New Power for Ethernet—The LTC4255 Delivers (Part 1 of a 3-Part Series)

by Dave Dwelley

Introduction

For years, data has passed over Ethernet CAT-5 networks, primarily to and from servers and workstations. The IEEE 802.3 group, the originator of the Ethernet standard, is currently at work on an extension to the standard, known as 802.3af, which will allow DC power to be delivered simultaneously over the same wires.[1] This promises a whole new class of Ethernet devices, including link-powered IP telephones, wireless access points, and PDA charging stations, which do not require additional AC wiring or external power transformers ("wall warts"). With about 13W of power available, small data devices can be powered by their Ethernet connection, free from AC wall outlets.

Modern Ethernet networks and traditional telephone systems share much in common. Both typically send data or voice over unshielded twisted-pair connections, and both are typically connected in a "star" configuration, where each terminal is connected to a central switch or hub. One significant difference, however, is that traditional phones are usually powered through the same wire as their "data" connection, whereas Ethernet devices require a local source of power. 802.3af changes this, by allowing the central switch to provide 48VDC at up to 13W through the familiar RJ45 connector. Sophisticated detection and power monitoring techniques prevent damage to legacy data-only devices, while still supplying power to newer, Ethernet powered devices over the CAT-5 wire.

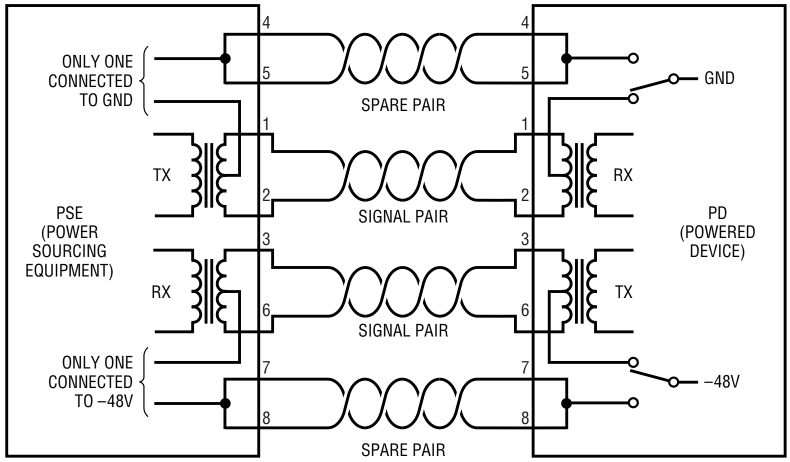

Figure 1. Delivering power over existing Ethernet cables using the center tap of the transformer

A device that supplies power is called a PSE (for Power Sourcing Equipment); a device that draws power from the wire is called a PD (for Powered Device). A PSE is typically an Ethernet switch, router, hub, or other network switching equipment that is commonly found in wiring closets or under desks where CAT-5 cables converge. PDs can take many forms: digital IP telephones, wireless network access points, PDA or notebook computer docking stations, cell phone chargers, and HVAC thermostats are examples of devices that can draw their power from the network. Virtually any device that requires a data connection and can run from 13W or less can shed its AC power cord or batteries and operate off the RJ45 connector alone.

This article is the first in a three-part series on Powered Ethernet. This issue features Part 1, which covers the power details of the system, with a particular focus on the PSE and its characteristics. Part 2 will cover the PD in detail, while Part 3 will discuss the nuances of detection and classification—the mechanism that the 802.3af standard uses to ensure that PDs receive power while legacy data-only devices remain unpowered.

