AN4006
Application note

Designing a high-efficiency (60 W on 4 pairs) PoE converter using the PM8803 and an external current booster

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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1 High-power PoE converter electrical specifications

Table 1. Specifications for 3.3 V output

Parameter	Description	Min	Typ	Max	Unit
Input voltage range	applied at J3 connector	0		57	V
Operative input voltage		42		57	V
UVLO	Vin rising edge			36	V
	Vin falling edge	30			V
Auxiliary input voltage range		42	48	54	V
Output voltage (Vout)	Vin= 42 V to 57 V, Iout 0 to Imax	3.25	3.35	3.45	V
Output current (Iout)	Vin= 42 V to 57 V	0		18	A
Peak-to-peak output ripple	48Vin, Iout=Imax		50	70	mVpp
Efficiency DC-DC only	Vin=48 V, Iout=Imax		91		%
Overall efficiency	Vin=48 V, Iout=Imax		88		%
Switching frequency			220		kHz

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

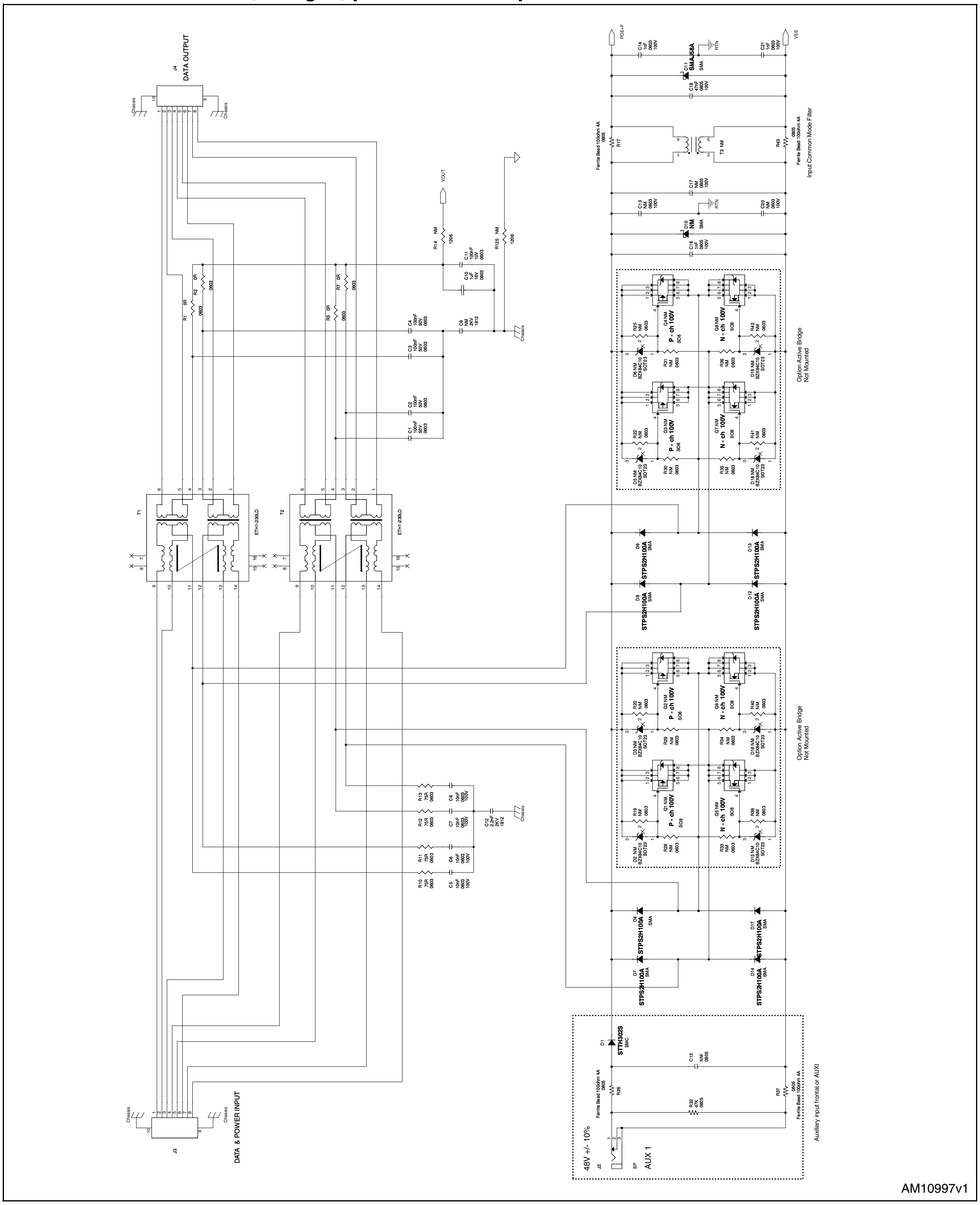
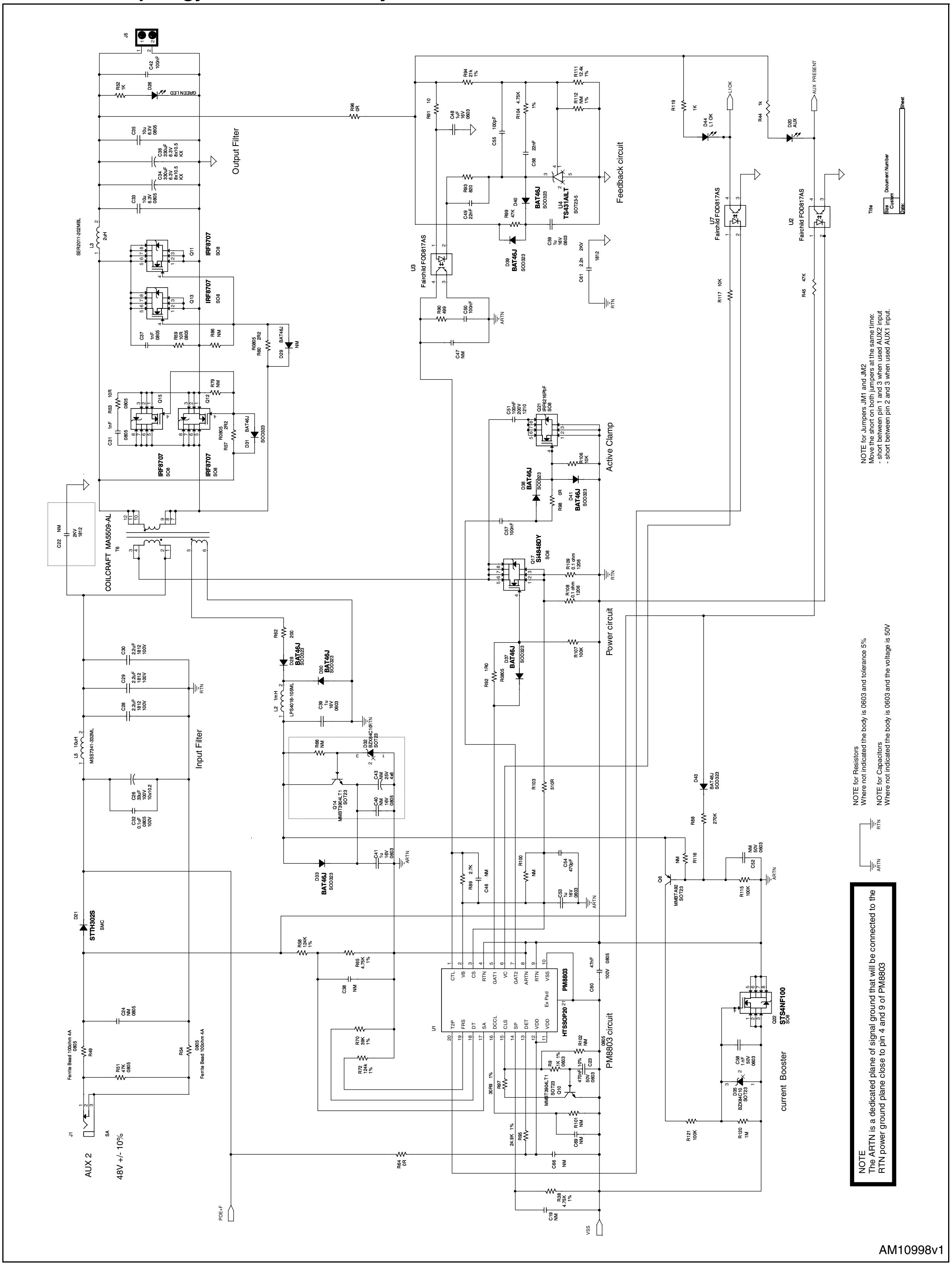


Figure 2. High-power converter: detail of the PoE converter based on active-clamp forward topology with self-driven synchronous rectification



