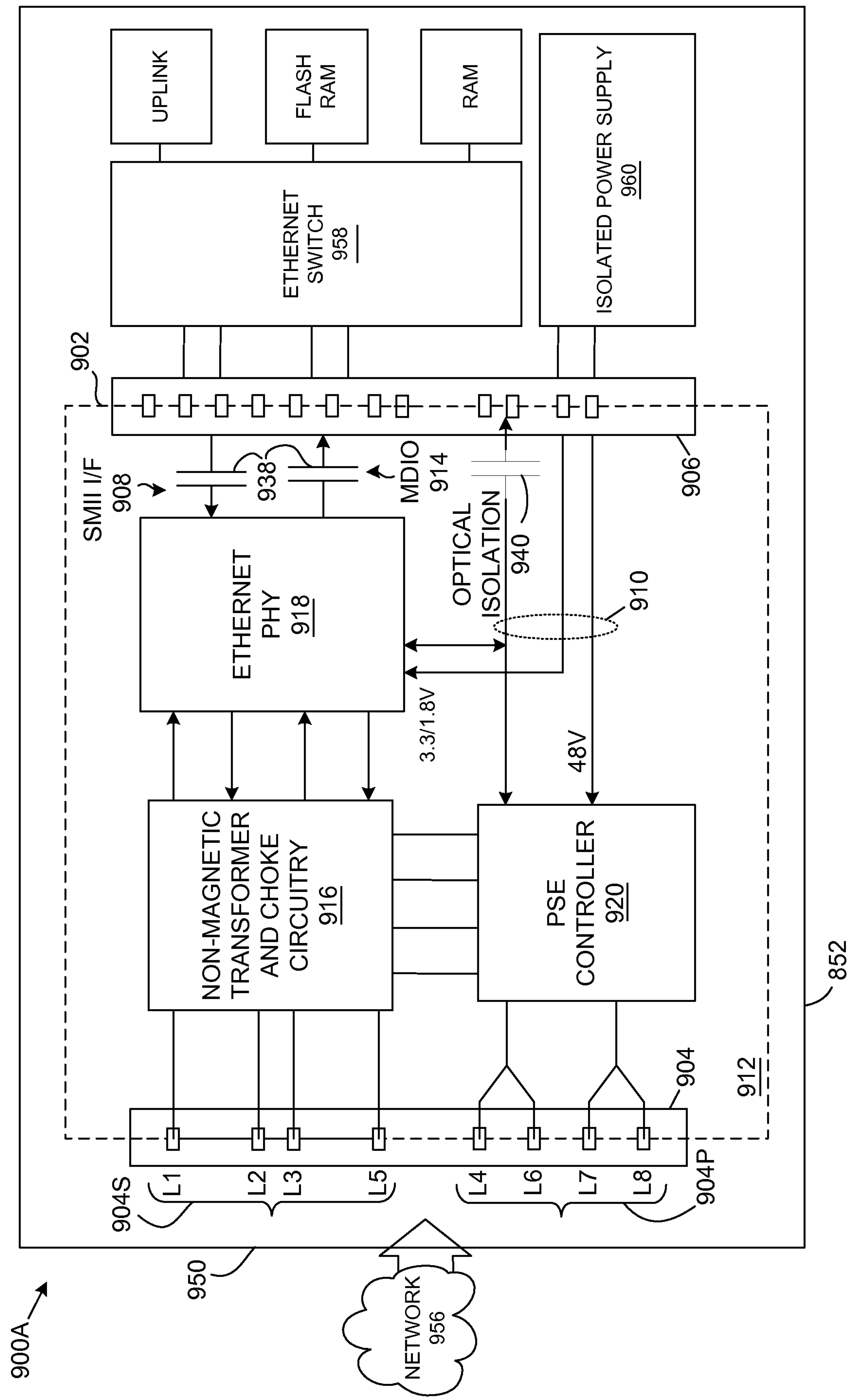

UPLINK
FLASH RAM
RAM
ISOLATED POWER SUPPLY 960
ETHERNET SWITCH 958
902
SMII I/F 908
938
MDIO 914
OPTICAL ISOLATION 940
906
ETHERNET PHY 918
910
3.3/1.8V
48V
NON-MAGNETIC TRANSFORMER AND CHOKE CIRCUITRY 916
PSE CONTROLLER 920
852
904
912
L1
L2
L3
L5
L4
L6
L7
L8
904S
904P
950
NETWORK 956
900A

