Optimized Class 1 PD Designs Using the Si3402

1. Introduction

The Si3402 is designed to support up to 20 W of input power with over 15 W of power delivered to the load. For this reason, the standard reference designs have been optimized for high-power situations.

The IEEE standard for PoE (802.3 clause 33) specifies the PD classes as listed in Table 1.

Table 1. PD Classes

PD Classification	Input Power Maximum	Output Power Allowing for 80% Conversion Efficiency
Class 0 or Class 3	13 W	10.4 W
Class 1	3.84 W	3.07 W
Class 2	6.49 W	5.19 W
Class 4	25.5 W	20.4 W

Even the 3 W of output power that can realistically be derived from a Class 1 interface is adequate for many applications. This application note shows how the standard reference design is modified and simplified to support lower power situations.

2. Optimized Reference Designs

Figure 1 shows the completed schematic of the Class 1 reference design for the isolated case, and Figure 2 shows the reference design for the non-isolated case. Tables 2 and 3 are the bills of materials corresponding to Figures 1 and 2.

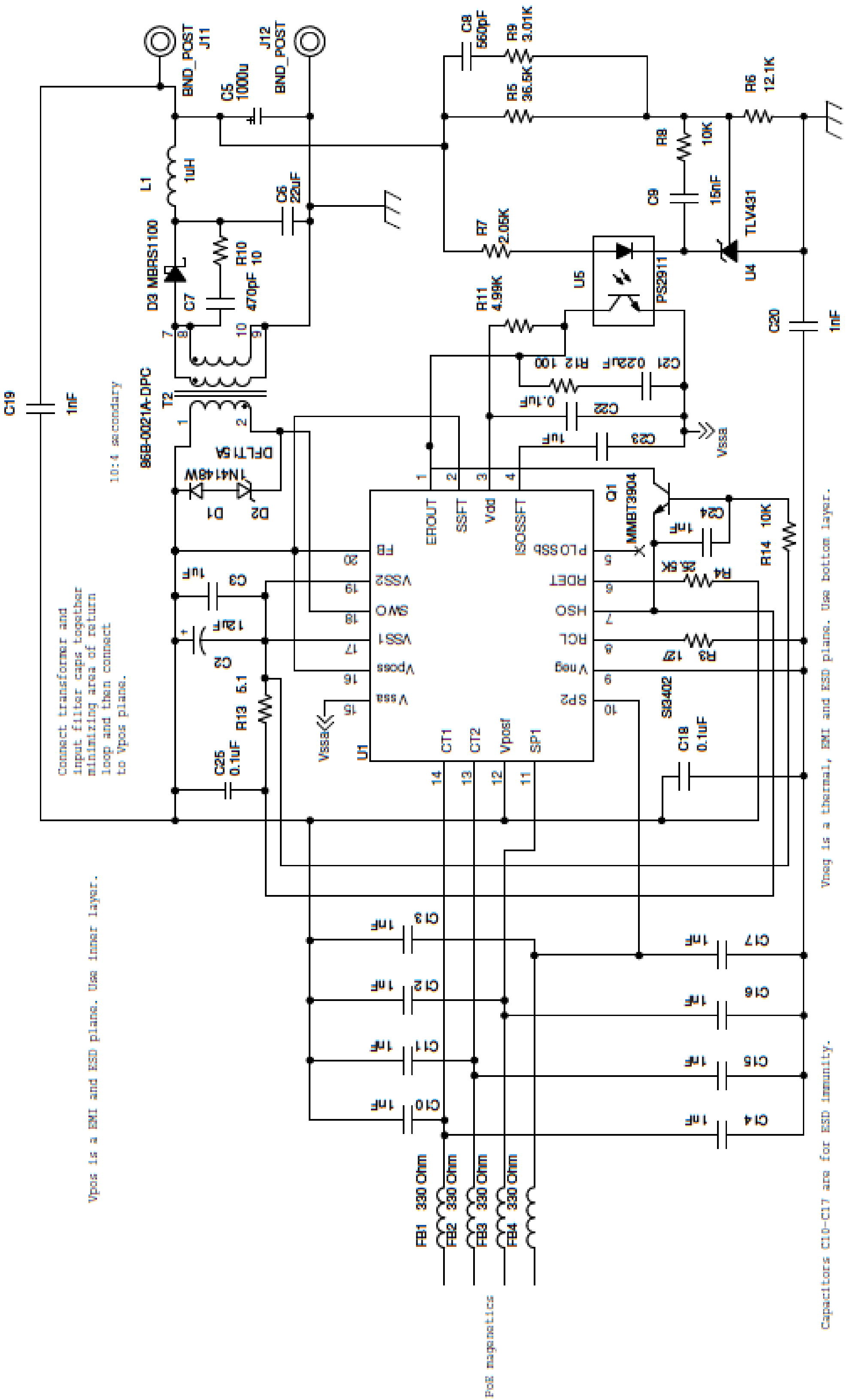


Figure 1. Optimized Class 1 Design (Isolated Case)

