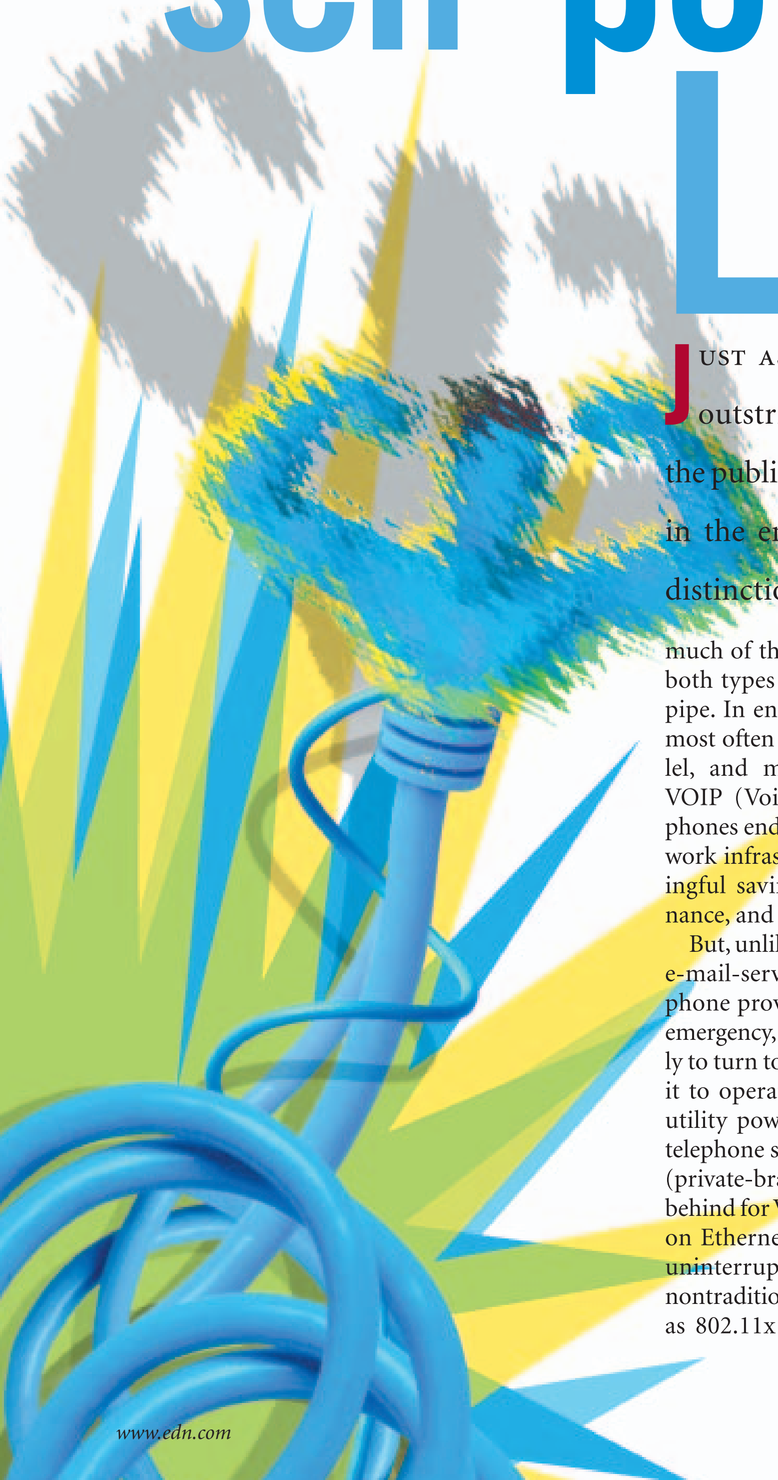
 By Joshua Israelsohn, Technical Editor

The self-powered LAN



A NEW TWIST ON AN OLD PAIR: DISTRIBUTING POWER ON SIGNAL CABLES INCREASES NETWORK FLEXIBILITY, UTILITY, AND UPTIME—NOT BAD FOR A CONCEPT THAT DATES BACK SOME 75 YEARS.

JUST AS DATA has long since outstripped voice traffic on the public network, so it is within the enterprise. One critical distinction however, is that much of the public network transports both types of traffic through the same pipe. In enterprises, phones and LANs most often operate on dissimilar, parallel, and mutually isolated networks. VOIP (Voice Over Internet Protocol) phones end the need for redundant network infrastructure and provide meaningful savings in installation, maintenance, and operations costs.