FIG. 9A

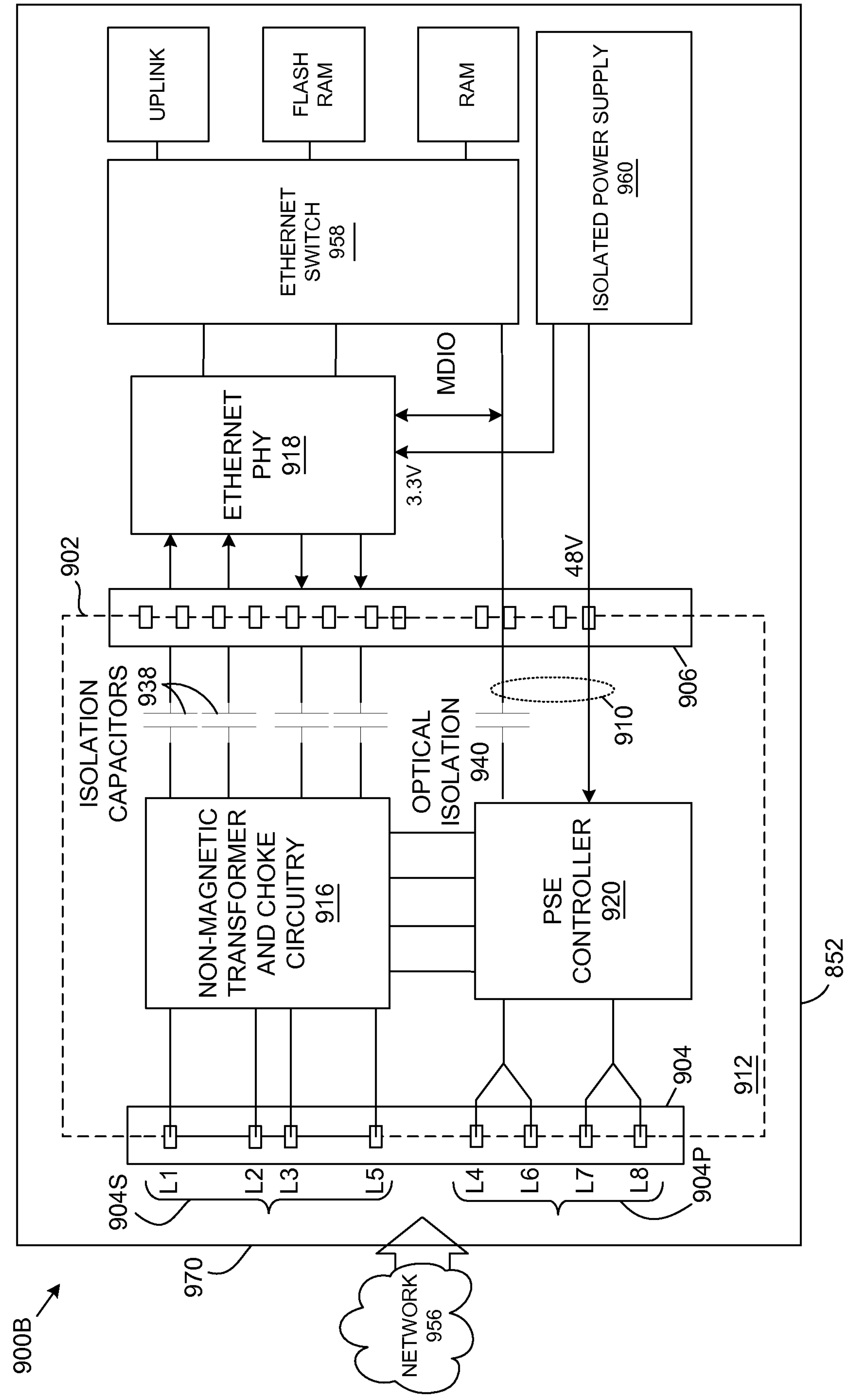

UPLINK
FLASH RAM
RAM
ISOLATED POWER SUPPLY 960
ETHERNET SWITCH 958
MDIO
ETHERNET PHY 918
3.3V
48V
902
906
ISOLATION CAPACITORS 938
OPTICAL ISOLATION 940
910
NON-MAGNETIC TRANSFORMER AND CHOKE CIRCUITRY 916
PSE CONTROLLER 920
852
904
912
904S
904P
L1
L2
L3
L5
L4
L6
L7
L8
970
900B
NETWORK 956