3. Bill of Materials (Isolated Class 1 Designs)

Table 2. Bill of Materials for Isolated Class 1 Designs

Item	Qty	Ref	Value	Rating	Tol	PCB Footprint	Mfr Part Number	Mfr
1	1	C2	12 µF		±20%	C2.5X6.3MM-RAD	EEUFC2A120	Panasonic
2	1	C3	1 µF		±10%	C1210	C1210X7R101-105K	Venkel
3	1	C5	1000 µF			C3.5X8MM-RAD		
4	1	C6	22 µF		±20%	C0805	C0805X5R6R3-226M	Venkel
5	1	C7	470 pF		±10%	C0603	C0603X7R101-471K	Venkel
6	1	C8	560 pF		±10%	C0603	C0603X7R160-561K	Venkel
7	1	C9	15 nF		±10%	C0603	C0603X7R160-153K	Venkel
8	9	C10,C11, C12,C13, C14,C15, C16,C17, C24	1 nF		±10%	C0603	C0603X7R101-102K	Venkel
9	1	C18	0.1 µF		±20%	C0603	C0603X7R101-104M	Venkel
10	2	C19,C20	1 nF		±10%	C1808	C1808X7R302-102K	Venkel
11	1	C21	0.22 µF		±10%	C0603	C0603X7R100-224K	Venkel
12	1	C22	0.1 µF		±20%	C0603	C0603X7R100-104M	Venkel
13	1	C23	1 µF		±10%	C0603	C0603X7R100-105K	Venkel
14	1	C25	0.1 µF		±10%	C0805	C0805X7R101-104K	Venkel
15	1	D1	1N4148W			SOD-123	1N4148W	Diodes Inc
16	1	D2	DFLT15A			POWERDI-123	DFLT15A	Diodes Inc
17	1	D3	MBRS1100	1 A		DO-214AA	MBRS1100T3	On Semi
18	4	FB1,FB2, FB3,FB4	330 Ω	1200 m A		L0603	BLM18PG331SN1	MuRata
19	2	J11,J12	BND_POST	15 A		BANANA-JACK	101	ABBA-TRON HH SMITH
20	1	L1	1 µH	2.3 A	±20%	IND-ME3215	ME3215-102ML	Coilcraft
21	1	Q1	MMBT3904	200 m A		SOT23-BEC	MMBT3904	Fairchild
22	1	R3	127	1/10 W	±1%	R0603	CR0603-10W-1270F	Venkel
23	1	R4	25.5K	1/16W	±1%	R0603	CR0603-16W-2552F	Venkel

Table 2. Bill of Materials for Isolated Class 1 Designs (Continued)

Item	Qty	Ref	Value	Rating	Tol	PCB Footprint	Mfr Part Number	Mfr
24	1	R5	36.5K	1/16W	±1%	R0603	CR0603-16W-3652F	Venkel
25	1	R6	12.1K	1/16W	±1%	R0603	CR0603-16W-1212F	Venkel
26	1	R7	2.05K	1/16W	±1%	R0603	CR0603-16W-2051F	Venkel
27	1	R8	10K	1/16W	±1%	R0603	CR0603-16W-1002F	Venkel
28	1	R9	3.01K	1/16W	±1%	R0603	CR0603-16W-3011F	Venkel
29	1	R10	10	1/10W	±1%	R0805	CR0805-10W-10R0F	Venkel
30	1	R11	4.99K	1/16W	±1%	R0603	CR0603-16W-4991F	Venkel
31	1	R12	100	1/16W	±1%	R0603	CR0603-16W-1000F	Venkel
32	1	R13	5.1	1/4W	±5%	R1210	CR1210-4W-5R1J	Venkel
33	1	R14	10K	1/10W	±1%	R0805	CR0805-10W-1002F	Venkel
34	1	T2	86B-0021A-DPC			XFMR-EP7-SMT	86B-0021A-DPC	Delta
35	1	U1	Si3402			QFN20N5X5P0.8	Si3402	SiLabs
36	1	U4	TLV431			TLV431-DBZ	TLV431BCDBZR	TI
37	1	U5	PS2911			OPTO-PS2911	PS2911-1	CEL