But, unlike your Internet-gateway and e-mail-server connections, your desk phone provides "lifeline" service. In an emergency, it's the first device you're likely to turn to, and when you do, you need it to operate properly, whether or not utility power is available. So, as office telephone systems leave traditional PBX (private-branch-exchange) technologies behind for VOIP phone systems running on Ethernet, each desk set requires an uninterruptible power source. Other nontraditional Ethernet appliances, such as 802.11x APs (access points), badge readers, and security cameras, also require power—often in locations lacking nearby power outlets.

Whether or not conveniently located power outlets are available, equipping every office cluster and security point with battery-backup power is expensive, and enterprisewide uninterruptible mains are rarely practical. The recently ratified IEEE 802.3af draft standard defines POE (power over Ethernet), which provides an economic means to distribute power from a centrally located uninterruptible source using the existing installed base of cabling, patch panels, and connectors.

The idea isn't new. Many applications combine power, signal, and control lines in multiconductor cables. What is unusual in the Ethernet LAN application is that the system must enable or disable the remote power without human intervention by identifying when a LAN-powered device is connected to or disconnected from the network. Furthermore, OEMs will classify their products according to the devices' power requirements, and the system must be able to identify each load's requirements during the power-initialization stage.

HOLDING BOTH ENDS

Common safety practices—those that prevent personal injury, damage to the premises, and damage to devices that users connect to the network—require a current-limited power source that is detached from a node except when a user attaches a network-powered appliance. Network-powered and externally powered devices connect to the same type of ports through standard RJ-45 jacks. A PSE (power-source-equipment)-control IC enables the power connection if it detects a valid PD (powered-device) signature on the appliance end. A PD con-

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AT A GLANCE

▷ POE (power over Ethernet) enables "lifeline" service delivery in an Internet Protocol environment.

▷ POE simplifies installation of nontraditional network terminal appliances, such as Web cameras and access-control devices.

▷ A fast, safe, and reliable method of distinguishing network-powered terminal equipment from externally powered devices, which IEEE 802.3af defines, is a necessary first step to ensuring POE interoperability.

▷ Though the IEEE only recently ratified the draft standard, key semiconductor vendors that have been tracking the standard's progress are now making available 802.3af-compliant chip sets.

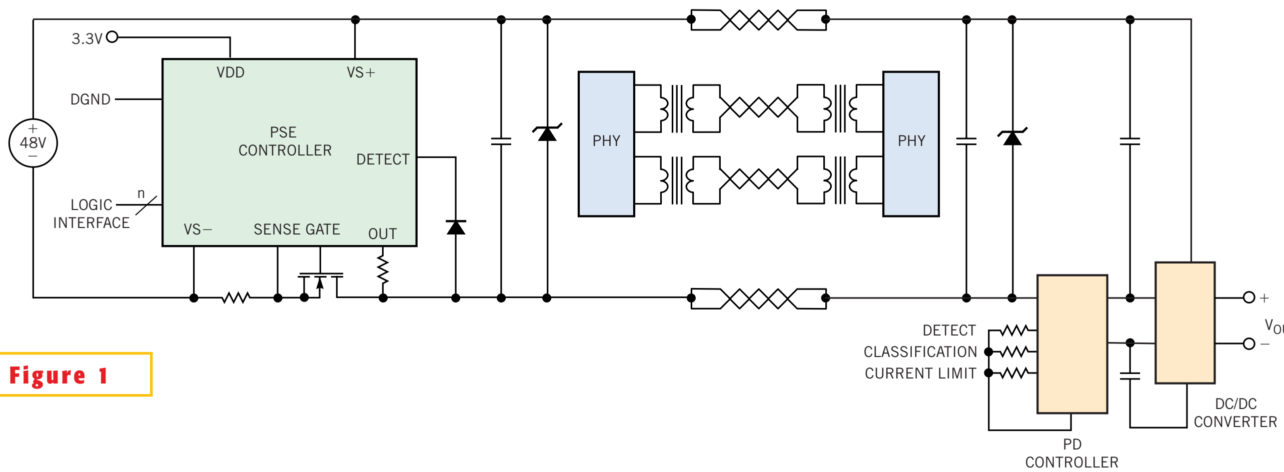

Figure 1

IEEE 802.3af provides remote power for Ethernet-terminal devices using the spare pair in a Category 3 or 5 cable as long as 100m.