FIG. 9B

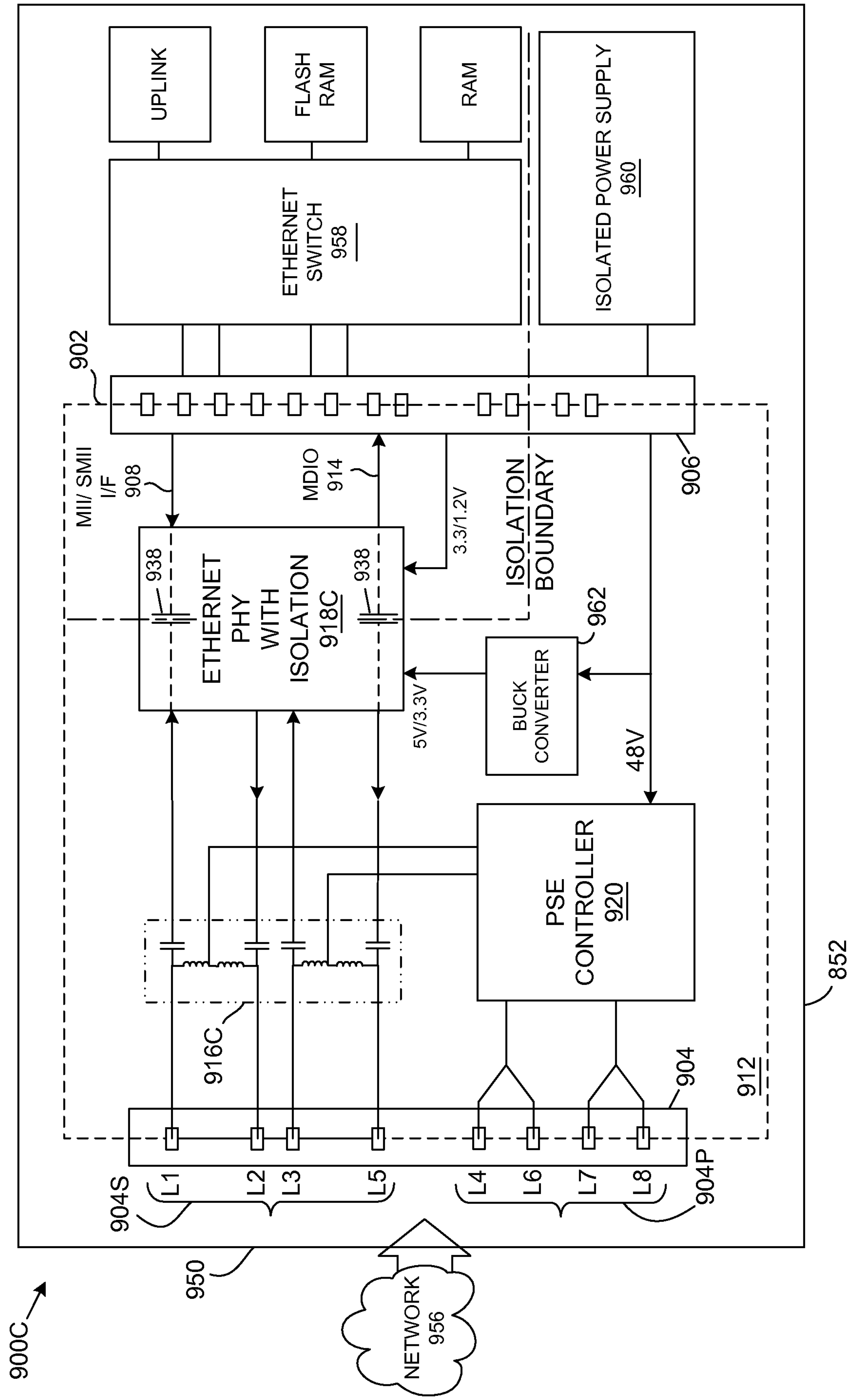

UPLINK
FLASH RAM
RAM
ISOLATED POWER SUPPLY 960
ETHERNET SWITCH 958
902
MII/ SMII I/F 908
MDIO 914
3.3/1.2V
ISOLATION BOUNDARY
906
938
938
ETHERNET PHY WITH ISOLATION 918C
962
BUCK CONVERTER
5V/3.3V
48V
PSE CONTROLLER 920
916C
904
912
852
904S
L1
L2
L3
L5
L4
L6
L7
L8
904P
950
NETWORK 956
900C

FIG. 9C

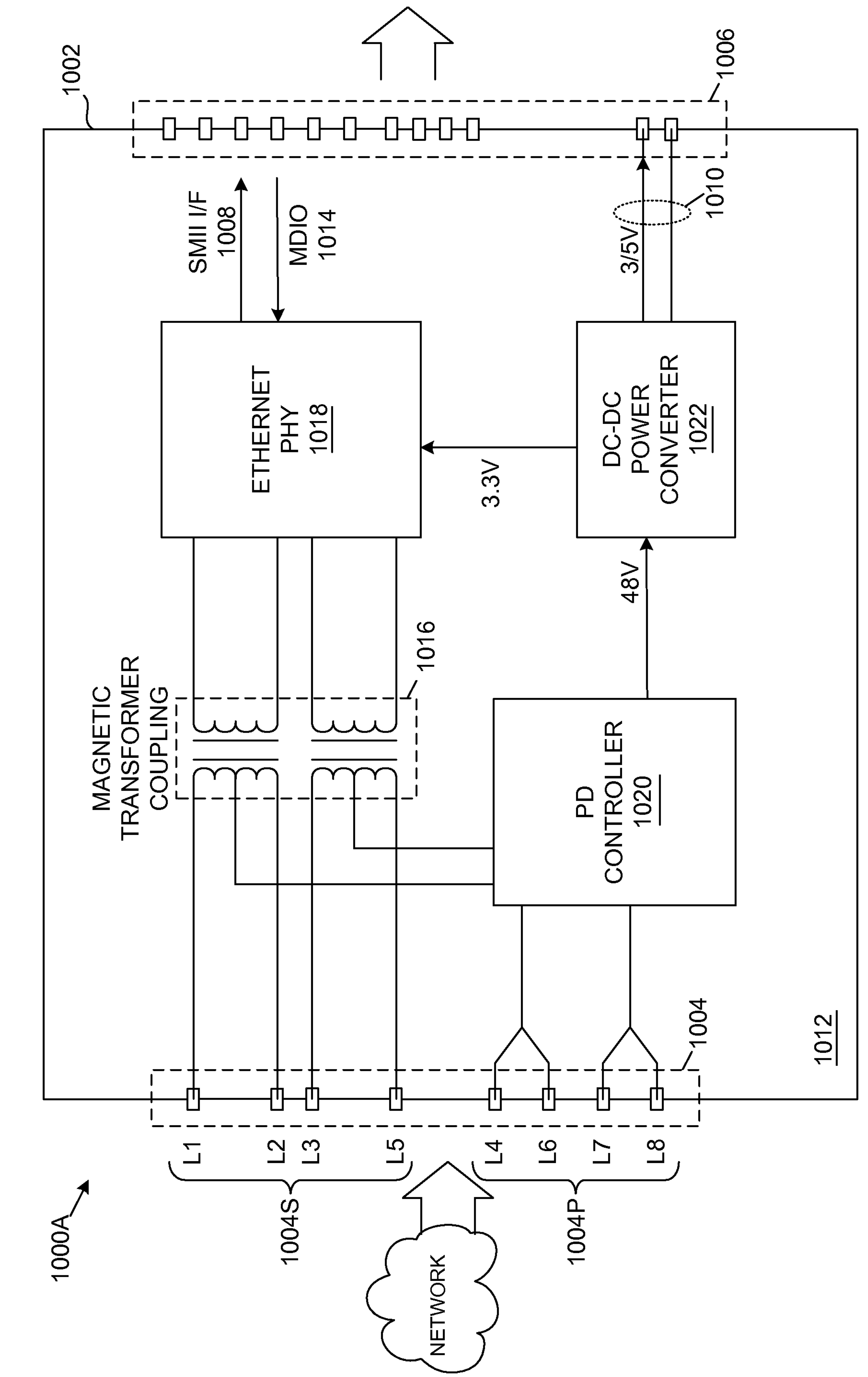

1002
1006
SMII I/F
1008
MDIO
1014
3/5V
1010
ETHERNET
PHY
1018
DC-DC
POWER
CONVERTER
1022
3.3V
48V
MAGNETIC
TRANSFORMER
COUPLING
1016
PD
CONTROLLER
1020
1004
1012
L1
L2
L3
L5
L4
L6
L7
L8
1004S
1004P
1000A
NETWORK