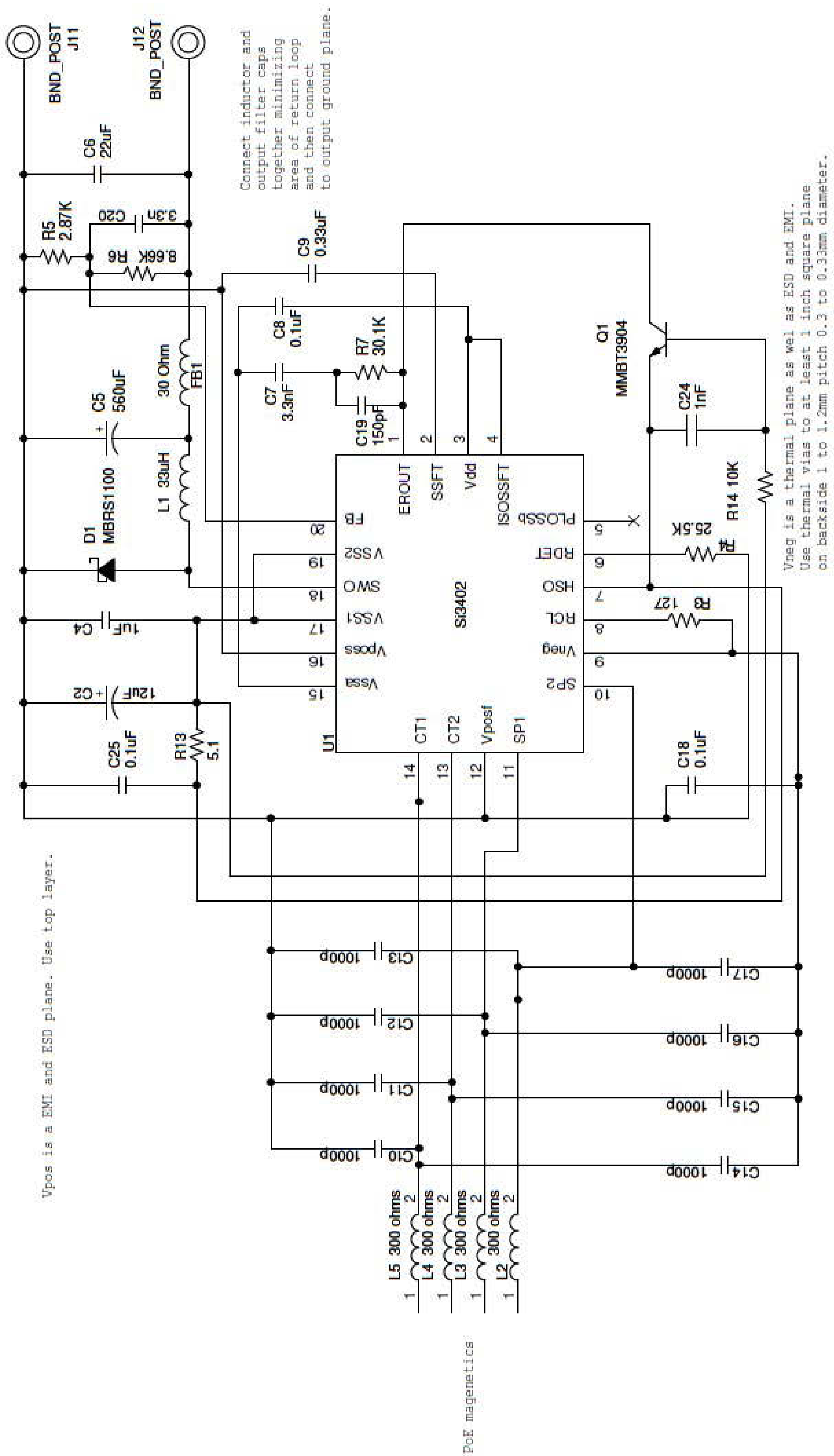


Figure 2. Optimized Design (Non-Isolated Case)

