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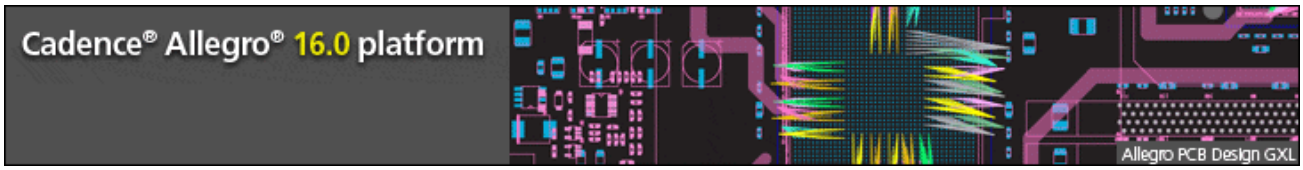

[Design View / Design Solution]

Banish Those "Wall Warts" With Power Over Ethernet

By taking advantage of the new IEEE-802.3af PoE standard, anything that uses less than 12.95 W can be powered through the CAT-5 cable already carrying Ethernet data.

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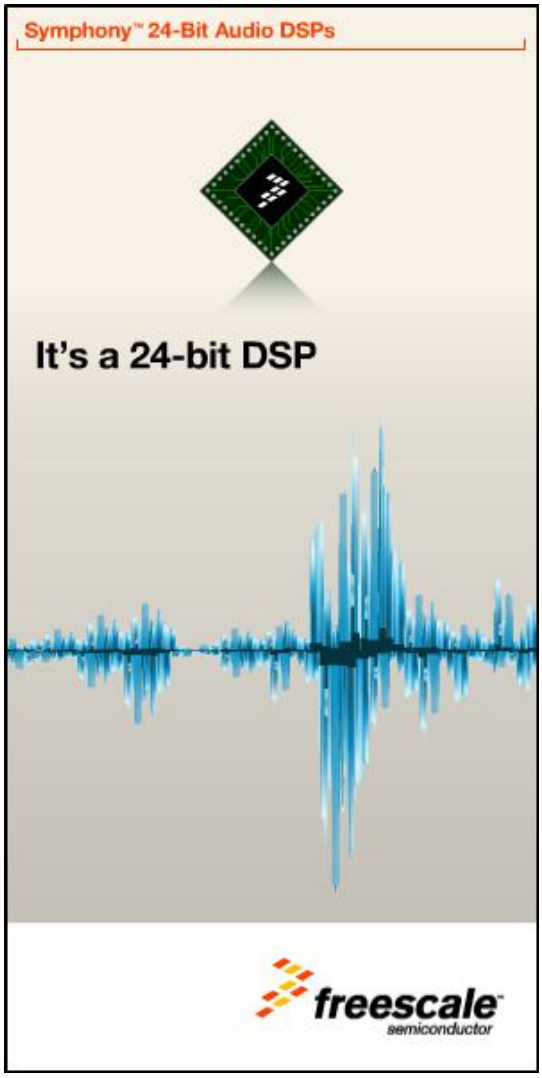


DESIGN VIEW is the summary of the complete *DESIGN SOLUTION* contributed article, which begins on Page 2.

The new Power-over-Ethernet (PoE) standard, IEEE-802.3af, will free wireless access points from ac outlets and allow a central uninterruptible power supply (UPS) to service an entire IP telephone installation. It also means bringing Ethernet into applications dominated by proprietary or entrenched older technology, such as telephony, burglar alarms, and video surveillance, as well as completely new applications.

Common devices that normally use wall warts—such as IP phones, HVAC thermostats, wireless access points, PDA docking stations, and anything else that consumes less than 12.95 W—can be powered through the CAT-5 cable already carrying Ethernet data. PoE not only eliminates wall transformers, it enables a whole new set of devices with a combined data and power interface. It also is backward-compatible with existing 10-, 100-, or 1000-Mbit/s Ethernet equipment.

IEEE-802.3af is essentially a power-transmission (not data-transmission) protocol that's predominantly analog. The standard operates entirely with common-mode signaling between the twisted pairs without disturbing differential data transmission.