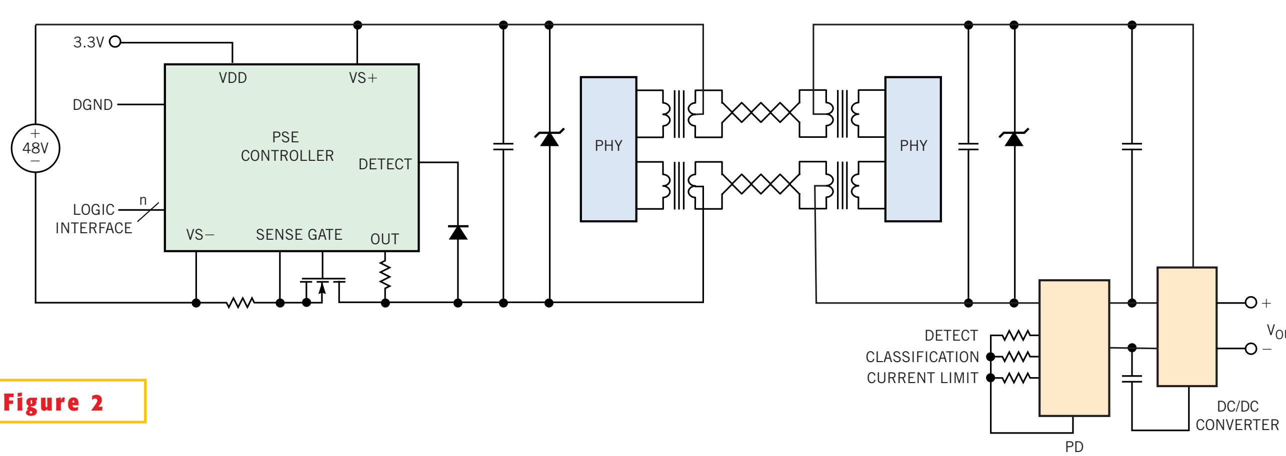

Figure 2

Network nodes lacking spare pairs, including those for 1000BaseT Gigabit Ethernet, must deliver power over signal wires.

SHAKING HANDS

By Todd Nelson, Linear Technology

The fundamental defining characteristic of a PD (powered device) is its 25-kΩ-signature impedance, which it presents to the Ethernet cable when the system probes it with voltages lower than 10V. Before a PSE (power-source-equipment) controller applies power to the line, it must check for this signature resistance with a power-limited probing source of 2.8 to 10V.

A valid PD signature looks like 25 kΩ ±5% in parallel with a capacitance of 120 nF or less. The PSE, in turn, must accept a somewhat wider range of 19 to 26.5 kΩ to account for parasitic resistances in the system. The PSE accepts only resistances of 15 to 33 kΩ or ports with less than 10 μF across their terminals.

The PD signature impedance can have a voltage offset as high as 1.9V, sufficient to accommodate two protection diodes in series. The signature can also have a current-offset as high as 10 μA to account for typical leakage currents in the PD. To eliminate these error terms from the resistance measurement, the PSE implements a two-point measurement separated by at least 1V at the PD. Calculating the difference between the two measurements strips out the leakage current and offset voltage error terms.

CLASS CHECK

Once the PSE detects a valid PD, it can optionally probe the PD to determine how much power it will draw. This second classification signature provides a means for the PSE to estimate how much power it needs to allocate to a port, because not all PDs draw the full 12.95W that the 802.3af allows.

The PSE controller checks the classification signature by forcing voltage across, or current into, the PD, pushing the port to 15 to 20V. In this classification-signature band, the PD must behave like a constant-current source with a shunt impedance of 19 kΩ or higher (**Figure A**). The PSE measures this current and compares it with a set of fixed values that determine the class into which the PD falls. The voltage source that the PSE uses during classification must be no higher than 100 mA to avoid damaging a malfunctioning PD, and it must not be connected for more than 75 msec to keep PD power dissipation under control.

PDs come in four classes, and the spec reserves a fifth for future use. Classes 1 to 3 designate quarter-, half-, and full-power PDs, respectively. Class 0 is the default if a PD does not implement class-signature circuitry; a 25-kΩ signature resistor all by itself lands in the Class 0 current range. The spec reserves Class 4 for future use; a PSE that discovers a Class 4 PD should treat it as a Class 0.