4. Bill of Materials (Non-Isolated Class 1 Designs)

Table 3. Bill of Materials for Non-Isolated Class 1 Designs

Item	Qty	Ref	Value	Rating	Tol	PCB Footprint	Mfr Part Number	Mfr
1	1	C2	12 µF		±20%	C2.5 x 6.3 mm-RAD	EEUFC2A120	Panasonic
2	1	C4	1 µF		±10%	C1210	C1210X7R101-105K	Venkel
3	1	C5	560 µF		±20%	C3.5 x 8 mm-RAD	EEUFM0J561	Panasonic
4	1	C6	22 µF		±20%	C0805	C0805X5R6R3-226M	Venkel
5	1	C7	3.3 nF		±10%	C0603	C0603X7R160-332K	Venkel
6	1	C8	0.1 µF		±20%	C0603	C0603X7R100-104M	Venkel
7	1	C9	0.33 µF		±10%	C0603	C0603X7R100-334K	Venkel
8	8	C10,C11, C12,C13, C14,C15, C16,C17	1 nF		±10%	C0603	C0603X7R101-102K	Venkel
9	2	C18,C25	0.1 µF		±20%	C0603	C0603X7R101-104M	Venkel
10	1	C19	150 pF		±10%	C0805	C0805X7R160-151K	Venkel
11	1	C20	3.3 nF		±10%	C0603	C0603X7R160-332K	Venkel
12	1	C24	1 nF		±10%	C0603	C0603X5R250-102K	Venkel
13	1	D1	MBRS1100	1 A		DO-214AA	MBRS1100T3	On Semi
14	1	FB1	30 Ω	3000 mA		L0805	BLM21PG300SN1	MuRata
15	4	L2, L3 L4, L5	330 Ω	1200 mA		L0603	BLM18PG331SN1	MuRata
16	2	J11,J12	BND_POST	15 A		BANANA-JACK	101	Abbatron HH Smith
17	1	L1	33 µH	1.1 A	±20%	6.1 x 6.1 mm	MSS6132-333ML	Coilcraft
18	1	Q1	MMBT3904	200 mA		SOT23-BEC	MMBT3904	Fairchild
19	1	R3	127 Ω	1/10 W	±1%	R0603	CR0603-10W-1270F	Venkel
20	1	R4	25.5 kΩ	1/16 W	±1%	R0603	CR0603-16W-2552F	Venkel
21	1	R5	2.87 kΩ	1/16 W	±1%	R0603	CR0603-16W-2871F	Venkel
22	1	R6	8.66 kΩ	1/16 W	±1%	R0603	CR0603-16W-8661F	Venkel
23	1	R7	30.1 kΩ	1/10 W	±1%	R0805	CR0805-10W-3012F	Venkel
24	1	R13	5.1 Ω	1/4 W	±5%	R1210	CR1210-4W-5R1J	Venkel
25	1	R14	10 kΩ	1/16 W	±1%	R0603	CR0603-16W-1002F	Venkel
26	1	U1	Si3402			QFN20N5X5P0.8	Si3402	SiLabs

5. Design Considerations

Following are the detailed design consideration for adapting the standard high-power design for lower power situations.

The Class 1 designs use smaller magnetic elements. In the isolated design, T1 is an EP7 core (10x10 mm footprint) vs. the EP13 core (13x13 mm) of the high-power design. In the non-isolated design, L1 is 6.1 x 6.1 mm vs. the 15 x 18 mm footprint required for full power. These components have been sized for the current level corresponding to 3 W of output power. For the isolated design, the magnetizing inductance and turns ratio of T1 was kept constant to avoid the need for feedback loop compensation changes and to keep the snubber and FET protection unchanged.

Since the Si3402 is designed for short-circuit protection at approximately 15 W of output power, Q1 and R13 are added as an input current limiter to prevent the magnetic elements form saturating. The input current limit is Vbe/R or about 120 mA at room temperature. At elevated temperatures, this current limit falls to about 90 mA, which is the input current draw at full output power. Because this circuit limits input current, the circuit operates at constant input power. Under fault conditions, the output current increases as the output voltage decreases. As the output current increases, the magnetic elements start to saturate, reducing efficiency and limiting the maximum output current under short-circuit conditions.

The input filter capacitor has been reduced from 12 µF electrolytic plus three parallel 1 µF X7R capacitors to 12 µF electrolytic plus one 1 µF X7R capacitor. The 5.1 Ω sense resistor and 0.1 µF input capacitors, C18 and C25, further reduce ripple reflected to the input.

For the isolated case, the first stage filter was reduced from 100 µF X5R to 22 µF X5R. The main output filter capacitor was not changed in order to avoid the need for feedback loop compensation changes and to give good load transient response.

Finally, the classification resistor, R1, was updated to the value required for Class 1.