PoE begins with a power-enabled switch (known as power-sourcing equipment, or PSE) detecting a device that requires power by measuring its common-mode termination. A valid powered device (PD) must have a 25-kΩ common-mode resistance "detection signature."

With a second measurement, called classification, the PSE can determine the PD's peak power requirements. With this data, the PSE can apply power to devices that need it without damaging those that don't, while efficiently allocating available power.

Once the PD is receiving power, it starts its own circuitry, consuming up to 12.95 W. If the PD is ever unplugged or turned off, the PSE stops sending power and again tries to detect the 25-kΩ signature of a valid PD. The PSE entirely controls the PoE link.

HIGHLIGHTS:

Powered Devices	The requirements for an 802.3af PD begin with a detection signature of 25 kΩ and less than 120 nF. This specific common-mode termination differentiates the PD from Ethernet devices that do not expect power. The PD only needs to display its detection signature while the link is in detection mode.
Power-Sourcing Equipment	The brains of the PoE operation are in the power-sourcing equipment. It detects, classifies, and controls power to compliant 802.3af PDs on the network.
Endpoints And Midspans	Endpoints typically send power over data pairs, even though the 802.3af standard allows them to alternatively use the spare pairs. Midspans apply power only to the spare pairs while the data pairs pass straight through.

Full article begins on Page 2

In the next year, the sales growth in local-area networking will derive from delivering watts, not bits. The new Power-over-Ethernet (PoE) standard, IEEE-802.3af, will free wireless access points from ac outlets and allow a central uninterruptible power supply (UPS) to service an entire IP telephone installation. It also means bringing Ethernet into applications dominated by proprietary or entrenched older technology, such as telephony, burglar alarms, video surveillance, and industrial sensors, and into completely new applications.

Multiple IC vendors are already bringing to market the silicon needed to make PoE work, and more devices are scheduled for release in 2004. Network equipment manufacturers are preparing switches, routers, and hubs that comply with PoE, while midspans are available to upgrade existing equipment.

The newly ratified standard is designed to cure the proliferation of wall warts. With this new standard, devices like IP phones, HVAC thermostats, wireless access points, PDA docking stations, and anything else that uses less than 12.95 W can be powered through the CAT-5 cable already carrying Ethernet data. PoE not only eliminates wall transformers, it also enables a whole new set of devices with a combined data and power interface. It's backward compatible with existing 10-, 100-, or 1000-Mbit/s Ethernet equipment as well. Breaking new ground for Ethernet, IEEE 802.3af is essentially a power-transmission (not a data-transmission) protocol that is predominantly analog. It operates entirely with common-mode signaling between the twisted pairs without disturbing differential data transmission *(Fig. 1 and Fig. 2)*.

PoE begins with a power-enabled switch (known as power-sourcing equipment, or PSE) detecting a device that requires power by measuring its common-mode termination. A valid powered device (PD) must have a 25-kΩ common-mode resistance "detection signature." With a second measurement, called classification, the PSE can determine the PD's peak power requirements. Armed with this information, the PSE can apply power to devices that need it without damaging those that don't, while efficiently allocating available power. Once the PD is receiving power (nominally 48 V dc), it starts its own circuitry, consuming up to 12.95 W. If the PD is ever unplugged or turned off, the PSE stops sending power and again tries to detect the 25-kΩ signature of a valid PD. The PSE entirely controls the PoE link. The common mode or port voltage (V_{PORT}) communicates the state of the link to the PD as listed in Table 1.

Powered Devices

The requirements for an 802.3af PD begin with a detection signature of 25 kΩ and less than 120 nF. This specific common-mode termination differentiates the PD from Ethernet devices that do not expect power. The PD only needs to display its detection signature while the link is in detection mode *(Table 1, again)*. The classification signature, which communicates the PD's peak power consumption, requires the PD to sink a specific dc current while the port voltage is between 14.5 and 20.5 V. The PD's classification current must correspond to one of the five power-consumption classes in Table 2. In the spirit of Auto MDI-X, PDs must be polarity-insensitive and be able to operate (provide detection and classification signatures as well as accept power) over both the spare and data pairs. This autopolarity circuitry is typically implemented with diode bridges *(Fig. 2, again)*. That's all the PD has to do to ask the PSE for power.