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

Reference	Description	Value	Tol	Voltage	Body	Vendor
EVALPM8803 FWD rev1	Board PCB					
C1,C2,C3,C4, C11C42,C50, C57	Ceramic capacitor	100 nF		50 V	603	Std
C5,C6,C7,C8	Ceramic capacitor	10 nF	10%	100 V	603	TDK
C10,C39,C41, C53C59	Ceramic capacitor	1 µF	20%	16 V	603	Std
C12	Ceramic capacitor	2.2 nF		2 kV	1812	TDK
C14,C16, C21	Ceramic capacitor	1 nF	10%	100 V	603	TDK
C18,C60	Ceramic capacitor	47 nF		100 V	805	TDK
C19,C38	Ceramic capacitor	22 nF		50 V	603	Std
C23,C54	Ceramic capacitor	470 pF		50 V	603	Std
C26	Aluminium capacitor	33 µF	20%	100 V	10x10.2	Std Low ESR
C27,C33,C37	Ceramic capacitor	22 µF	20%	6.3 V	805	Std
C28,C29,C30	Ceramic capacitor	2.2 µF	20%	100 V	1812	TDK
C31,C37	Ceramic capacitor	1 nF	10%	100 V	805	Std
C32	Ceramic capacitor	100 nF	10%	100 V	805	TDK
C33,C35	Ceramic capacitor	10 µF		6.3 V	805	TDK
C34,C36	Aluminium capacitor	330 µF		6.3 V	8x10.2	Std Low ESR
C49, C56	Ceramic capacitor	22 nF		50 V	603	Std
C51	Ceramic capacitor	100 nF		200 V	1210	Std
C55	Ceramic capacitor	100 pF		50 V	603	Std
C58	Ceramic capacitor	1 nF		50 V	603	Std
C61	Ceramic capacitor	2.2 nF		2 kV	1812	TDK
D1, D21	Std diode	STTH302S		200 V	SMC	STMicroelectronics
D32,D35	Zener diode	BZX84C10			SOT23	Std
D4,D7,D8,D9, D12D13,D14, D17	Schottky diode	STPS2H100A		100 V	SMA	STMicroelectronics

Table 2. Bill of material (continued)

Reference	Description	Value	Tol	Voltage	Body	Vendor
D11	TVS diode	SMAJ58A			SMA	STMicroelectronics
D28,D30,D31, D33,D37,D38, D39,D40,D41, D43	Schottky diode	BAT46J		100 V	SOD323	STMicroelectronics
D20,D26,D44	LED	Green LED SMD		2.2 V	PLCC-2	Std
J1,J2	Power jack	SA, SP				Std
J3	RJ45 connector	DATA & POWER INPUT				Std
J4	RJ45 connector	DATA OUTPUT				Std
J5	Terminal block 2 way	MOR-10X10.5-P5-2PIN				Std
L2	SMT inductor	1 mH			LPS4018-105ML	Coilcraft
L3	SMT inductor	2 µH			SER2011-202MBL	Coilcraft
L5	SMT inductor	10 µH			MSS7341-103ML	Coilcraft
Q6	Transistor, PNP	MMBTA92		300 V	SOT23	STMicroelectronics
Q10, Q14	Transistor, NPN	MMBT3904LT1		40 V	SOT23	Std
Q11,Q12,Q13, Q15	MOSFET, N-channel	IRF8707		30 V	SO8	IR
Q17	MOSFET, N-channel	Si4848DY		150 V	SO8	VISHAY
Q21	MOSFET, P-channel	IRF6216PbF		150 V	SO8	NM
Q22	MOSFET, N-channel	STS4NF100		100 V	SO8	STMicroelectronics
R1,R2,R5,R7	Chip resistor	0 Ω			603	Std
R9	Chip resistor	1 kΩ	1%		603	Std
R10,R11,R12, R13	Chip resistor	75 Ω			603	Std
R17,R26,R37, R43,R49,R54	Ferrite Bead	MPZ012101A		100 Ω, 4 A	805	TDK
R26,R37,R49, R54	Chip resistor	0 Ω			805	Std
R19,R20,R22, R25R39,R40, R41,R42	Chip resistor	NM			603	NM
R58,R72	Chip resistor	124 kΩ	1%		603	Std
R32,R51	Chip resistor	47 kΩ			805	Std
R38,R65	Chip resistor	4.75 kΩ	1%		603	Std

