1 Introduction

The Power-over-Ethernet (PoE) technology provides electrical power via standard Cat-5 Ethernet cables, thereby eliminating the need for wall adapters or other external power sources for equipment connected in an Ethernet network. The two major components in a PoE system are the power sourcing equipment (PSE), that provides the power, and the powered device (PD), that receives and uses this power (see Figure 1).
Recommended Characteristics

Recently, practical applications using PoE have been developed. Many of these new applications require more power than the power limit defined in the current 802.3af standard (approximately 13 W at the PD end). For example, a sophisticated security system with motor-controlled cameras would benefit from high-power PoE.

2 Recommended Characteristics

Any high-power solution must meet the following basic criteria:

- Must not result in overheating of the Ethernet cables
- Must not result in imbalance of current within a pair of wires, so as not to risk saturating Ethernet transformers
- Must be useable with the existing cabling system, based on Cat-5 cable type.
- No overheating in PSE nor in PD
- Operating voltage within the 802.3af standard voltage range

Also, any four-pair solution providing more than 30 W should provide (if possible) the following features:

- Compatible with 802.3af standard PDs: discovery, classification, current consumption, inrush current, current limit, etc.
- Power management capability
- Use of magnetic components compatible with 802.3af standard
- No additional heating in PSE, PD, or in between
- No loss of efficiency of complete system; even better if efficiency increases

3 Simple Four-Pair High-Power PSE Solution

The IEEE802.3af standard stipulates a PSE output voltage from 44 V to 57 V, with an $I_{\text{CUT}}$ (represents a level beyond which power consumption is regarded as an overload) of 350 mA minimum and an $I_{\text{LIM}}$ (represents the highest consumption level possible) of 400 mA minimum. Using 100 m of Cat-5 cable with a worst-case feed resistance of 20 Ω (from IEEE802.3af) results in a limit of 12.95 W at the PD’s input, when operating at the minimum allowed voltage.

Integrated power controllers like the TPS2384 are factory set to meet this requirement. The TPS2384 is capable of delivering 425 mA ($I_{\text{LIM}}$) nominally to the port for a short time. Also, if the port current exceeds 375 mA ($I_{\text{CUT}}$) for more than 62 ms ($T_{\text{OVLD}}$), the TPS2384 turns off the port.
The high-power solution, based on use of the TPS2384, involves operating at higher bus voltage and using two PSE ports; each one is connected to a separate PD, isolated from each other on the PD end of the cable. Each PD then has its own switching power supply, electrically isolated from input to output. The outputs of these two power supplies then are connected in series to provide the total required voltage to a common load.

Today, Cat-5 communication wiring is the recognized minimum for broadband services. Its specific designation is EIA/TIA-568 and is built with 24 AWG conductors which results in a worst-case feed resistance of 12.5 Ω. In the following demonstration, it is assumed that such cable is used.

The minimum operating voltage must increase to 53 V, with 55 V nominal and 57 V maximum. This results in more power available per PSE port.

Having two PSE ports operating in tandem almost doubles the total PD input power available. Note that power is not exactly doubled because of some imbalance due to several factors including efficiency and output voltage tolerance of PD power supplies (see Figure 2).

Figure 2. Diagram of a Simple Four-Pairs Solution for 31-W PD (Minimum Worst Case)

The benefits of such a solution include:
- System efficiency increases by 2.5%.
- Dissipation in the cables, PSE, and PD front-end does not increase even if PD input power increases by 138%.
- Existing Cat-5 cable installations are still useable.
- The risk of imbalance on wires and saturation of magnetics is no greater than with standard PoE. However, good design rules must be followed to ensure that no such situation becomes a problem. In some cases, resistor-capacitor ballast networks may have to be installed.
- Compatible with 802.3af standard PDs
- Operating voltage of 53 V to 57 V is within the 802.3af standard voltage range of 44 V to 57 V.
Simple Four-Pair High-Power PSE Solution

- Power management achievable with the MSP430 microcontroller
- The magnetic components are the same as those used for a standard 802.3af PSE.

However, for this solution to work, the switching power supply providing the 55 V must regulate at a tighter tolerance (±3.5%).

Because the operating voltage is high, the 55-V overvoltage protection (OVP) function must be disabled by the MSP430 software. The TPS2384 allows disabling both the OVP and Port Under Voltage Protection on all four ports simultaneously. The 55-V power supply must incorporate OVP to ensure that any power supply failure does not propagate to the PSE, the loads, or the end-users (as should always be the case in any standard PoE application).

The PD should have the following characteristics:
- Electrical isolation from its input to its power supply output
- The total power available at the PD inputs is based on the usage of a well-designed PD power supply. Imbalance between pairs is determined by differences in efficiency and output voltage level between both PDs, including their power supplies. The total power available could be lower than indicated depending on the performance and quality of those power supplies.

For applications requiring even more power, it is possible to increase the minimum PD input power to as much as 35 W, using a special release of the MSP430 software.

The characteristics of such a system are:
- Power provided at the PD input increases by 168% versus a standard PoE system while the system efficiency increases by 1.3%.
- Operating voltage of 53 V to 57 V is within the 802.3af standard voltage range of 44 V to 57 V.
- Power management achievable with the MSP430 microcontroller
- The magnetic components are the same as those used for a standard 802.3af PSE.
- Existing Cat-5 cable installations are still useable.
- This level of power requires operation up to 400 mA. This is within the capability of the magnetic components, cables (Cat-5), and connectors used in PoE applications, and it is within the 802.3af standard.
- Current balancing between wires within each pair is required and is even more important at this current level.
- The \( I_{\text{cut}} \) function is disabled, but the \( I_{\text{lim}} \) (400 mA to 450 mA) is still in operation.
- In overload, the output is limited to the \( I_{\text{lim}} \) current level. The difference is that the port shutdown is triggered by a thermal detection mechanism rather than by a timer.
- This extra power requires that the PD input current limit is not below 400 mA
4 Conclusion

For higher power close to 35 W, a four-pair (Cat-5 cable) simple solution based on usage of a tighter tolerance power supply and operating two PSE ports in tandem is possible, using the TPS2384. Available power then can be increased anywhere from 138% to 168%.

5 References

1. TPS2384 User’s Guide (SLVU126)
2. PSE Solution Delivers High Power-Over-Ethernet to 25-W PD Over Two Pairs (SLVA221)
3. Simple PSE Solution Delivers High Power-Over-Ethernet to 16-18-W PD Over Two Pairs (SLVA224)
4. High-Power PoE PD Using TPS2375/77-1 application report (SLVA225)
IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

<table>
<thead>
<tr>
<th>Products</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amplifiers</td>
<td>Audio</td>
</tr>
<tr>
<td>Data Converters</td>
<td>Automotive</td>
</tr>
<tr>
<td>DSP</td>
<td>Broadband</td>
</tr>
<tr>
<td>Interface</td>
<td>Digital Control</td>
</tr>
<tr>
<td>Logic</td>
<td>Military</td>
</tr>
<tr>
<td>Power Mgmt</td>
<td>Optical Networking</td>
</tr>
<tr>
<td>Microcontrollers</td>
<td>Security</td>
</tr>
<tr>
<td></td>
<td>Telephony</td>
</tr>
<tr>
<td></td>
<td>Video &amp; Imaging</td>
</tr>
<tr>
<td></td>
<td>Wireless</td>
</tr>
</tbody>
</table>

Mailing Address: Texas Instruments
Post Office Box 655303 Dallas, Texas 75265

Copyright © 2006, Texas Instruments Incorporated