Power Over Ethernet Glossary

- **PSE (Power Sourcing Equipment)**—usually a router or hub, but can also be a midspan
- **PD (Powered Device)**—any device that is powered over the Ethernet by a PSE: can be a phone, a WAP (Wireless Access Point) or even a PDA charger or an exit sign
- **Midspan**—a device that plugs in-line to convert a conventional router to a PSE; typically powers the spare pairs
- **Signal Pairs**—pairs 1-2 and 3-6 in CAT-5 cable
- **Signal Pairs**—pairs 4-5 and 7-8 in CAT-5 cable
- **PHY (Physical Layer Interface)**—the differential transceiver that transmits and receives data over the link

Delivering Power over Ethernet Cables

A CAT-5 Ethernet cable contains four unshielded twisted pairs of 24-gauge copper wire in a common sheath, with RJ45 connectors on each end. In a typical 10BASE-T or 100BASE-TX

(10/100) network, two of the pairs (the "signal pairs") are used for data transmission (one for transmit, one for receive) and two pairs (the "spare pairs") are unused. 1000BASE-T (Gigabit over Copper) networks use all four pairs, and are compatible with most aspects of Powered Ethernet, although there are some incompatibilities and some aspects of the 802.3af standard do not explicitly support 1000BASE-T.

A PSE is required to provide a nominal 48V DC between either the signal pairs or the spare pairs (but not both)—see Figure 1. The power is applied as a common mode voltage difference between the two powered pairs, typically by powering the center-taps of the isolation transformers used to couple the differential data signals to the wire. Since Ethernet data lines are transformer-isolated at each end of the wire, this 48V potential difference between the transmit pair and the receive pair has no effect on the data transceivers on either end. The spare pairs can be tied together and powered directly (as shown in Figure 1), or they can be powered via transformer center taps in the same manner as the signal pairs if compatibility with 1000BASE-T is required.

The 48V supply used to power the line must be isolated from the PSE chassis ground to maintain the isolated link between the PSE and the PD. The IEEE defines two methods of isolation, named Environment A and Environment B. Environment A PSEs must isolate the 48V supply from the PSE chassis but need not isolate between adjacent ports, while the more stringent Environment B requires that ports be isolated both from the chassis and each other. In keeping with telecom conventions, the 48VDC supply is often referred to as a –48V supply; however, since the supply must be isolated from the chassis, which end is deemed to be "ground" is relatively arbitrary.

PSEs are physically located in one of two places: either integrated into data switch/router/hub devices, or as a standalone unit known as a "midspan" that connects in-line between an existing data switch and the PD. An integrated PSE/switch is allowed to drive either set of pairs, but typically will drive the signal pairs. A midspan is required to drive the spare pairs.

PSE Power Requirements

- Output is –44V to –57V (usually –48V), isolated from chassis—
  Environment A: ports not isolated from each other
  Environment B: isolated from chassis and port-to-port
- 15.4W (44V • 350mA) minimum power supply—current limit may drop as voltage rises.
- Turn on within 1s after PD is plugged in (single port only)
- Support ≤400mA loads for at least 50ms without current limiting—
  Disconnect on overcurrent (>350mA) between 50ms and 75ms
  Disconnect on undercurrent (<5mA) between 300ms and 400ms

PSE Operation

A PSE is required to probe the cable for the characteristic PD signature before applying voltage to the wire. A valid PD signature consists of a 25k resistor with up to three diodes in series with it, and no more than 0.11µF in parallel. The cable must be probed with voltages of less than 10V to minimize the chance of damaging a legacy data-only Ethernet device that may not be prepared to see 48V between its terminals. Only after a valid signature is detected may the PSE apply power to the wire.

After detecting a valid signature, a PSE may optionally check for a second PD classification signature that indicates the maximum power the PD will ever draw. This classification signature appears as one of several specific currents drawn by the PD when probed with a voltage between 15V and 20V. If the PSE opts to classify the PD, it can use the information to allocate power from a common power supply, or even deny power if it finds that the PD is requesting more than the PSE has available. The entire detection/classification/power up sequence must be complete within one second from the time the PD is first connected to the port.