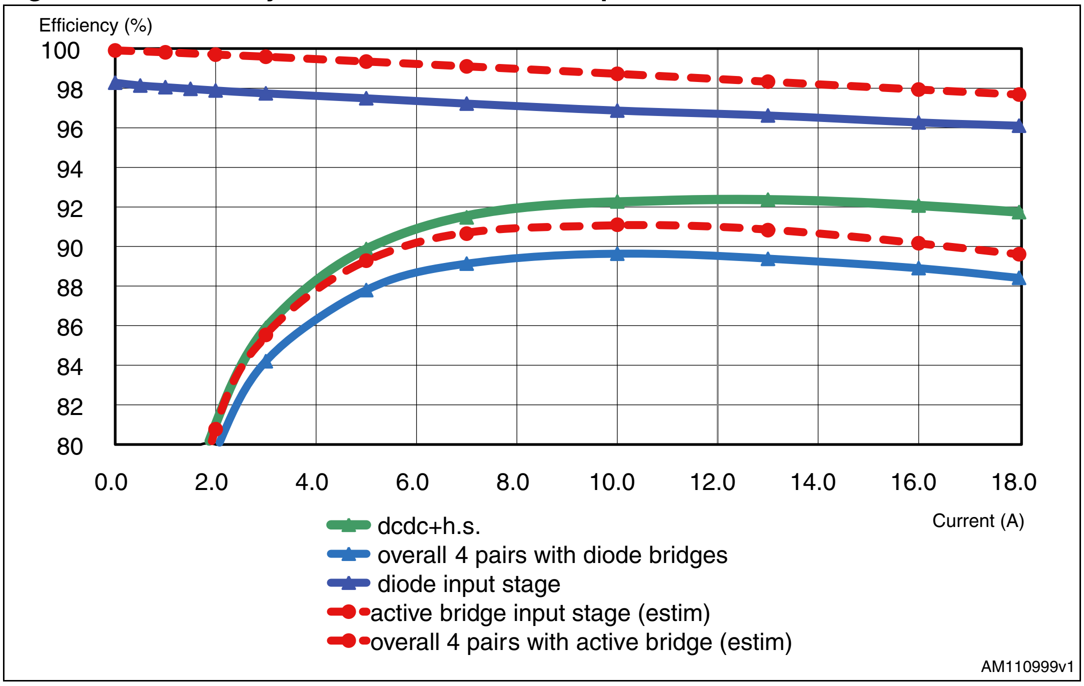
Table 2. Bill of material (continued)

Reference	Description	Value	Tol	Voltage	Body	Vendor
R44,R52,R119	Chip resistor	1 kΩ			603	Std
R45	Chip resistor	47 kΩ			603	Std
R53,R59	Chip resistor	10 Ω			805	Std
R57	Chip resistor	5.6 Ω			805	Std
R60	Chip resistor	2.2 Ω			805	Std
R62	Chip resistor	200 Ω			603	Std
R64,R98	Chip resistor	0 Ω			603	Std
R70	Chip resistor	39 kΩ	1%		603	Std
R106,R117	Chip resistor	10 kΩ			603	Std
R88	Chip resistor	270 kΩ			805	Std
R89	Chip resistor	2.7 kΩ			603	Std
R90	Chip resistor	499 Ω	1%		603	Std
R91	Chip resistor	10 Ω			603	Std
R92	Chip resistor	1 Ω			603	Std
R93	Chip resistor	820 Ω	1%		603	Std
R94	Chip resistor	21 kΩ	1%		603	Std
R95	Chip resistor	24.9 kΩ	1%		603	Std
R96	Chip resistor	0 Ω			603	Std
R97	Chip resistor	30.9 Ω	1%		603	Std
R102	Chip resistor	35.7 Ω	1%		805	Std
R103	Chip resistor	510 Ω			603	Std
R104	Chip resistor	4.75 kΩ	1%		603	Std
R107,R115,R121	Chip resistor	100 kΩ			603	Std
R108,R109	Chip resistor	0.10 Ω			1206	Std low value
R111	Chip resistor	12.4 kΩ	1%		603	Std
R120	Chip resistor	1 MΩ			603	Std
T1,T2	POE+ Magnetics	ETH1-230LD				Coilcraft
T6	Power transformer	MA5509-AL				Coilcraft
U1	POE+ controller	PM8803			HTSSOP20	STMicroelectronics
U2,U3,U7	SMT optocoupler	Fairchild FOD817AS			4PDIP	Fairchild
U4	Shunt regulator	TS431AILT			SOT23-5	STMicroelectronics

