AN4473
Application note

PoE synchronous flyback, IEEE802.3at compliant, 5V - 4A PD converter based on the PM8803 controller

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Introduction

This document describes a reference design for a POE+, high efficiency, 5 V - 4 A flyback converter based on the PM8803 PoE controller.

The PM8803 is a highly integrated device embedding an IEEE802.3at compliant “Powered Device” (PD) interface together with a PWM controller and support for auxiliary sources.

The STEVAL-TSP004V2 reference design is based on an isolated flyback topology CCM converter with synchronous rectification with a gate driver transformer. The same PCB can be populated in different ways to support various configurations and topologies (the flyback with diode rectification, synchronous flyback with or without an active clamp, self-driven synchronous flyback).

Figure 1. STEVAL-TSP004V2 evaluation board photo

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1 Main characteristics and circuit description

The main characteristics (reference and electrical specifications) of the converter are listed in*Table 1* and *Table 2*.

Table 1. Reference

Reference code	
Device	PM8803
Evaluation board	STEVAL-TSP004V2

Table 2. Electrical specification

Parameter	Specifications
Input voltage supplies VIN [VDC]	From 40 to 60 V
Auxiliary input voltage range	From 30 to 60 V
Output voltage Vout [VDC]	5 VDC ± 5% at 4 A
Peak-to-peak output ripple	< 30 mVpp
Efficiency DC-DC at full load	> 92%
Efficiency overall at full load	> 89%
Transient response ΔVoutpk to 50% load step	< 180 mV
ΔVout in load line case	< 0.5%
GLOOP bandwidth	> 3 kHz
GLOOP phase margin at 0dB	> 70 deg.
GLOOP dB margin at 0 deg.	> 10 dB

This document details the characteristics and performances of the PM8803 evaluation kit STEVAL-TSP004V2, which has been designed to cover a broad range of Power over Ethernet (PoE) applications.

The PM8803 is a highly integrated device embedding an IEEE802.3af/at compliant powered device (PD) interface together with a PWM controller and support for auxiliary sources.

Even though the PM8803 device can be configured to work in several isolated topologies, self-driven or a transformer gate driven; this application note focuses on a high efficiency isolated flyback converter topology with synchronous rectification, 5 V output voltage with a 4 A output current capability.

Auxiliary sources can be connected to the board on 2 different input connectors. One input (AUX II) allows prevalence of the auxiliary sources with respect to the PoE, while the other input (AUX I) allows the usage of a wall adaptor with voltage lower than the internal PoE UVLO threshold and still benefits from the inherent inrush and DC current limit.

The possible configurations supported by the PM8803 demonstration kit as options on the same PCB are:

- Alternative input bridge rectification: 4 possible options including standard diode bridges, discrete schottky diode bridges, half active bridges and full active bridges; schottky diode bridges are mounted on this eval board.
- Optional 4 pairs detection circuit, to detect if power is provided on 2 pairs or on 4 pairs by a high power PSE source; this circuit is not used on this eval board.
- Optional booster circuit, to increase the max. input current over 1 A; this circuit is not used on this eval board.
- Diode or synchronous rectification; 4 package options for the diode and 2 package options for the MOSFET.
- Primary side snubber; 3 options included an active clamp: a simple R-C snubber is used on this eval board.
- Power transformer; 3 size options for transformer gate driven solutions and 2 size options for self-driven applications.

The bill of material (BOM) in *Table 3* provides the list of components to be mounted to obtain a flyback CCM converter with a gate transformer driven synchronous rectifier, with 5 V output at a 4 A evaluation board.