FIG. 10A

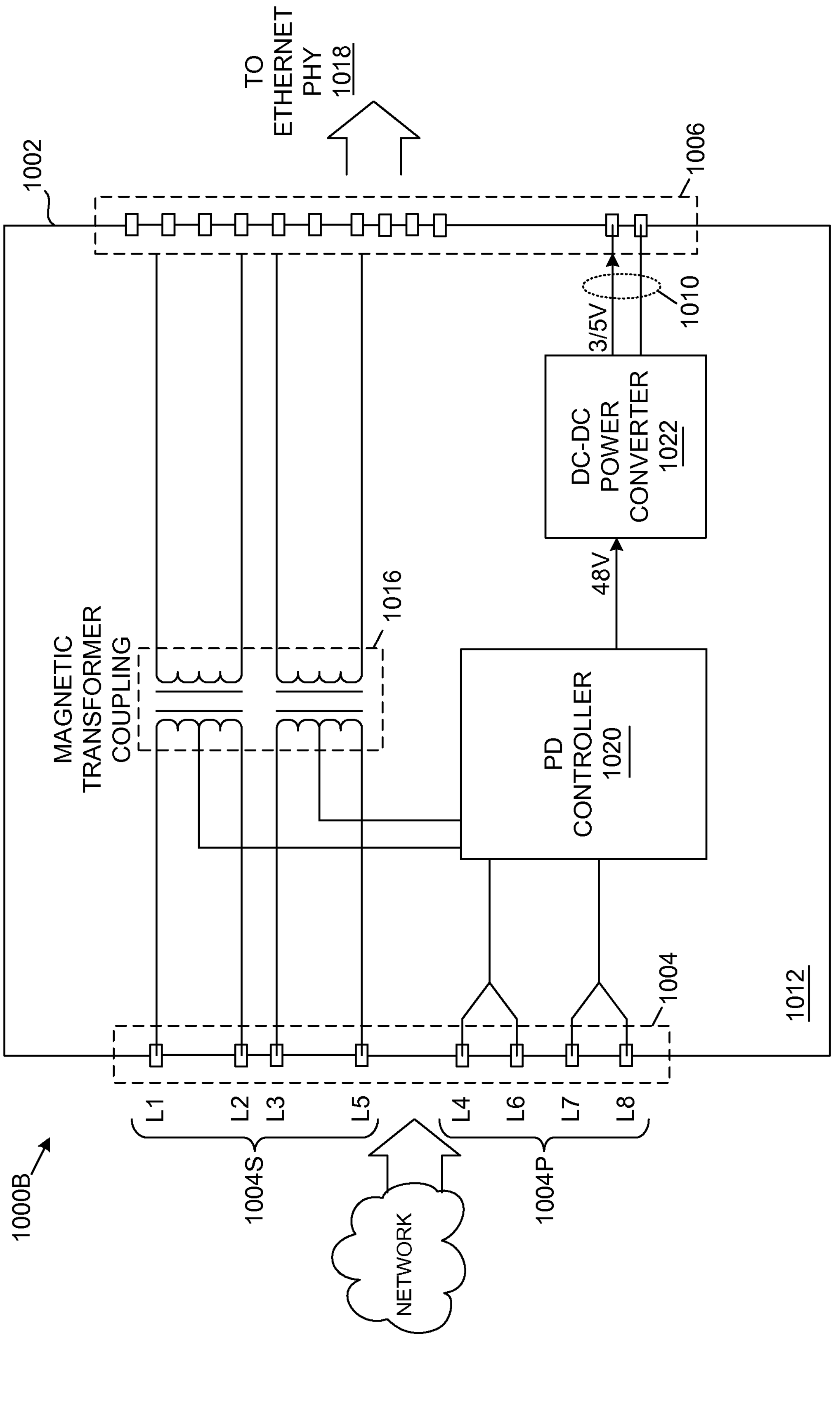

TO
ETHERNET
PHY
1018
1002
1006
1010
3/5V
DC-DC
POWER
CONVERTER
1022
48V
MAGNETIC
TRANSFORMER
COUPLING
1016
PD
CONTROLLER
1020
1004
1012
L1
L2
L3
L5
L4
L6
L7
L8
1004S
1004P
NETWORK
1000B