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

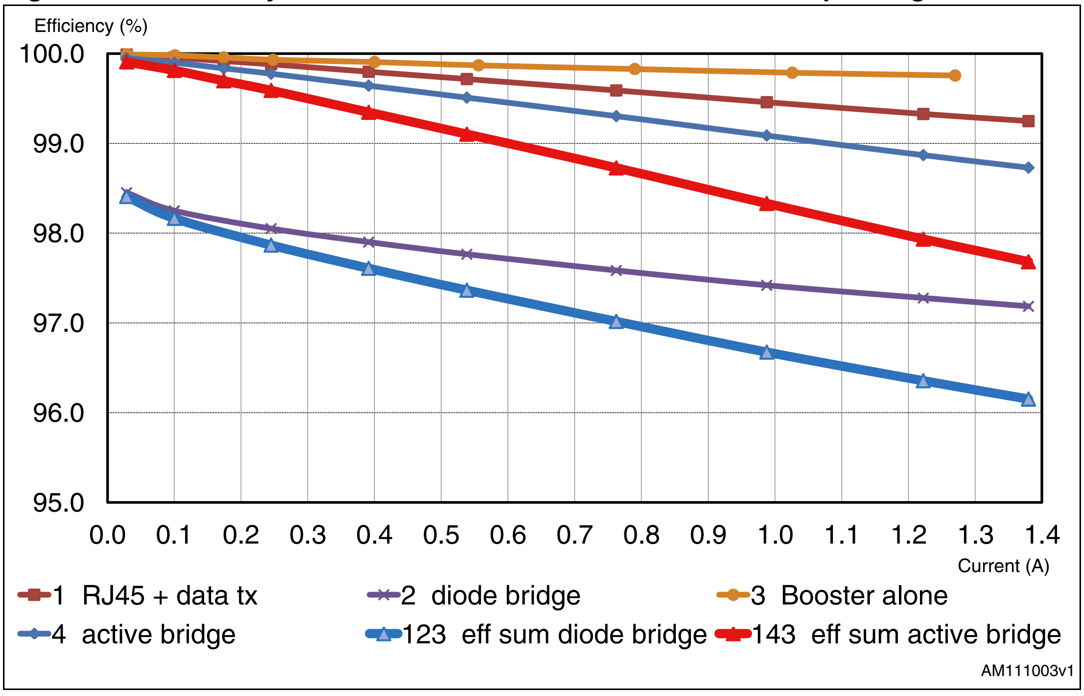
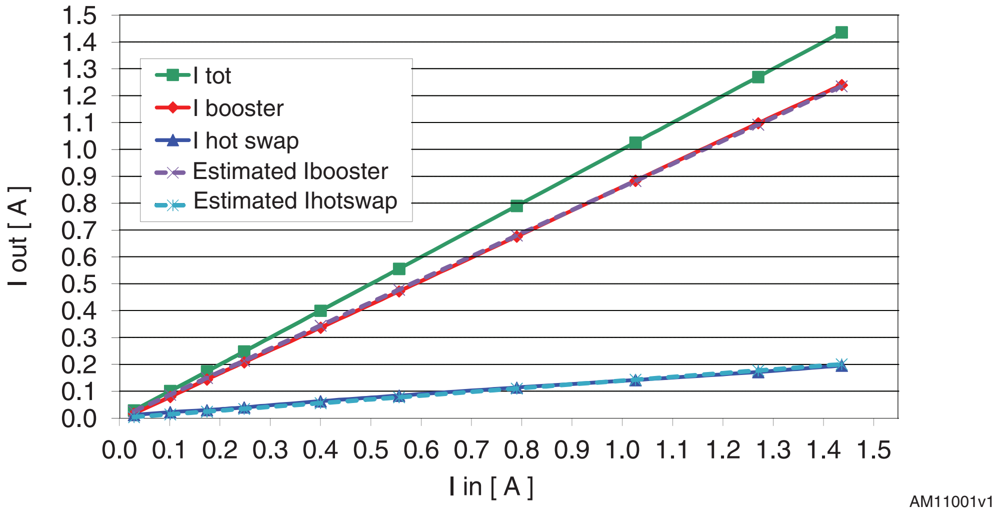


Figure 4 shows the various contributions to the total losses of the PD interface section of the converter:

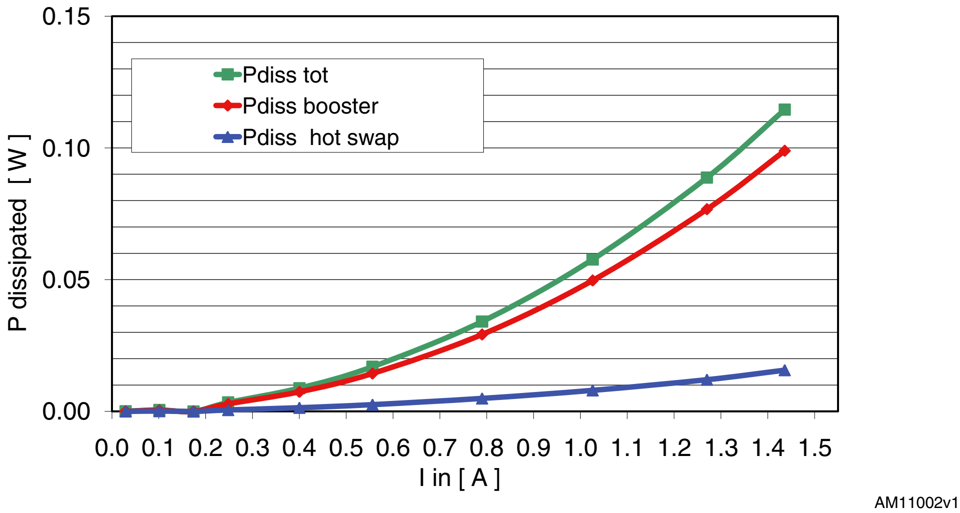
- RJ45 and data transformer value is small but not negligible at high input current/power
- Booster value is negligible
- Major contribution comes from the rectification bridge; an active bridge with MOSFETs for a total value of about 150 mΩ per leg (about 100 mΩ for the P-channel MOSFET and 50 mΩ for the N-channel) will assure a gain of about 1.6% on the total efficency 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

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Figure 8. Startup with 10 A load

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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