6. Layout Considerations

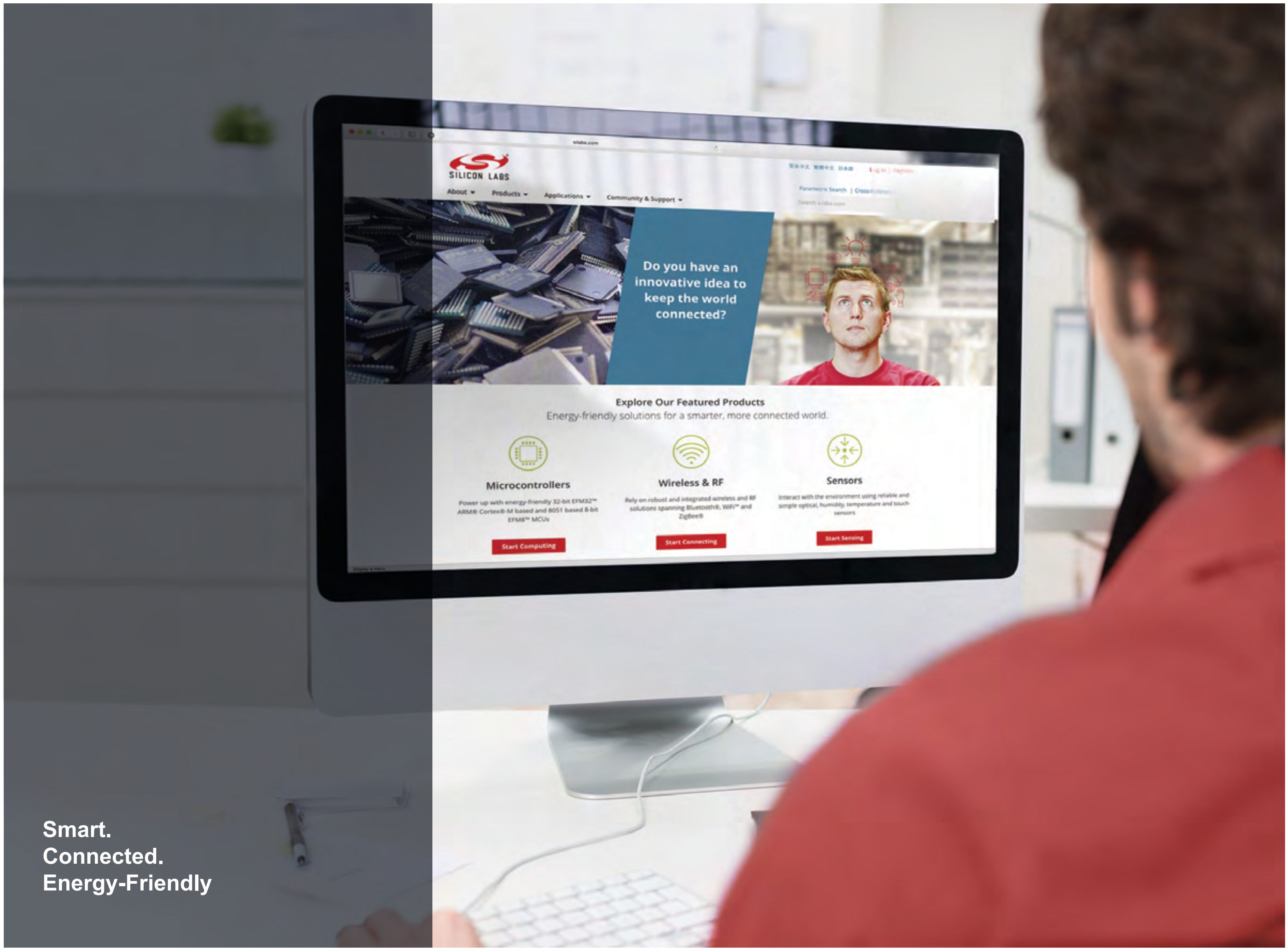
While the circuits of Figures 1 and 2 have been tested, detailed layout data bases are not available. Due to the smaller magnetic element sizes and reduced filtering, it should be possible to substantially reduce the area encompassed by the input and output current loops so as to reduce EMI (see also “AN296: Using the Si3402 PoE PD Controller in Isolated and Non-Isolated Designs). The size of the thermal heat spreader for the Si3402 can be safely reduced from two square inches to less than one square inch. Even though the power level is substantially reduced, careful layout is highly recommended. Visit SiLabs support at www.silabs.com or submit layouts to PoEinfo@silabs.com for schematic and layout review.

Document Change List

Revision 0.1 to Revision 0.2

- Updated Table 3, “Bill of Materials for Non-Isolated Class 1 Designs,” on page 6.
  - Modified rating, footprint, and part number for inductor L1 in non-isolated Class 1 designs.

NOTES:



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