Once the PSE has detected and optionally classified the PD and has decided to turn on the power, it must provide between 44V and 57V (nominally 48V) to the appropriate pairs on the cable. The port must be able to supply at least 400mA for 50ms without current limiting, and must be able to supply 15.4W (44V • 350mA). As the port voltage rises, the PSE may reduce the current limit it allows, as long as the 15.4W power level is maintained. The 15.4W requirement allows for a PSE operating at the minimum voltage (44V) to supply the full 12.95W a PD is allowed to draw, plus the drop through a worst-case 20Ω round-trip cable at the 350mA maximum continuous current. The port must limit output current to below 450mA at all times to protect against short circuits on the cable. If the PSE senses an overcurrent condition for more than 75ms, it must turn the power off.

Once the power is on, the PSE must keep it on as long as the PD presents a valid *power maintenance signature*. This power maintenance signature consists of two components, both of which the PD must exhibit: a minimum DC current draw of at least 10mA, and an AC impedance lower than 33kΩ at all frequencies from DC to 500Hz. The PSE can opt to monitor either or both components of this signature to determine if the PD is still present. If the PSE senses that the signature is invalid, it must wait between 300ms and 400ms before removing power from the line. The 300ms minimum prevents false disconnects caused by glitches on the line or sudden drops in the line voltage, and the 400ms maximum prevents a fleet-fingered technician

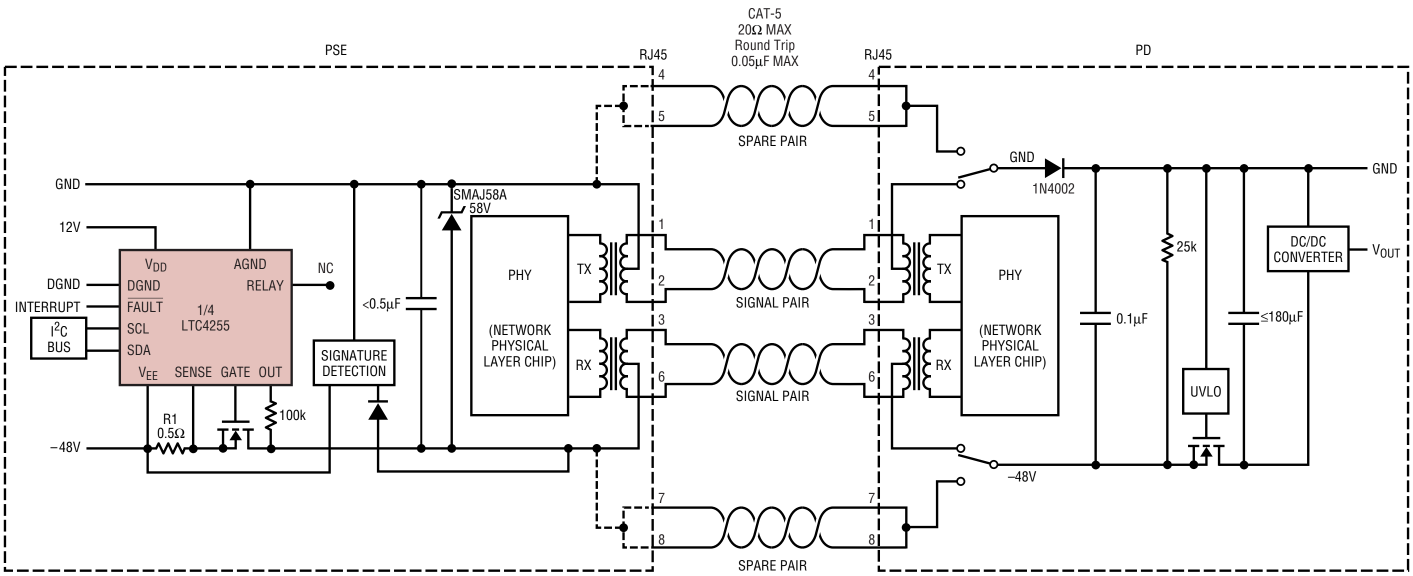

Figure 2. Power control circuitry using LTC4255 quad network power controller

from unplugging a valid PD and connecting a legacy device before the PSE has a chance to turn the power off.