The PD does not begin drawing power until the port voltage rises to between 30 and 42 V so as not to interfere with detection and classification. Initially, the PD connects 5 µF or more of input bypass capacitance to the port. Although switching in the bypass cap may draw the port voltage down below the PD's 30- to 42-V turn-on threshold, it cannot let this momentary drop cause it to oscillate. The IEEE-802.3af standard allows the PD 50 ms of startup time, sufficient to charge up 180 µF of bypass, before it must adhere to the current limits of its class *(Table 2, again)*. PDs can use inrush current limiting to charge larger capacitors while staying within current-limit requirements. Typically, a PD will keep the rest of its circuitry disabled until the bypass capacitor is charged. This is particularly important with dc-dc converters, as they tend to draw more current at lower input voltages, making it especially difficult to charge the bypass cap.

Once the bypass capacitor is charged, the port voltage rises into powering mode, and the PD enables the rest of its circuitry and begins drawing power (while sticking to the power-consumption limits of its class). Excessive current for more than 50 ms may result in power being turned off. On the other end of the scale, the PD must draw a minimum of 10 mA to tell the PSE that it is still connected. Power-sensitive applications like thermostats can reduce power dissipation by pulsing the "Maintain Power Signature" (MPS) current to 10 mA for at least 75 ms and waiting no more than 250 ms between pulses. The PD must also have an MPS common-mode impedance of less than 26.25 kΩ in parallel with more than 50 nF. Usually, the PD's bypassing and load create an impedance well below this level.

The 802.3af specification intends for PDs to be relatively simple, and a basic compliant PD interface can be constructed from a handful of discretes. However, IC vendors are offering chips that simplify implementing a complete PoE PD interface. The LTC4257 supplies a detection signature, programmable classification signature, UVLO with hysteresis, port current limit, and a power-good pin to enable a dc-dc converter once the bypass capacitor is charged. The device can tolerate port voltages up to 100 V, allowing it to survive real-world abuse like inductive flyback from cables under load, high-voltage cable discharge, and electrostatic discharge strikes. Together with a pair of diode bridges and a transient suppressor, the LTC4257 and devices like it can bring a PD most of the way to compliance. This enables network-equipment manufacturers to concentrate on what makes their devices different, not what makes them the same.

Power-Sourcing Equipment

The brains of the PoE operation is the PSE. It detects, classifies, and controls power to compliant 802.3af PDs on the network. During detection, the PSE determines the port's common-mode termination by measuring two V-I points and calculating resistance from the slope between them. PSEs

can perform either force-current or force-voltage measurements as long as the two test voltages are separated by more than a volt, and both fall between 2.8 and 10 V, which allows room for the PD's series diodes. Detection is critical to PoE as it ensures that 48 V dc is applied only to valid PDs and never damages equipment not designed to accept 802.3af power. Detection, like the rest of PoE, does not benefit from the common-mode rejection of Ethernet's twisted pairs. PSEs must reject 50/60 Hz by integrating over multiple ac line cycles, but not too many, because detection must complete within 500 ms.

Following a successful detection, the PSE forces 15.5 to 20.5 V onto the port, placing the PD in classification mode. The PSE will give the PD 10 ms to settle before classifying it (measuring the port current). To keep power dissipation reasonable, classification must complete within 75 ms.

The PSE may now apply power, but only if it can provide the power demanded by the PD's class, per Table 2. The PSE may opt to skip classification altogether if it has sufficient power. Since power supplies cost money and classification makes better use of this valuable resource, most PSEs will implement it. Whether it classifies the PD or not, if a PSE is going to apply power, it must do so within 400 ms of a valid detection. A PSE that waits too long may end up damaging a nonpowered Ethernet device that's been plugged in in place of a genuine PD.