Once a PSE has successfully detected and classified a PD, it decides whether to power it. If the available power in the PSE is adequate to power the PD, the PSE turns on the power to the PD and begins monitoring the port for the power-maintenance signature. This signature comprises a minimum-dc-current draw of 10 mA and an ac impedance of less than 33 kΩ at frequencies of 500 Hz or lower. If the PSE senses that the signature is invalid, it must wait 300 to 400 msec before removing power from the line. The 300-msec minimum prevents false disconnections that spikes on the line or sudden drops in the supply voltage cause, and the 400-msec maximum prevents a fleet-fingered technician from unplugging a valid PD and connecting a legacy device before the PSE has a chance to turn off the power.

In normal operation, the port must be able to supply at least 400 mA for 50 msec without current-limiting and must be able to supply 15.4W (44V×350 mA). Therefore, the PSE must monitor a 350- to 400-mA continuous current limit, I_{CUT}, and a timed current limit, I_{LIM}, of 400 to 450 mA. The port must also always limit output current, I_{SC}, to less than 450 mA (**Figure B**).

AUTHOR'S BIOGRAPHY

Todd Nelson is product marketing manager at Linear Technology (Milpitas, CA).

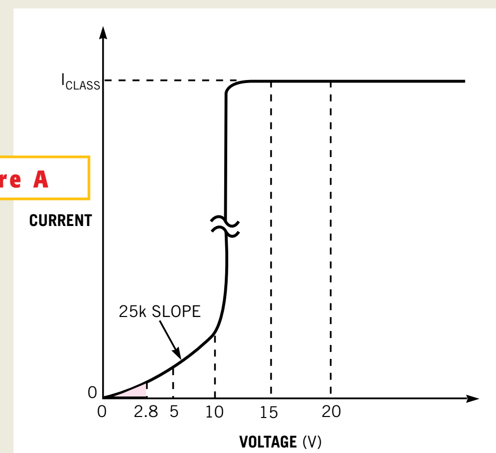

Figure A

In addition to presenting the appropriate detection signature to the line, the PD controller is also responsible for presenting appropriate V-I characteristics to identify the PD's load classification.

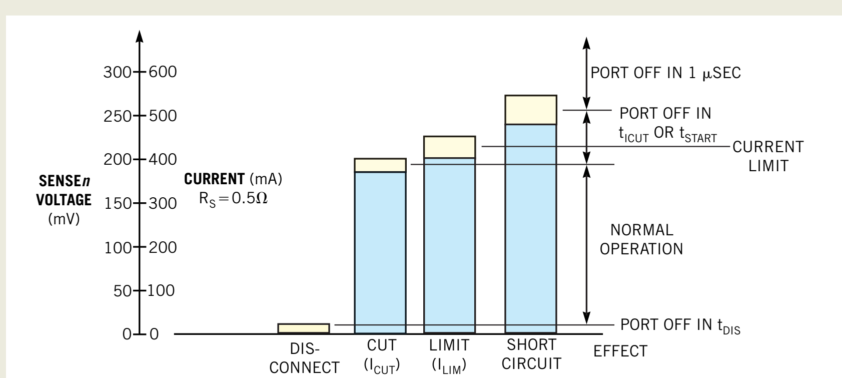

Figure B

The PD controller must balance the current limits that the application's safety requirements impose with reasonable fast charge times at start-up and accommodate line and load transients.

troller identifies a network-powered appliance to the PSE and manages a local dc/dc converter that feeds the appliance circuitry.

The basic architecture simplifies the detection process but by no means reduces the problem to a triviality. Ethernet's 100-Mbps 10BaseT and 100-Mbps 100BaseTX and 100BaseT2 configurations use two pairs of the four available in Category 3 and 5 cable, extending as far as 100m (**Reference 1**). The PSE and PD controllers commonly use the spare pairs to control and deliver power to network nodes presenting appropriate detection signatures (**Figure 1**). An alternative connection, which 1000BaseT networks require to support POE, connects the supply to the signal transformers' center taps (**Figure 2**).

The PSE controller's initialization routine must identify a valid PD signature during a brief interval over as much as 100m of cable, despite the line inductance, shunt capacitance, and interference signals coupling from adjacent cables. Like data modems and other remote-communications devices, the PSE and PD controllers initialize a connection by engaging in a stimulus-and-response handshake algorithm. Unlike modems that handshake on variously modulated bit streams, the PSE and PD use V-I profiles for detection and classification (see **sidebar** "Shaking hands").