FIG. 10B

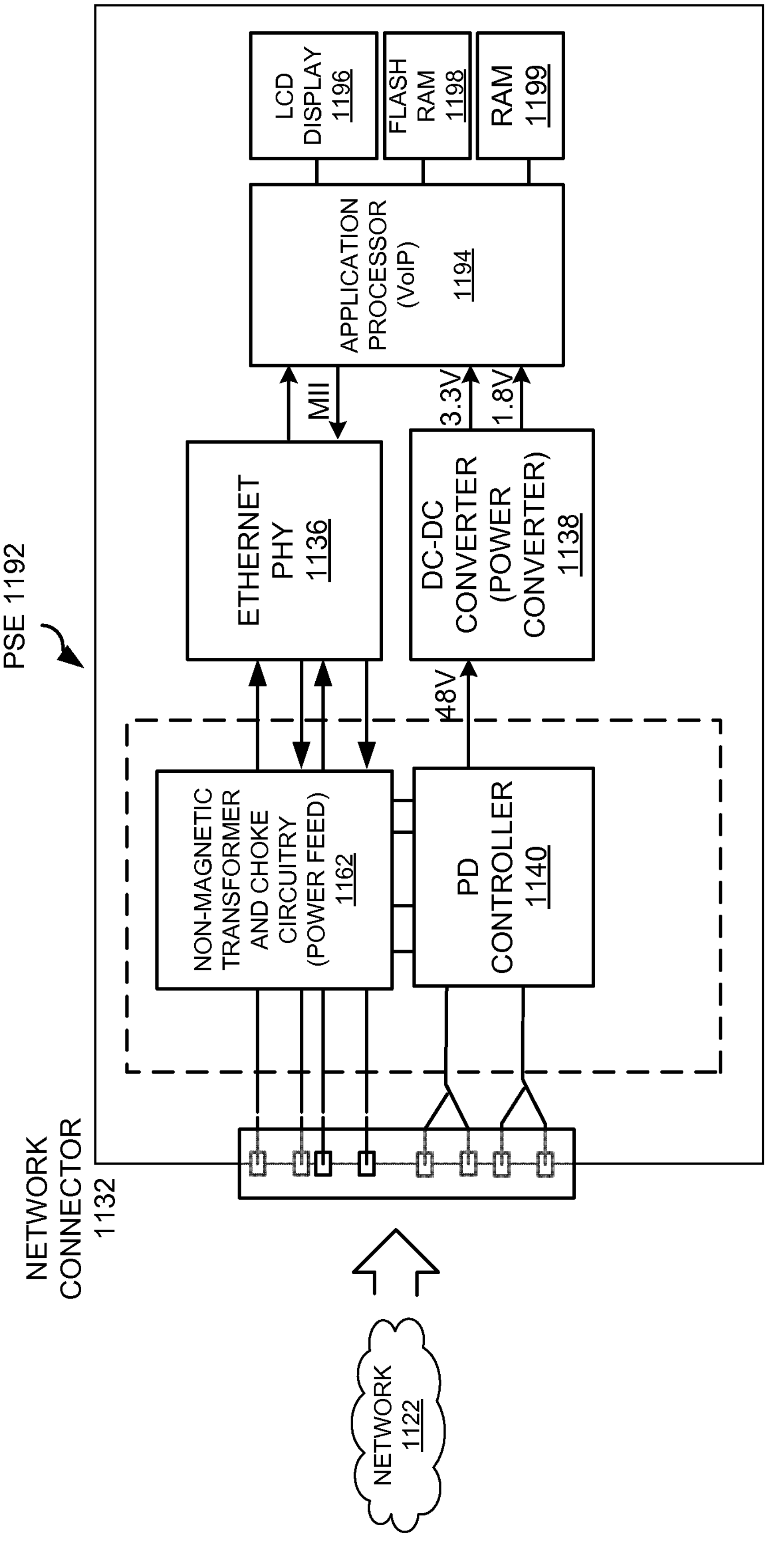

LCD DISPLAY 1196
FLASH RAM 1198
RAM 1199
APPLICATION PROCESSOR (VoIP) 1194
MII
3.3V
1.8V
ETHERNET PHY 1136
DC-DC CONVERTER (POWER CONVERTER) 1138
PSE 1192
48V
NON-MAGNETIC TRANSFORMER AND CHOKE CIRCUITRY (POWER FEED) 1162
PD CONTROLLER 1140
NETWORK CONNECTOR 1132
NETWORK 1122

FIG. 11

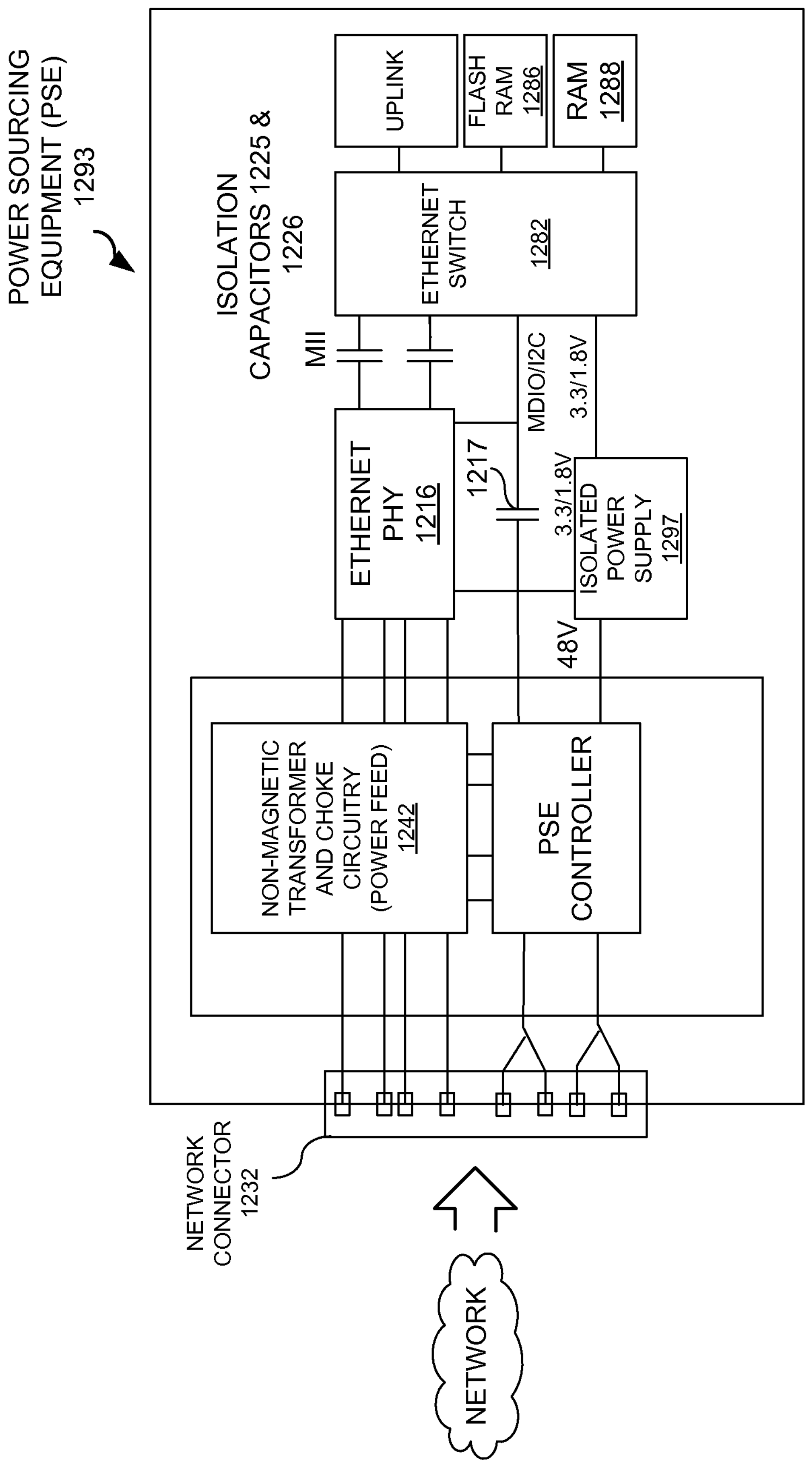

POWER SOURCING EQUIPMENT (PSE) 1293
ISOLATION CAPACITORS 1225 & 1226
UPLINK
FLASH RAM 1286
RAM 1288
ETHERNET SWITCH 1282
MII
MDIO/I2C
3.3/1.8V
ETHERNET PHY 1216
1217
3.3/1.8V
ISOLATED POWER SUPPLY 1297
48V
NON-MAGNETIC TRANSFORMER AND CHOKE CIRCUITRY (POWER FEED) 1242
PSE CONTROLLER
NETWORK CONNECTOR 1232
NETWORK