Once the power comes on, the current must be actively limited to I_{LIM} (between 400 and 450 mA) and passively limited at an I_{CUT} threshold of 350 to 400 mA. Port current may never exceed I_{LIM}, and if it is larger than I_{CUT} for more than T_{OVLD} (50 to 75 ms), the port is turned off. These limits apply during startup as well as in powering mode. And although the IEEE standard calls the maximum current during startup I_{INRUSH}, the value is identical to I_{LIM}. These limits keep a tight reign on the port power, stopping failures from becoming meltdowns and allowing the PSE to control the port with inexpensive pass FETs. They are also the reason the PD must charge its bypass cap or limit current 50 ms after being powered on. PSEs can opt to enforce tighter I_{CUT} thresholds, for class 1 and class 2 PDs.

When a link is powered, the PSE must continually monitor it to make sure a PD is still connected and the cable is not lying in wait, ready to give a 48-V jolt to the next Ethernet device that comes along. The 802.3af standard specifies two methods, dc disconnect and ac disconnect, for the PSE to determine if it is still connected to a PD. The dc disconnect relies on the PD to draw at least 10 mA. If the current falls below an I_{MIN} threshold between 5 and 10 mA for more than T_{MPS} (300 to 400 ms), the PSE turns power off. Because PDs may pulse their port current above 10 mA to remain powered, PSEs must respond to pulses as narrow as 60 ms. With ac disconnect, the PSE measures the port impedance. A high impedance means the PD is no longer connected and the port must be turned off after T_{MPS}.

Endpoints And Midspans

The 802.3af standard defines two types of PSE. A typical PSE combines 802.3af power-sourcing abilities with the data terminal equipment (DTE) or repeater capabilities of Ethernet switches and hubs in the field today. These PSEs, called endpoints, exist at the end of a network connection. Endpoints typically send power over the data pairs, even though the standard allows them to alternatively use the spare pairs, because these wires definitely connect to the PD.

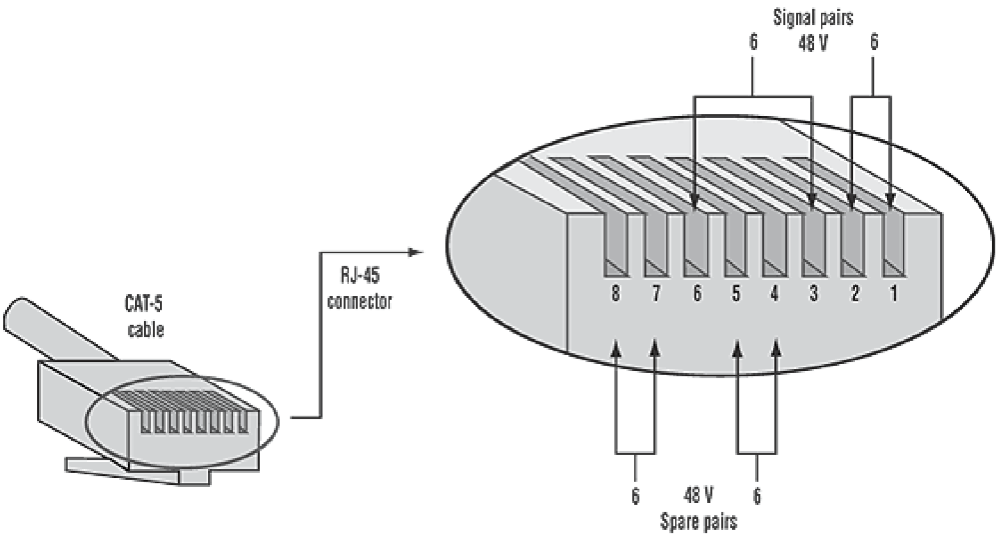
A second type of PSE fits in-line between the data switch and the PD. This type, called a midspan, applies power only to the spare pairs while the data pairs pass straight through. With a midspan-based network, the PD receives data from an existing non-802.3af switch but receives power from the midspan.

It is possible to connect an endpoint and a midspan in series so power is available on both the spare and data pairs. To prevent unwanted interactions, a powered PD must not present a 25-kΩ signature on the other pairs. The diode ORing circuit shown in Figure 2 prevents this. Additionally, a midspan must wait at least two seconds after a failed detection before attempting another detection. This delay gives the endpoint a head start to detect and power the PD before the midspan detects again.

