Introduction

Power over Ethernet (PoE) applications are covered by the IEEE 802.3 working group with specifications released in 2003 (IEEE 802.3af) and in 2009 (IEEE 802.3at).

Power at the input of the powered device (PD) increased from 12.95 W (of the .af standard) to 25.5 W (made available by the .at standard). In both cases the power delivery was based on the “2-pair” system, where 4 wires of the Ethernet cable are used (Tx, Rx pairs or spare pairs).

Applications requiring more power are constantly emerging and some solutions are already on the market even though there is no standard fully supporting these applications yet. Some of the alternatives are based on a 4-pair delivery system that allows doubling the power delivered along the Ethernet cable with respect to a 2-pair system.

This document focuses on a reference design for a high-efficiency, high-power PD (up to 60 W input) power converter based on an active-clamp forward topology with self-driven synchronous rectification using the PM8803 as the main controller. The total power is delivered on the 4 pairs of a single Ethernet cable by a high-power injector.

The PM8803 is a highly integrated device embedding an IEEE 802.3at compliant powered device (PD) interfaced with a PWM controller and support for auxiliary sources.

To manage the higher input current (up to 1.4 A) of high-power applications, a simple current booster is introduced in parallel to the PM8803 internal hot-swap MOSFET.

The proposed converter prototype is built from the PM8803 demonstration board, but several component changes have been introduced in order to manage the higher current on the input/output section of the converter.

Schematics of the PoE converter are given in Section 2 while the bill of material is detailed in Section 3. In Section 4 efficiency measurements together with main waveforms of the PoE interface and power converter are shown.
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# High-power PoE converter electrical specifications

## Table 1. Specifications for 3.3 V output

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
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<td>UVLO</td>
<td>Vin rising edge</td>
<td></td>
<td></td>
<td>36</td>
<td>V</td>
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<td></td>
<td>Vin falling edge</td>
<td></td>
<td></td>
<td>30</td>
<td>V</td>
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<tr>
<td>Auxiliary input voltage range</td>
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<td>48</td>
<td>54</td>
<td>V</td>
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<tr>
<td>Output voltage (Vout)</td>
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<td>3.25</td>
<td>3.35</td>
<td>3.45</td>
<td>V</td>
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<tr>
<td>Output current (Iout)</td>
<td>Vin= 42 V to 57 V</td>
<td>0</td>
<td></td>
<td>18</td>
<td>A</td>
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<tr>
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<td>70</td>
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<tr>
<td>Efficiency DC-DC only</td>
<td>Vin=48 V, Iout=Imax</td>
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<tr>
<td>Overall efficiency</td>
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2 High-power converter schematic

Figure 1. High-power converter schematic: detail of the input section including data transformers, bridges, protection and optional CM choke
Figure 2. High-power converter: detail of the PoE converter based on active-clamp forward topology with self-driven synchronous rectification.
3 Bill of material

The following table summarizes the bill of material for the high-power PoE converter based on the PM8803, configured in active-clamp forward topology with self-driven synchronous rectification.

Table 2. Bill of material

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<tr>
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<th>Description</th>
<th>Value</th>
<th>Tol</th>
<th>Voltage</th>
<th>Body</th>
<th>Vendor</th>
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Table 2. Bill of material (continued)

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4 Test results

4.1 Efficiency measurements with synchronous rectification

Figure 3. Efficiency measurements at 48 V input

The difference between dc-dc and overall measurements is about 3-4% from 10 A to 18 A.

Figure 4. Efficiency of the different circuits on the converter input stage
Figure 4 shows the various contributions to the total losses of the PD interface section of the converter:
- RJ45 and data transformer value is small but not negligible at high input current/power
- Booster value is negligible
- Major contribution comes from the rectification bridge; an active bridge with MOSFETs for a total value of about 150 mΩ per leg (about 100 mΩ for the P-channel MOSFET and 50 mΩ for the N-channel) will assure a gain of about 1.6% on the total efficiency over the full input current range.

Figure 5. Booster current characteristics

The external MOSFET carries about 85% of the whole input current. The current ratio is inversely proportional to the Ron of the MOSFET used, in this case 65 mΩ for the external MOSFET while for the PM8803 internal hot-swap MOSFET 400 mΩ can be used, as confirmed by the estimations done.

Figure 6. Booster power dissipation vs. input current

The power dissipation of the MOSFET booster is about 6 times higher than the internal hot-swap MOSFET.
4.2 Converter waveforms

4.2.1 Startup sequence using PowerDsine 9501G injector

Figure 7. Startup with 0 A load

Figure 8. Startup with 10 A load

The current unbalance in the Ethernet cable at steady state (between Tx, Rx and spare pairs) is minimum even at high load: see pink and blue traces.

For details on the injector please visit www.microsemi.com.
4.2.2 Primary-side MOSFET

Figure 9. Primary-side power MOSFET waveforms at 0 A load

Figure 10. Primary-side power MOSFET waveforms at 16 A load
4.2.3 Secondary-side MOSFET

Figure 11. Secondary-side power MOSFET waveforms at 0 A load

Figure 12. Secondary-side power MOSFET waveforms at 16 A load
4.2.4 Output ripple

Figure 13. Output ripple measurement at 0 A

Figure 14. Output ripple measurement at 16 A
Figure 15. Output ripple measurement at 16 A with infinite persistence
4.2.5 \( G_{\text{loop}} \) measurement and load transient response

Figure 16. Control loop of the converter at 48 V input and 18 A output

Figure 17. Response of the converter to a 8 A - 16 A load transient
## 5 Revision history

Table 3. Document revision history

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