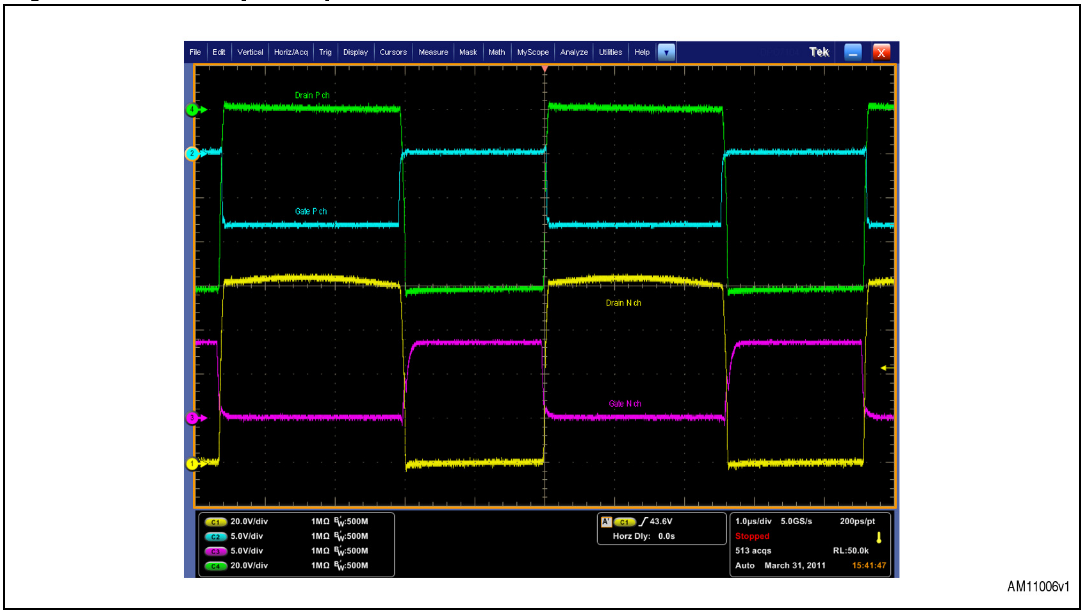
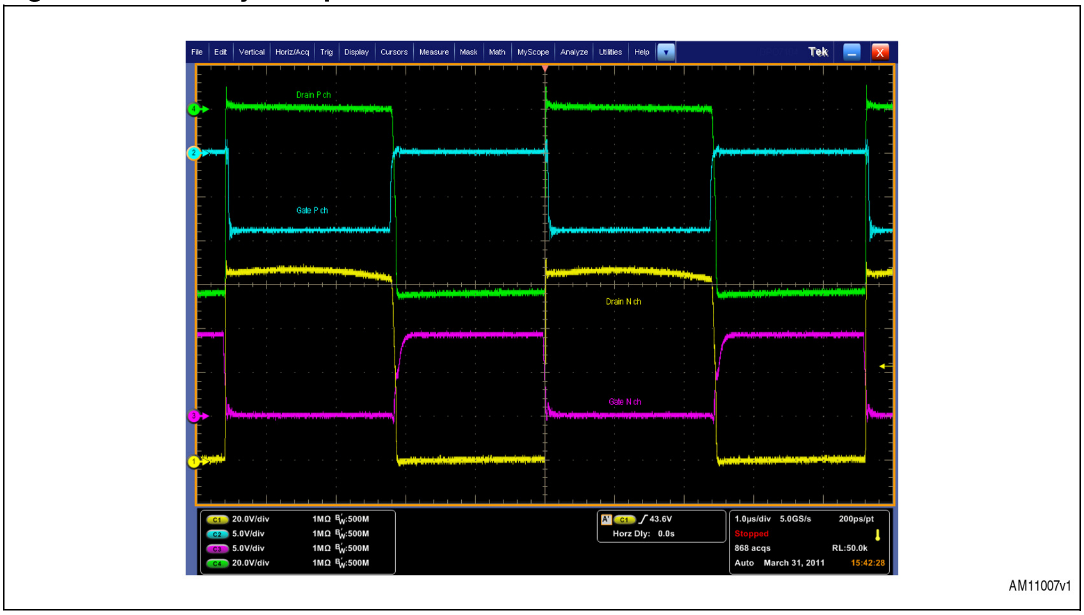