2 Schematics for 5 V at 4 A

2.1 Schematic

Figure 2. STEVAL-TSP004V2 evaluation board: electrical schematic (1/2)

Figure 3. STEVAL-TSP004V2 evaluation board: electrical schematic (2/2)

2.2 Bill of material

Table 3. Bill of material

Item	Ref.	Description	Value	PCB footprint	Supplier	Voltage
1	C5	Ceramic Capacitor	10 nF 10%	C0603	TDK	100 V
2	C6	Ceramic Capacitor	10 nF 10%	C0603	TDK	100 V
3	C7	Ceramic Capacitor	10 nF 10%	C0603	TDK	100 V
4	C8	Ceramic Capacitor	10 nF 10%	C0603	TDK	100 V
5	C9	Ceramic Capacitor	2.2 nF	C1812	AVX	2 kV
6	C12	Ceramic Capacitor	2.2 nF	C1812	AVX	2 kV
7	C14	Ceramic Capacitor	1 nF 10%	C0603	TDK	100 V
8	C16	Ceramic Capacitor	1 nF 10%	C0805	TDK	100 V
9	C18	Ceramic Capacitor	0.1 µF 10%	C0805	TDK	100 V
10	C19	Ceramic Capacitor	10 nF	C0603	Several	50 V
11	C21	Ceramic Capacitor	1 nF 10%	C0603	TDK	100 V
12	C22	Ceramic Capacitor	TBD	C1812	AVX	2 kV
13	C23	Ceramic Capacitor	470 nF 10%	C0603	Several	50 V
14	C26	Aluminium capacitor	33 µF 20%	C-POL8-10	Panasonic - EEEFK2A330P	100 V
15	C27	Ceramic Capacitor	22 µF	C1206	Murata - GRM31CR61C226 ME15L	16 V
16	C28	Ceramic Capacitor	2.2 µF	C1210	Murata - GRM32ER72A225 KA35L	100 V
17	C29	Ceramic Capacitor	2.2 µF	C1210	Murata - GRM32ER72A225 KA35L	100V
18	C30	Ceramic Capacitor	68 pF	C0805	TDK	100 V
19	C31	Ceramic Capacitor	1.5 nF	C0805	Several	50 V
20	C33	Ceramic Capacitor	22 µF	C1206	Murata - GRM31CR61C226 ME15L	16 V
21	C34	Aluminium capacitor	330 µF	C-POL8-10	Panasonic - EEEFK1C331P	16 V
22	C35	Ceramic Capacitor	22 µF	C1206	Murata - GRM31CR61C226 ME15L	16 V
23	C36	Ceramic Capacitor	0.1 µF	C0603	Several	50 V
24	C37	Ceramic Capacitor	22 µF	C1206	Murata - GRM31CR61C226 ME15L	16 V

Table 3. Bill of material (continued)

Item	Ref.	Description	Value	PCB footprint	Supplier	Voltage
25	C38	Ceramic Capacitor	10 nF	C0603	Several	50 V
26	C39	Ceramic Capacitor	1 µF	C0603	KEMET	25 V
27	C40	Ceramic Capacitor	1 µF	C1206	KEMET	25 V
28	C41	Ceramic Capacitor	1 µF	C0603	KEMET	25 V
29	C44	Ceramic Capacitor	0.1 µF	C0603	Several	50 V
30	C45	Ceramic Capacitor	0.1 µF	C0603	Several	50 V
31	C48	Ceramic Capacitor	1 µF	C0603	KEMET	25 V
32	C49	Ceramic Capacitor	3.3 nF	C0603	Several	50 V
33	C50	Ceramic Capacitor	47 nF	C0603	Several	50 V
34	C53	Ceramic Capacitor	1 µF	C0603	KEMET	25 V
35	C54	Ceramic Capacitor	470 pF	C0603	Several	50 V
36	C55	Ceramic Capacitor	100 pF	C0603	Several	50 V
37	C56	Ceramic Capacitor	47 nF	C0603	Several	50 V
38	C59	Ceramic Capacitor	1 µF	C0603	KEMET	25 V
39	C60	Ceramic Capacitor	1 nF	C0805	TDK	100 V
40	C61	Ceramic Capacitor	2.2 nF	C1812	AVX	2 kV
41	C64	Ceramic Capacitor	2.2 µF	C1210	MURATA - GRM32ER72A225 KA35L	100 V
42	C67	Ceramic Capacitor	22 µF	C1206	Murata - GRM31CR61C226 ME15L	16 V
43	C68	Ceramic Capacitor	22 µF	C1206	Murata - GRM31CR61C226 ME15L	16 V
44	C69	Ceramic Capacitor	10 nF	C0603	Several	50 V
45	D1	Diode	STTH302S	SMC	STMicroelectronics	
46	D4	Schottky Diode	STPS2H100A	SMA	STMicroelectronics	
47	D7	Schottky Diode	STPS2H100A	SMA	STMicroelectronics	
48	D8	Schottky Diode	STPS2H100A	SMA	STMicroelectronics	
49	D9	Schottky Diode	STPS2H100A	SMA	STMicroelectronics	
50	D11	TVS diode	SMAJ58A	SMA	STMicroelectronics	
51	D12	Schottky Diode	STPS2H100A	SMA	STMicroelectronics	
52	D13	Schottky Diode	STPS2H100A	SMA	STMicroelectronics	
53	D14	Schottky Diode	STPS2H100A	SMA	STMicroelectronics	
54	D17	Schottky Diode	STPS2H100A	SMA	STMicroelectronics	
55	D20	Diode LED	Aux det	KA-3528SGT	Kingbright	