FIG. 12

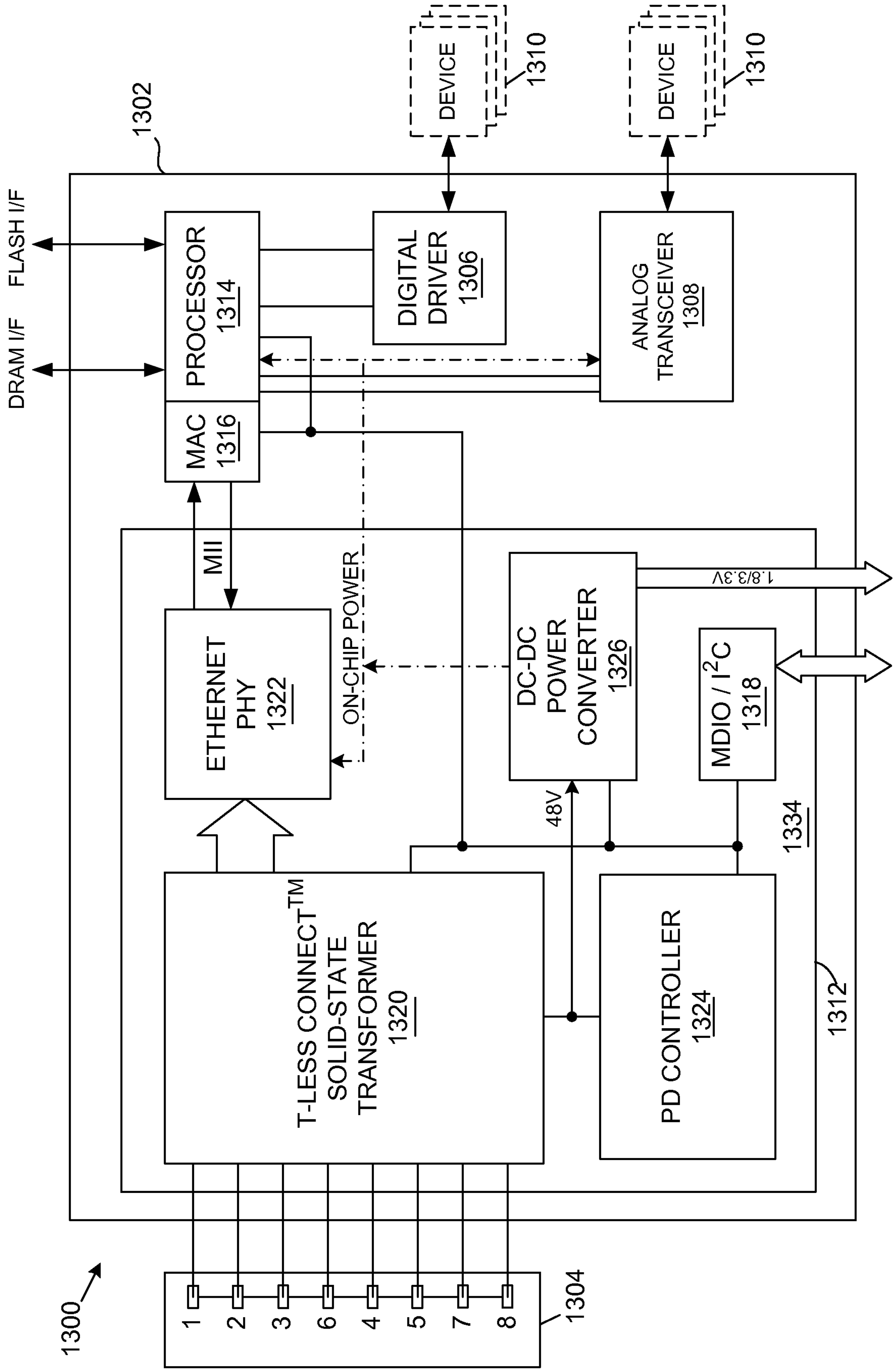

1300
1302
1304
1 2 3 6 4 5 7 8
DRAM I/F
FLASH I/F
PROCESSOR 1314
MAC 1316
DIGITAL DRIVER 1306
ANALOG TRANSCEIVER 1308
DEVICE
1310
DEVICE
1310
MII
ETHERNET PHY 1322
ON-CHIP POWER
DC-DC POWER CONVERTER 1326
1.8/3.3V
MDIO / I2C 1318
48V
1334
T-LESS CONNECT™ SOLID-STATE TRANSFORMER 1320
PD CONTROLLER 1324
1312