Figure 10. Primary-side power MOSFET waveforms at 16 A load



4.2.3 Secondary-side MOSFET

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

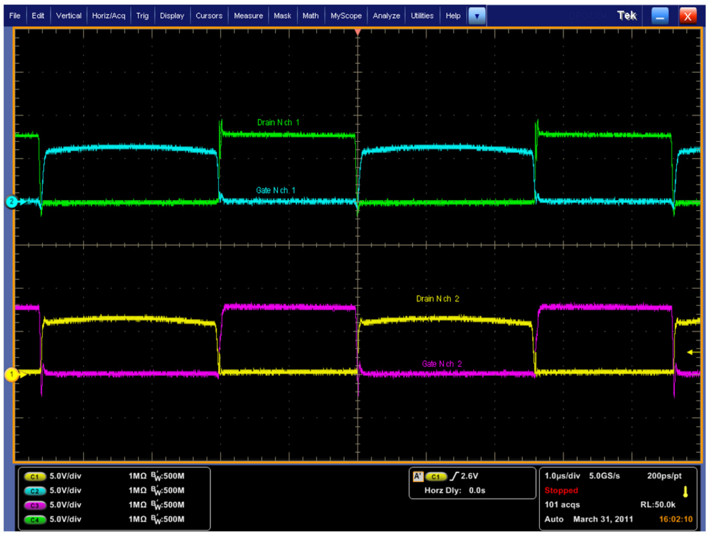
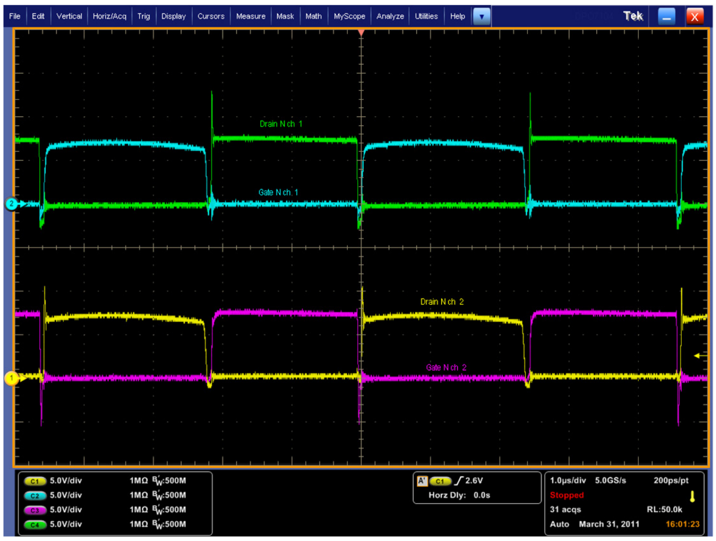


Figure 12. Secondary-side power MOSFET waveforms at 16 A load



4.2.4 Output ripple

Figure 13. Output ripple measurement at 0 A

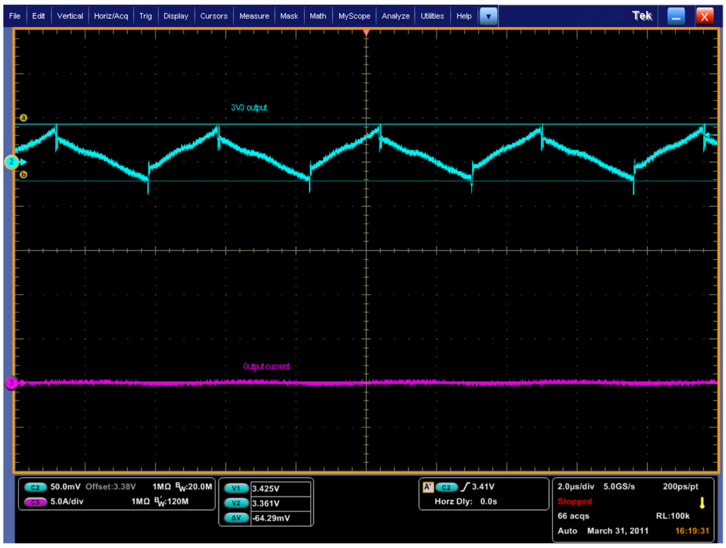


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Figure 14. Output ripple measurement at 16 A