Table 3. Bill of material (continued)

Item	Ref.	Description	Value	PCB footprint	Supplier	Voltage
56	D21	Diode	STTH302S	SMC	STMicroelectronics	
57	D26	Diode LED	Out det	KA-3528SGT	Kingbright	
58	D28	Schottky Diode	BAT46J	SOD323	STMicroelectronics	
59	D32	Zenere Diode	MM3Z15VT1	SOD323	Onsemi	
60	D34	Schottky Diode	BAT46J	SOD323	STMicroelectronics	
61	D36	Schottky Diode	BAT46J	SOD323	STMicroelectronics	
62	D39	Schottky Diode	BAT46J	SOD323	STMicroelectronics	
63	D40	Schottky Diode	BAT46J	SOD323	STMicroelectronics	
64	D44	Diode LED	T2P det	KA-3528SGT	Kingbright	
65	D52	Schottky Diode	BAT46J	SOD323	STMicroelectronics	
66	D57	Schottky Diode	BAT46J	SOD323	STMicroelectronics	
67	JM1	Connector	Jumper-doppio	3PIN-P254	Several	
68	JM2	Connector	Jumper-doppio	3PIN-P254	Several	
69	J1	Connector	SA	P-JACK-RAPC722	Several	
70	J2	Connector	SP	P-JACK-RAPC722	Several	
71	J3	Connector	DATA & POWER INPUT	RJ45-8PIN	Molex	
72	J4	Connector	DATA OUTPUT	RJ45-8PIN	Molex	
73	J5	Connector	MOR-10X10.5-P5-2PIN	MOR-2POLI-508	Several	
74	L5	Inductor	10uH	MSS7341-103ML	Coilcraft	
75	L6	Inductor	0.33uH	DO1813H	Coilcraft	
76	Q12	Mosfet	STL60N3LLH5	PowerFLAT™ 5x6	STMicroelectronics	
77	Q16	Mosfet	MMBT3906LT1	SOT23	Several	
78	Q17	Mosfet	Si4848DY	so8pwrpak-SO8	VISHAY	
79	Q18	Mosfet	MMBT3904LT1	SOT23	Several	
80	R1	Resistor	75R	R0603	Several	
81	R2	Resistor	75R	R0603	Several	
82	R5	Resistor	75R	R0603	Several	
83	R7	Resistor	75R	R0603	Several	
84	R9	Resistor	1K 1%	R0603	Several	
85	R10	Resistor	75R	R0603	Several	
86	R11	Resistor	75R	R0603	Several	
87	R12	Resistor	75R	R0603	Several	
88	R13	Resistor	75R	R0603	Several	
89	R17	Resistor	0R0	R0805	Several	
90	R21	Resistor	220R	R1206	Several	