FIG. 13A

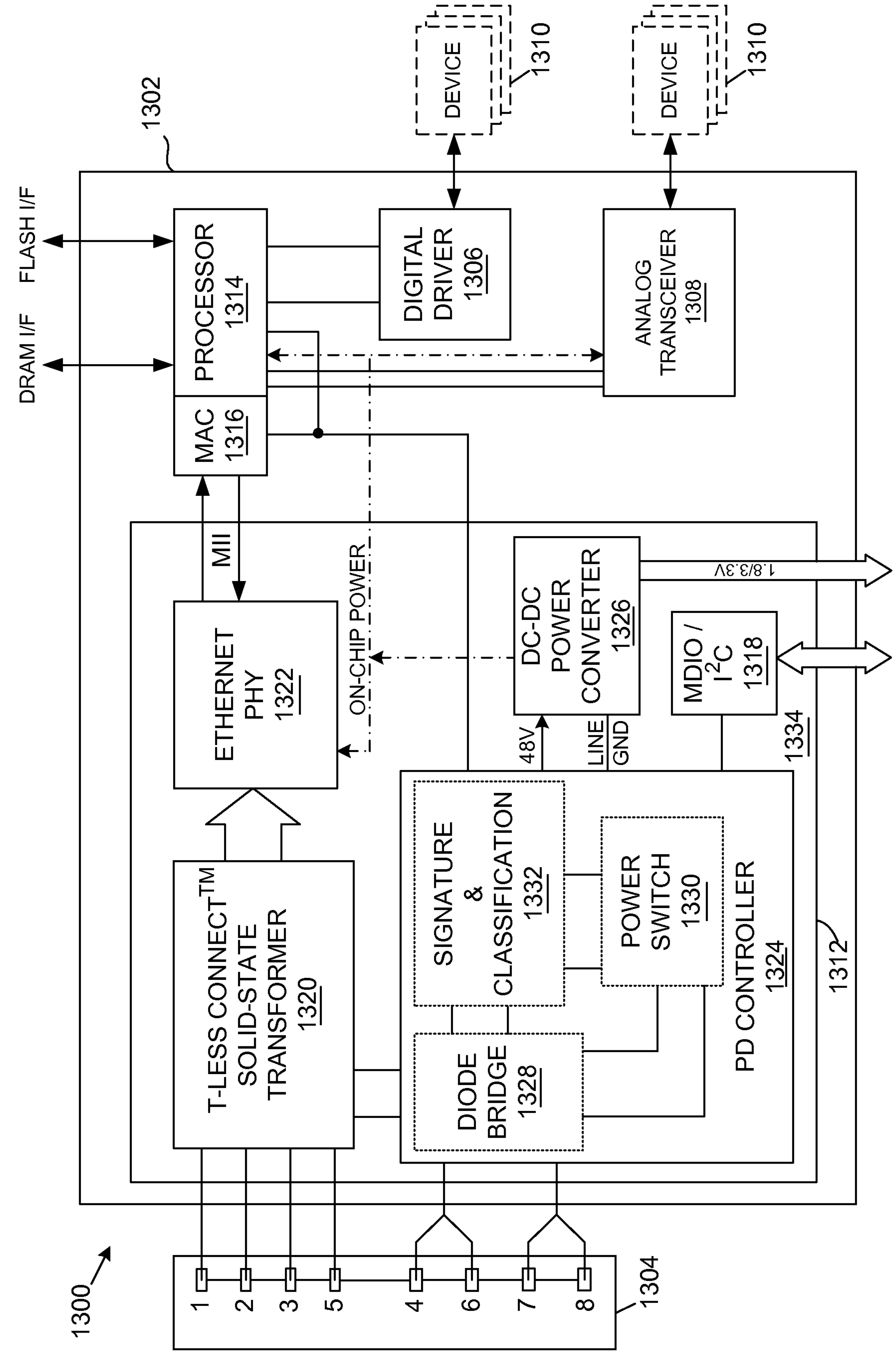

1300
1302
1304
1310
DEVICE
1310
DEVICE
FLASH I/F
DRAM I/F
PROCESSOR 1314
MAC 1316
DIGITAL DRIVER 1306
ANALOG TRANSCEIVER 1308
MII
ON-CHIP POWER
ETHERNET PHY 1322
DC-DC POWER CONVERTER 1326
1.8/3.3V
MDIO / I2C 1318
48V
LINE GND
1334
T-LESS CONNECT™ SOLID-STATE TRANSFORMER 1320
SIGNATURE & CLASSIFICATION 1332
POWER SWITCH 1330
PD CONTROLLER 1324
DIODE BRIDGE 1328
1312
1 2 3 5 4 6 7 8