LTC4255 Quad Network Power Controller

The LTC4255 is a quad –48V power controller, designed to implement the power path portion of a PSE device. It contains complete power management and switching circuitry for four channels, including –48V Hot Swap™ switching, current inrush control, current limit, and DC disconnect sensing for four ports. Internal status and control registers allow the LTC4255 to accept commands and report back status to the host system via the industry-standard two-wire I^{2}C™ serial bus protocol. One LTC4255 channel, together with a standard differential data transceiver (commonly known as a "PHY"), a detection/classification circuit, and a couple of external components make a complete powered Ethernet port. The quad configuration of the LTC4255 makes it useful in multiport PSEs, such as powered Ethernet switches or hubs.

The primary function of the LTC4255 is to control the delivery of power to the PSE port. It does this by controlling the gate drive voltage to an external MOSFET (Figure 2) while monitoring the output current via sense resistor R1 and the voltage at the OUT pin. This circuitry serves to couple the raw –48V supply to the port in a manner than meets the PD's requirements while minimizing disturbances on the backplane.

When it receives an I^{2}C bus command to turn on a port, the LTC4255 enters a timed startup mode where it powers up the PD in a mode that limits inrush current. The internal power control circuitry servos the gate drive to the external MOSFET to limit the port current, allowing the voltage at the port to rise in a controlled manner as the PD input capacitance charges. An internal timer controls the inrush duration, and foldback current limiting reduces the maximum current limit when the output voltage is below 30V, minimizing power dissipation in the external MOSFET. If the port reaches full voltage and the current draw drops below the current limit before the timer expires, the LTC4255 assumes the port turned on normally. It sets the Power OK bit in the status register and keeps the MOSFET gate turned fully ON until a disconnect or fault event occurs. If the port is still in current limit when the timer expires, the LTC4255 assumes there is something wrong with the PD, turns off the power and sets the corresponding fault bit in the status register.

Current Limit Protection

Once power has ramped up to its final value and the start-up timer has expired, the LTC4255 shifts to normal operation. In normal operation, the port current should never exceed the current limit level, I_{MAX}. The current limit circuit monitors the port current by watching the voltage across R1 and reduces the MOSFET gate voltage as needed to keep the current below I_{MAX}. When the current drops below I_{MAX}, the gate voltage is restored to the full value to keep the MOSFET resistance to a minimum.

If the port reenters current limit at any time after startup, a current limit timer starts. If this timer expires, the port is turned off and the fault bit is set in the corresponding power status register. The current limit timer is an integrating counter that decrements at a slower rate than it increments, preventing intermittent current limits from overheating the external power MOSFET.

DC Disconnect Detection

An additional current monitoring circuit trips when the port current drops below the minimum allowed level, signifying that the PD has been unplugged or has removed its power maintenance signature. If the current is still below the minimum when

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the disconnect timer runs out, the port power is turned off and the corresponding status bit is set. The LTC4255 monitors the DC component of the Power Maintenance Signature only; additional circuitry is needed to monitor the AC component of the signature if required by the application.

Conclusion

The LTC4255 provides complete power control circuitry to switch 48V onto Ethernet wires, greatly simplifying the design of the power path of PSE devices. An LTC4255, together with a standard quad PHY chip, a detection/classification circuit, and a handful of external components make four complete powered Ethernet ports. Fault protection, startup control, and disconnect sensing are all performed by the LTC4255, minimizing external circuitry. The I^2C interface simplifies monitoring and control of the LTC4255 by a host system.

Part 2 of this series will cover the details of PD design and show how to put together the power receiving end of the link.

Notes

[1] The 802.3af standard is still in draft form, and parts of the standard are still in flux. No product can yet claim full compliance, but compatible products are already available in advance of the final standard. For the latest information on the state of the 802.3af standard or on LTC products designed to meet the standard, contact the LTC Applications department.

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