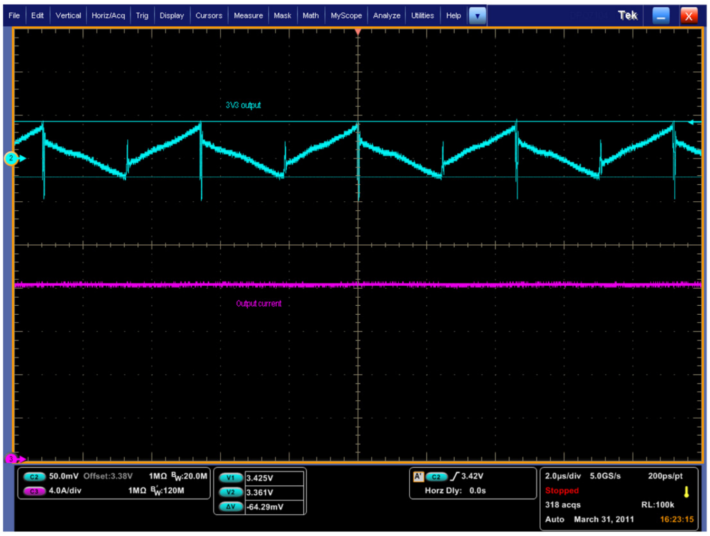

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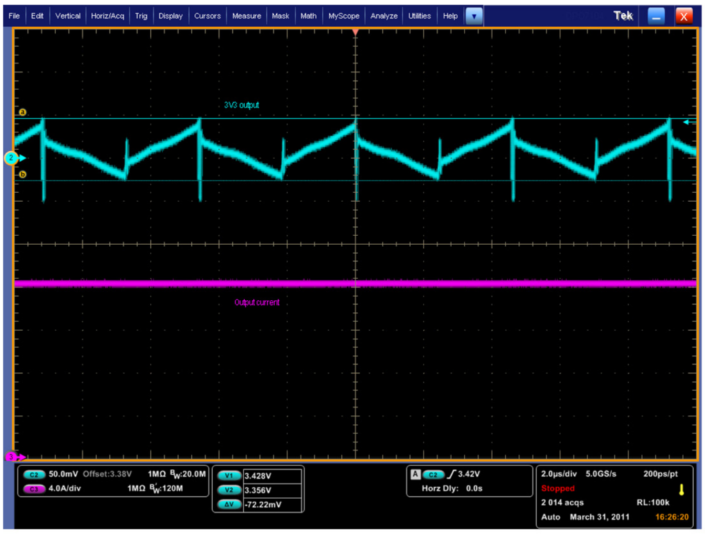
Figure 15. Output ripple measurement at 16 A with infinite persistance



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4.2.5 G_{loop} measurement and load transient response

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

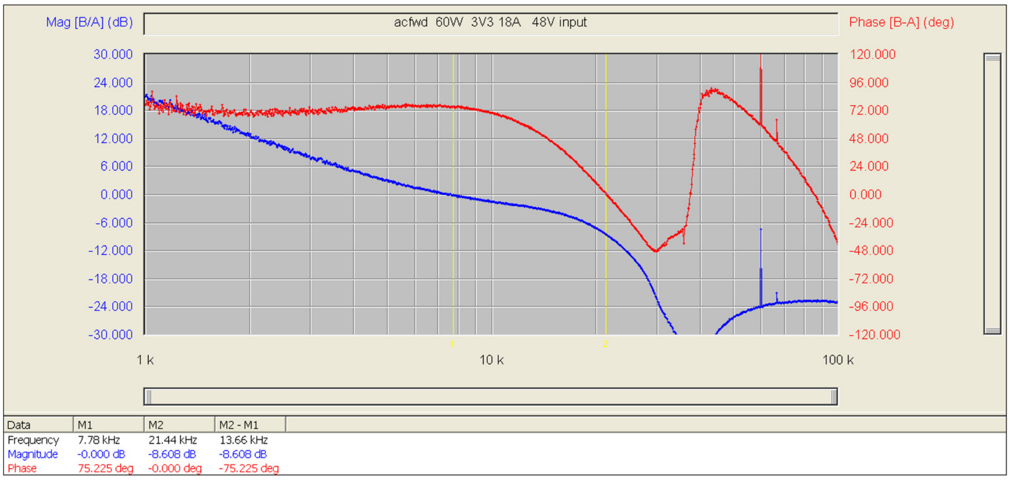

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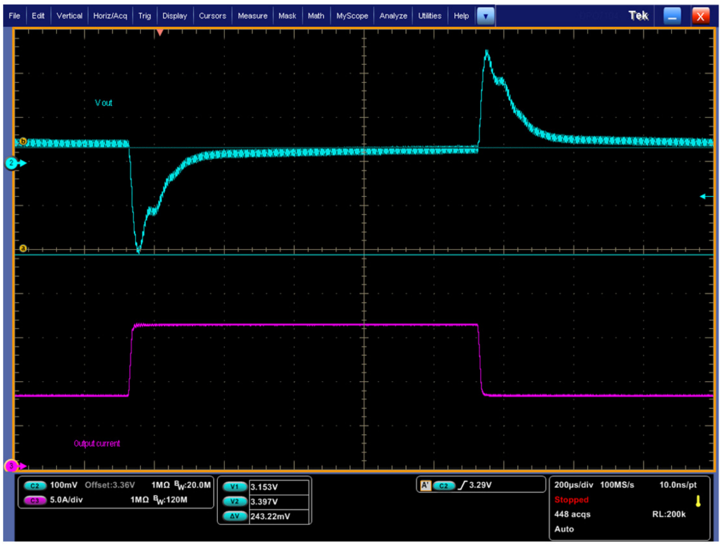
Figure 17. Response of the converter to a 8 A - 16 A load transient



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5 Revision history

Table 3. Document revision history

Date	Revision	Changes
22-Feb-2012	1	Initial release