Table 3. Bill of material (continued)

Item	Ref.	Description	Value	PCB footprint	Supplier	Voltage
91	R23	Resistor	100R	R1206	Several	
92	R26	Resistor	0R0	R1206	Several	
93	R27	Resistor	27k	R0603	Several	
94	R32	Resistor	15K	R0805	Several	
95	R37	Resistor	0R0	R1206	Several	
96	R38	Resistor	1k	R0603	Several	
97	R43	Resistor	0R0	R0805	Several	
98	R44	Resistor	3K3	R0603	Several	
99	R45	Resistor	24.9K	R0603	Several	
100	R49	Resistor	0R0	R1206	Several	
101	R51	Resistor	15K	R0805	Several	
102	R52	Resistor	3K3	R0603	Several	
103	R53	Resistor	5R	R1206	Several	
104	R54	Resistor	0R0	R1206	Several	
105	R58	Resistor	27K	R0603	Several	
106	R62	Resistor	10R	R0603	Several	
107	R64	Resistor	0R0	R0603	Several	
108	R65	Resistor	1K	R0603	Several	
109	R66	Resistor	10R	R0603	Several	
110	R70	Resistor	10K 1%	R0603	Several	
111	R72	Resistor	120K 1%	R0603	Several	
112	R80	Resistor	20R	R0805	Several	
113	R83	Resistor	10K	R0603	Several	
114	R84	Resistor	0R0	R0603	Several	
115	R89	Resistor	3.3K	R0603	Several	
116	R90	Resistor	1k5	R0603	Several	
117	R91	Resistor	10R	R0603	Several	
118	R92	Resistor	10R	R0805	Several	
119	R93	Resistor	1K	R0603	Several	
120	R94	Resistor	21K 1%	R0603	Several	
121	R95	Resistor	24.9K 1%	R0603	Several	
122	R96	Resistor	0R0	R0603	Several	
123	R99	Resistor	47K	R0603	Several	
124	R101	Resistor	24.9K 1%	R0603	Several	
125	R103	Resistor	510R	R0603	Several	

Table 3. Bill of material (continued)

Item	Ref.	Description	Value	PCB footprint	Supplier	Voltage
126	R104	Resistor	4.7K 1%	R0603	Several	
127	R107	Resistor	10K	R0603	Several	
128	R108	Resistor	0.30 ohm 1%	R1206	Bourns	
129	R109	Resistor	0.30 ohm 1%	R1206	Bourns	
130	R111	Resistor	12.4K 1%	R0603	Several	
131	R112	Resistor	15K 1%	R0603	Several	
132	R117	Resistor	5.1K	R0603	Several	
133	R119	Resistor	3.3K	R0603	Several	
134	R122	Resistor	0R0	R0603	Several	
135	R125	Resistor	0R0	R1206	Several	
136	R131	Resistor	30R9 1%	R0805	Several	
137	TP2	Test Point	Red	TH-5013	Keystone	
138	TP3	Test Point	BLACK	TH-5013	Keystone	
139	TP4	Test Point	Red	TH-5013	Keystone	
140	TP5	Test Point	Red	TH-5013	Keystone	
141	TP6	Test Point	Red	TH-5013	Keystone	
142	TP7	Test Point	Red	TH-5013	Keystone	
143	TP8	Test Point	BLACK	TH-5013	Keystone	
144	TP9	Test Point	Red	TH-5013	Keystone	
145	TP10	Test Point	Red	TH-5013	Keystone	
146	TP11	Test Point	BLACK	TH-5013	Keystone	
147	TP12	Test Point	BLACK	TH-5013	Keystone	
148	TP13	Test Point	Red	TH-5013	Keystone	
149	TP14	Test Point	Red	TH-5013	Keystone	
150	TP15	Test Point	Red	TH-5013	Keystone	
151	TP16	Test Point	Red	TH-5013	Keystone	
152	TP18	Test Point	Red	TH-5013	Keystone	
153	TP19	Test Point	BLACK	TH-5013	Keystone	
154	TP20	Test Point	Red	TH-5013	Keystone	
155	TP21	Test Point	Red	TH-5013	Keystone	
156	TP22	Test Point	Red	TH-5013	Keystone	
157	TP23	Test Point	BLACK	TH-5013	Keystone	
158	TP24	Test Point	BLACK	TH-5013	Keystone	
159	T1	Data Transfo	ETH1-460	ETH1-460	Coilcraft	
160	T5	Power Transfo	COILCRAFT HA3691-AL	PA2328NL	Coilcraft	