During the 802.3af draft standard's evolution, the resistive-based V-I profile was by no means the only detection method that the working group considered. A read through the presentation documents, particularly those from the January 2000 working-group meeting, show a flurry of ideas and supporting arguments for diode-detection schemes, oscillator-based arrangements, and current-pulse coding, as well as various approaches to the resistive-detection method (**references 2** to **7**).

THE CHIPS ARE DOWN

Several IC manufacturers that have been tracking the progress of 802.3af have PSE/PD controller chip sets available. Due care is warranted, however: With the current draft standard only recently ratified, several products implement early, unratified drafts, perhaps recalling to mind the saying "The early bird may get the worm, but the *second* mouse gets the cheese." Whether you liken chip vendors to birds or to mice, familiarize yourself with the attachment and detachment algorithms, operational limits, and other parametric features of the standard and compare them with the manufacturer's data sheet. Parts that claim 802.3af conformance or compatibility designed to a superseded draft could fail to conform to the ratified standard or interoperate with conforming parts.

Beyond issues of standards conformance and interoperability, differences may manifest themselves in protection features, the adequacy and value of which you determine in the context of your design. Keep in mind that PSE systems nominally operate over 44 to 48V and, under fault conditions, deliver as much as 450 mA. Though the PSE and PD controllers provide orderly power-up and -down routines, users can routinely disconnect network-powered appliances without warning. The same users can also source ESD strikes, either to the network's RJ-45 jack or to a detached appliance's network connector. Consider subsystem protection in POE applications as central to your design as you would in any hot-swap environment.

The Texas Instruments TPS2383 PSE controller can detect valid PD signatures, classify loads, and deliver power to eight network nodes. You can embed the 2383, which is available in an LQFP-64 package, in head-end equipment or as a midspan retrofit. Your system can manage and monitor the PSE controller on a per-port basis by writing and reading registers through an I^2C interface.

The PSE controller limits di/dt during both power-up and -down sequences to minimize EMI. While charging the PD's bypass capacitance, the controller limits the PD current to less than 400 mA for 50 msec—enough to charge 450 μF to 44V. After the 50-msec turn-on interval, the controller continuously monitors the average and peak PD current. If the average current falls below 10 mA or exceeds 375 mA, or if the peak current is greater than 425 mA, the controller sets appropriate status bits and removes power from the load. The controller makes its monitoring measurements with an on-chip 12-bit ADC and stores the conversion results in read-back registers.

In applications that benefit from budgeting node power, the PSE controller can read power classification resistances during the power-up sequence. In cases in which such budgeting information is of no value, you can shorten the power-up sequence by programming the $7 (1000) TPS2383 to bypass the classification routine.

Linear Technology's LTC4258 and LTC4259 quad PSE controllers can operate either autonomously or under a microprocessor through an I^2C interface. A 4-bit device address allows one two-wire I^2C bus to control 64 channels. The 4258/59 detects and classifies four 802.3af-compliant PDs, senses PD disconnections, and indicates each channel's status. Unlike PSEs currently available from other vendors, the Linear Technology parts operate on a -48V supply, common in currently available telephone systems.

The two PSE chips can operate in any of four modes. A manual mode allows the host system to directly supervise ports. On command, the PSE controller runs a detection or classification cycle and stores the outcome in a port-status register. The host can also instruct the controller to turn off a port. In the semiautomatic mode, the PSE controller continuously polls a port to detect and classify a valid PD load and stores the poll results in the port-status register. The controller waits for the host to set the power-on bit in the power-enable PB register. The controller polls, detects, classifies, and energizes PD loads when operating in its auto mode. The LTC4258 and LTC4259 also have a shutdown mode, which disables the ports and resets the detect-, fault-event-, status-, and enable-bits.

Independent of operating mode, both devices de-energize any node that draws excessive current longer than the start-time- or current-limit-time-out intervals. They shut off channels that fail to draw the minimum valid-PD load current—typically 7.5 mA with a tolerance of ± 2.5 mA, so that ports are not left with power applied when a user removes network-powered appliances. The LTC4259 can also implement an ac-disconnection-detection method that monitors the load's ac impedance.