Several IC vendors are producing chips that handle the complexities of an 802.3af PSE. Some of these solutions are microcontroller peripherals that provide an interface to the PoE port but rely on the controller software to do much of the work. Devices with more capability detect and classify valid PDs autonomously and manage overcurrent and disconnect with minimal software overhead. These devices may need only the system software to decide whether there is enough power remaining to meet the PD's demands.

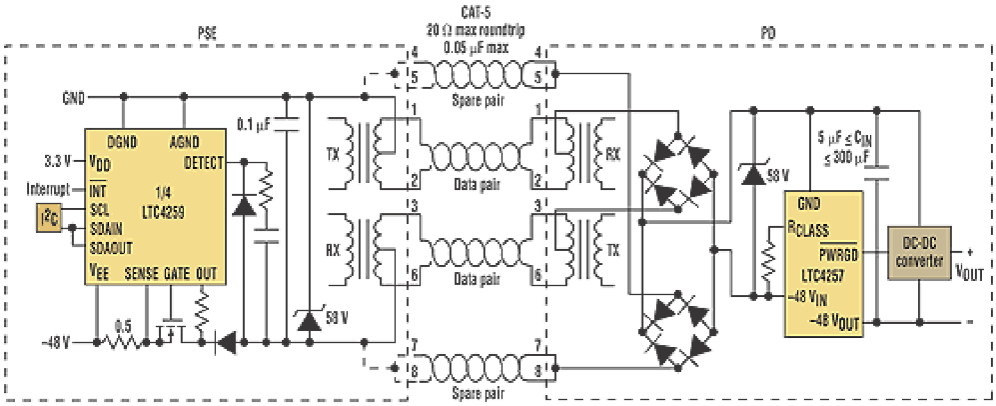
For example, the LTC4259 can control four 802.3af-compliant ports with little or no software intervention. In auto mode, the device assumes there is 15.4 W available for every port. Alternatively, the LTC4259 can alert the controller when it detects a new PD, letting the controller decide to power the port or not. The device's analog circuitry implements 802.3af-compliant detection, classification, I_{LIM}, and I_{CUT} limits, as well as ac and dc disconnect with a minimum of external components. The device uses standard 1/8-W surface-mount resistors to sense the port current, and its ac-disconnect circuitry measures the PD impedance without being fooled by long cables or stray capacitance. In large systems, up to 16 of the ICs can coexist on the same I^2C or SMBus, controlling up to 64 Ethernet ports. Programmable interrupts and push-button registers keep software complexity to a minimum.

Figure 1



1. IEEE 802.3af, the PoE standard, assigns pairs on the CAT-5 cable and RJ-45 connector to carry up to 12.95 W to power peripheral devices.

Figure 2



2. A complete PoE connection includes diode bridges that implement autopolarity circuitry.

Table 1

TABLE 1: PORT VOLTAGE VERSUS LINK STATE TO POWERED DEVICE

PSE voltage range (V)	PD voltage range (V)	State name	Description
2.8 to 10	2.7 to 10.1	Detection	PSE probes PD for 25-kΩ detection signature resistance
15.5 to 20.5	14.5 to 20.5	Classification	PSE forces voltage, measures PD class current signature
30 to 44	30 to 42	Startup	PSE applies power, PD comes out of UVLO
44 to 57	36 to 57	Powering	PSE providing power to PD
0 to 2.8	N/A	Idle	PSE output voltage while not in other states

Table 2

TABLE 2: POWER-CONSUMPTION CLASSES FOR POWERED DEVICES

802.3af class	Classification current (mA)	Maximum PD power (W)	Minimum PSE power (W)	Class description
0	0 to 4	12.95	15.4	Unknown, PD doesn't implement classification
1	9 to 12	3.84	4.0	Low-power PD
2	17 to 20	6.49	7.0	Medium-power PD
3	26 to 30	12.95	15.4	High- or full-power PD
4	36 to 44	12.95	15.4	Reserved for future use, power as Class 0

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