Table 3. Bill of material (continued)

Item	Ref.	Description	Value	PCB footprint	Supplier	Voltage
161	T8	Power Transfo	COILCRAFT DA2319-AL	DA2318-AL	Coilcraft	
162	U1	Controller IC	PM8803	HTSSOP20-LARGE	STMicroelectronics	
163	U2	Optocoupler	Fairchild FOD817AS	FOD817	Fairchild	
164	U3	Optocoupler	Fairchild FOD817AS	FOD817	Fairchild	
165	U4	Voltage Reference	TS431AILT	SOT23-5L	STMicroelectronics	
166	U7	Optocoupler	Fairchild FOD817AS	FOD817	Fairchild	

3 Measurements results

3.1 Efficiency comparison with three rectification bridge options

STEVAL-TSP004V2 provides different rectification bridge options: single Schottky diode, half active bridge, full active bridge and diode bridge. They are alternatively usable thanks the options available on the STEVAL-TSP004V2 demo's PCB. Efficiency measurements have been executed to compare the different characteristics cost/efficiency through three different rectification bridge options. Here below the schematics:

Figure 4. Schematic Schottky bridge

Figure 5. Schematic full active bridge

Figure 6. Schematic half active bridge

The measurement has been executed providing a 48V on the RJ45 connector and connecting the Poe+/Vss (TP22 vs TP23) with external electronic load with different current values to cover around 40W of input power.

Figure 7. Comparison efficiency bridge

Figure 7 shows the input stage efficiency comparison with three different bridge rectification type. The green line shows the efficiency of the Schottky diode bridge option, the cheaper of them, populated with four Schottky diodes STPS2H100A of each bridge. The yellow line shows the efficiency of the full active bridge, the most efficient, using two 100 V- 240 mΩ P-channel MOSFET on high side and two 100V 65 mΩ N-channel MOSFET on low side of each bridge. The red line shows the half active bridge solution, which represent a right compromise in term of cost vs. efficiency.

Changing the input bridge it is possible to gain up to 2% about on the overall converter efficiency.

3.2 Converter efficiency

Figure 8. Overall and DC/DC efficiency

Figure 8 shows overall and DC/DC efficiencies for the converter at 48Vindc.

The dotted green line is the STEVAL-TSP004V2 DC-DC efficiency. The measurement has been executed supplying 48 V to the input RJ45 connector J1 and measuring the input voltage by TP22/TP23, input voltage of DC-DC converter stage. *Figure 8* shows also the overall efficiency comparison measured with the same DC-DC converter stage connected to the three different rectification bridge stages previously mentioned.

Please note that:

- Overall efficiency includes all loss from RJ45 to the output voltage rail.
- DC/DC efficiency is a figure of merit of the converter standalone and typically does not include the losses associated to the PoE interface section that are: the RJ45 connector, data transformer, bridges, power consumption of the I/F of the PM8803 device.

On the STEVAL-TSP004V2 evaluation board is mounted the simple Schottky diodes bridge solution (green line).

Thanks to the bridge rectification options foreseen on the pcb it is then possible to select the best compromise cost/efficiency depending on the target request.

Figure 9. Output voltage drift

3.3 Voltage ripple

Figure 10. Ripple on 5 V at 0.4 A

CH2: output current
CH4: output voltage

Figure 11. Ripple on 5 V at 4 A

CH2: output current
CH4: output voltage

Above measurements are referred at the output voltage ripple.