FIG. 13B

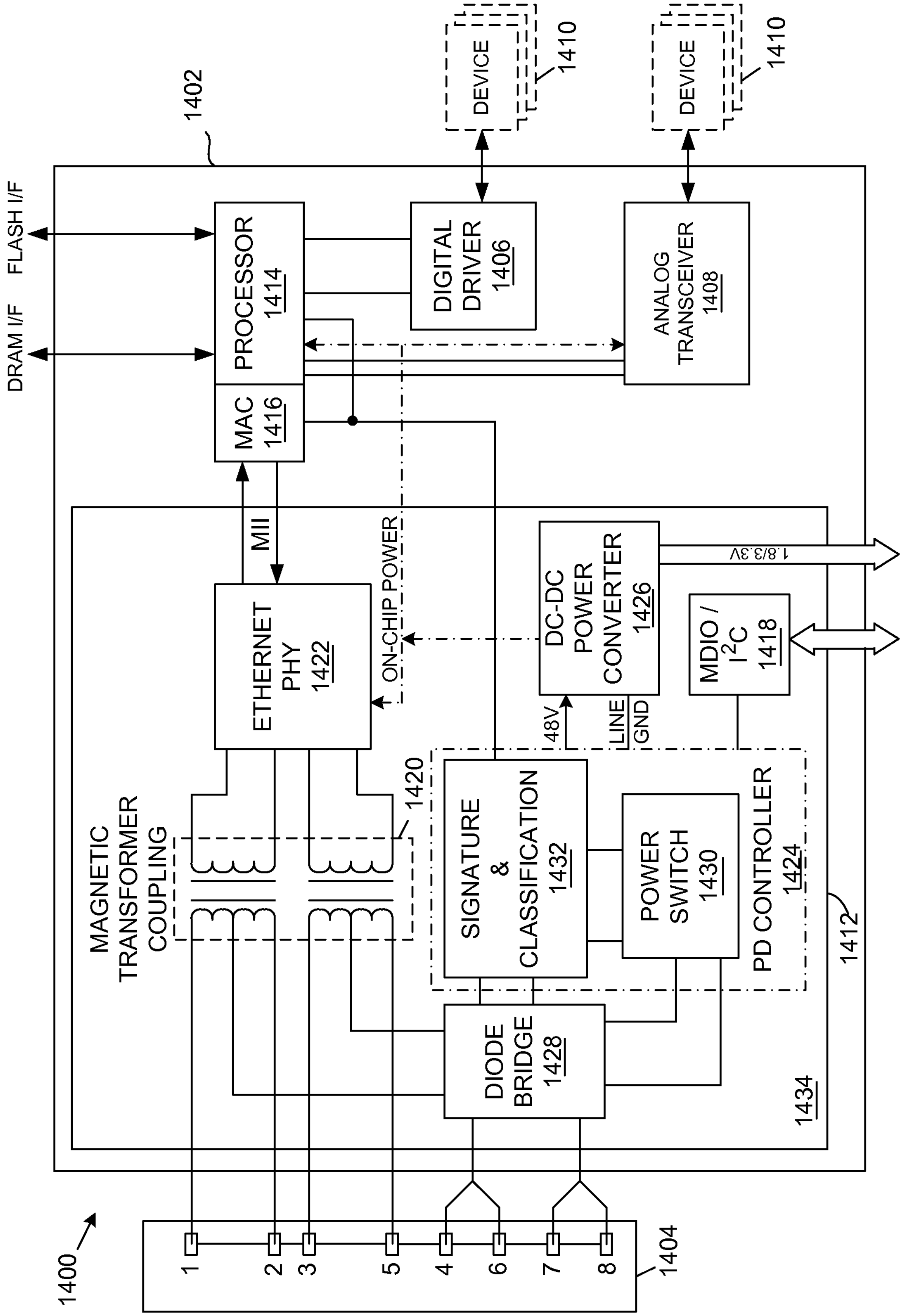

1400
1402
1404
1410
DEVICE
DEVICE
1410
FLASH I/F
DRAM I/F
PROCESSOR
1414
MAC
1416
DIGITAL
DRIVER
1406
ANALOG
TRANSCEIVER
1408
MII
ON-CHIP POWER
ETHERNET
PHY
1422
DC-DC
POWER
CONVERTER
1426
1.8/3.3V
MDIO /
I2C
1418
48V
LINE
GND
MAGNETIC
TRANSFORMER
COUPLING
1420
SIGNATURE
&
CLASSIFICATION
1432
POWER
SWITCH
1430
PD CONTROLLER
1424
1412
DIODE
BRIDGE
1428
1434
1
2
3
5
4
6
7
8

FIG. 14

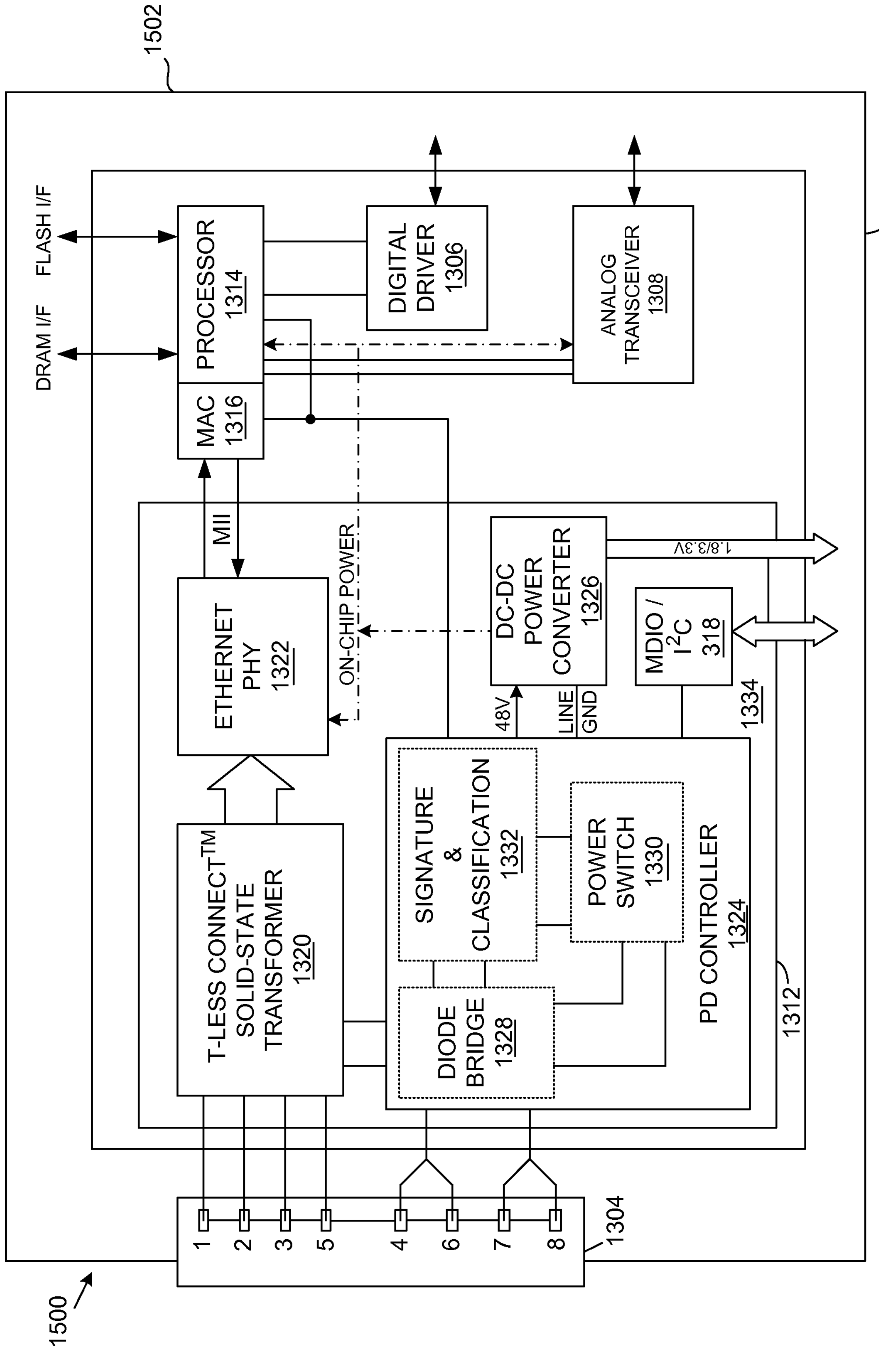

1502
1540
FLASH I/F
DRAM I/F
PROCESSOR
1314
MAC
1316
DIGITAL
DRIVER
1306
ANALOG
TRANSCEIVER
1308
MII
ON-CHIP POWER
ETHERNET
PHY
1322
DC-DC
POWER
CONVERTER
1326
1.8/3.3V
MDIO /
I2C
318
48V
LINE
GND
1334
T-LESS CONNECTTM
SOLID-STATE
TRANSFORMER
1320
SIGNATURE
&
CLASSIFICATION
1332
POWER
SWITCH
1330
PD CONTROLLER
1324
DIODE
BRIDGE
1328
1312
1
2
3
5
4
6
7
8
1304
1500

FIG. 15