The $6.35 (1000) LTC4258 and the $6.95 (1000) LTC4259 provide gate control for each channel's associated pass element. Sense resistors provide feedback for inrush control and current limiting. Linear Technology packages both devices in SSOP-36 packages.

FOR MORE INFORMATION...

For more information on products such as those discussed in this article, contact any of the following manufacturers directly, and please let them know you read about their products in *EDN*.

Cisco Systems
www.cisco.com

Extreme Networks
www.extremenetworks.com

Hewlett-Packard
www.hp.com

Linear Technology
www.linear.com

Lucent Technologies
www.lucent.com

Maxim Integrated Products
www.maxim-ic.com

Nortel Networks
www.nortelnetworks.com

PowerDsine Ltd
www.powerdsine.com

Texas Instruments
www.ti.com

3Com
www.3com.com

OTHER COMPANIES THAT CONTRIBUTED TO THE 802.3AF STANDARD PROCESS

Alcatel
www.alcatel.com

Avaya
www.avaya.com

Intel
www.intel.com

Mitel
www.mitel.com

Proxim
www.proxim.com

Symbol Technologies
www.symbol.com

TRADE GROUPS, STANDARDS ORGANIZATIONS, AND LABS

ANSI (American National Standards Institute)
www.ansi.org

EIA (Electronic Industries Alliance)
www.eia.org

IEEE (Institute of Electrical and Electronics Engineers)
http://grouper.ieee.org/groups/802/3/af

TIA (Telecommunications Industry Association)
www.tiaonline.org

University of New Hampshire Interoperability Laboratory
www.iol.unh.edu

Maxim's PSE controller, the \$3 (1000) MAX5922 single-port device integrates a 0.45Ω power-MOS output switch with the controller. It features a programmable current limit and zero-current detection with a PD leakage tolerance of 100 μA.

When the 5922 identifies a valid PD load, it minimizes EMI during start-up by limiting the output-voltage slew rate to 100V/msec and current slew rate to 35A/msec. The \$3 (1000) PSE controller accommodates an operating-voltage range of 32 to 60V and provides for a resistor-programmable UVLO (undervoltage lockout).

Unlike the other PSE controllers currently available, Maxim's controller has no serial bus for programming. Individual logic inputs enable the device, zero-current detection, PD detection, and classification. Similarly, individual logic outputs provide flags for overtemperature or overcurrent faults, power-OK, and zero-current detection. The controller, available in a TSSOP-28 package, also reports the load classification through a 3-bit status word.

On the PD-appliance end, the Texas Instruments TPS2370 connects an external detection-signature resistor across its supply rails when powered with 1.8 to 10V. During the detection phase, the controller draws a maximum of 12 μA. When the controller's supply is 15 to 20V, the 2370 presents an external classification resistor across its supply. At ranges greater than 20V, the device disconnects the classification resistor, limiting its dissipation, and idles in its UVLO state until the supply reaches 40V.

At 40V, the \$1.25 (1000) controller connects the PD appliance's dc/dc converter to the supply rails through an integrated 300-mΩ FET, and the converter's bypass capacitor begins to charge. The PD controller's EN_DC pin connects an external soft-start capacitor to a current sink to prevent the capacitor from charging until the converter's supply has ramped to within 1.5V of the input voltage. Once the converter's supply is within range, the PD controller's current sink lets go of the capacitor, allowing the converter to soft-start. Texas Instruments provides the TPS2370 in either a TSSOP-8 or an SO-8 package.

Linear Technology's LTC4257 PD controller offers functions similar to those of the TPS2370 but with somewhat fewer external components. The LTC4257 integrates the 25-kΩ-signature resistor and a precision inrush-current limiter, leaving only the classification resistor on its system-side interface. On the appliance side, an external pullup resistor completes the open-drain power-good indicator.

Though designed for nominal −48V power rails, the 4257 can operate on supplies as large as −100V, allowing you to use unregulated power sources and maintain a healthy safety margin. The \$1.65 (1000) PD controller in an SO-8 package features a 39V nominal UVLO with about 9V of hysteresis.

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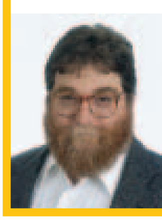

THIS JUST IN

At press time, the University of New Hampshire Interoperability Laboratory was performing multivendor POE tests on products from 3Com, Extreme Networks, Nortel Networks, PowerDsine, and Texas Instruments. An update notice will be posted with the online version of this article when results are available.□

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