In *Figure 12* and *Figure 13* a measure of the ripple on the input voltage has been done, to give an indication of the noise at the input of the converter.

Figure 12. Ripple before and after input filter with 5 V at 0.4 A (measured on C26 and C28)

CH1: ripple after input filter
CH2: input current
CH3: ripple before input filter
CH4: primary Vgate

Figure 13. Ripple before and after input filter with 5 V at 4 A (measured on C26 and C28)

CH1: ripple after input filter
CH2: input current
CH3: ripple before input filter
CH4: primary Vgate

3.4 Startup

Figure 14. Startup from Microsemi 9001G injector - 5 V at 0.4 A

CH1: VCC
CH2: input current
CH3: VSS - RTN
CH4: output voltage

Figure 15. Startup from Microsemi 9001G injector - 5 V at 4 A

CH1: VCC
CH2: input current
CH3: VSS - RTN
CH4: output voltage

Figure 16. Startup from Microsemi 9501G injector- 5 V at 0.4 A

CH1: Tx Rx input current
CH2: spare input current
CH3: VSS - RTN
CH4: output voltage

Figure 17. Startup from Microsemi 9501G injector- 5 V at 4 A

CH1: Tx Rx input current
CH2: spare input current
CH3: VSS - RTN
CH4: output voltage

Figure 18. Detail of the output voltage at startup with no load

CH2: input current
CH4: output voltage

Figure 19. Detail of the output voltage at startup with 4 A load

CH2: input current
CH4: output voltage

3.5 Primary side waveforms

Figure 20. Primary steady state 0.4 A

CH1: primary MOSFET drain
CH2: input current
CH4: primary MOSFET gate

Figure 21. Primary steady state 4 A

CH1: primary MOSFET drain
CH2: input current
CH4: primary MOSFET gate

Figure 22. Detail of primary drain at 4 A load

CH1: primary MOSFET drain
CH2: input current
CH4: primary MOSFET gate

3.6 Secondary side waveforms

Figure 23. Secondary steady state 0.4 A

CH1: secondary MOSFET drain
CH2: input current
CH4: secondary MOSFET gate

Figure 24. Secondary steady state 4 A

CH1: secondary MOSFET drain
CH2: input current
CH4: secondary MOSFET gate

Figure 25. Detail of secondary drain at 4 A load

CH1: secondary MOSFET drain
CH2: input current
CH4: secondary MOSFET gate

3.7 Load transients

Figure 26. 2 A - 4 A load transient

CH2: output current
CH4: output voltage

Figure 27. 0.4 A - 4 A load transient

CH2: output current
CH4: output voltage

3.8 PoE to auxiliary switchover

Figure 28. PoE to auxiliary switchover

CH1:converter input voltage
CH2: PoE input current
CH3: T2P signal
CH4: output voltage

In *Figure 28* is shown a smooth transition from a PoE line set to 54 V toward an auxiliary adapter at 44 V; the output voltage is maintained stable during the transition.

3.9 Gloop

Figure 29. Gloop 48 V at 4 A

Bw: 3.2 KHz
GM:10.6 dB
PM: 70 deg.

Figure 30. Gloop 48 V at no load

Bw: 4.0 KHz
GM:12.2 dB
PM: 77 deg.

Figure 31. Gloop 40 V at 4 A

Bw: 3.2 KHz
GM:10.6 dB
PM: 70 deg.

Figure 32. Gloop 57 V at no load

Bw: 4.2 KHz
GM:11.7 dB
PM: 78 deg.

4 Supporting material

4.1 PCB layers

Figure 33. PCB top assembly

Figure 34. PCB bottom assembly

Figure 35. PCB layer 1 top

Figure 36. PCB layer 2

Figure 37. PCB layer 3

Figure 38. PCB layer 4 bottom

5 Electrical diagram general

Figure 39. Schematic 1 of 2 (general)

Figure 40. Schematic 2 of 2 (general)

6 Revision history

Table 4. Document revision history

Date	Revision	Changes
25-May-2015	1	Initial release.

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