

STEVAL-ISA081V1 demonstration board based on a 12 V / 1 A isolated flyback

Introduction

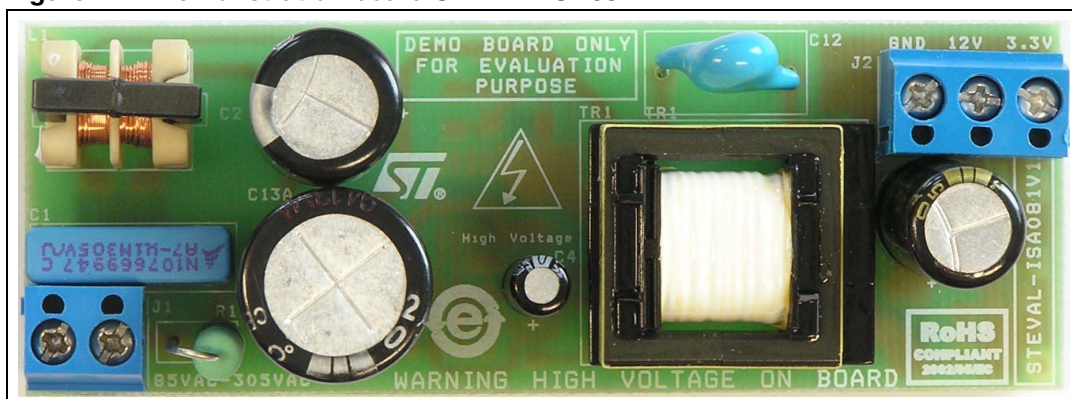
The purpose of this document is to provide information on the STEVAL-ISA081V1 switched mode power supply (SMPS) demonstration board. The STEVAL-ISA081V1 is an isolated SMPS capable of delivering a 12 W output over a wide input voltage range. It is designed for a mains application focused on providing a cost-effective and space saving solution.

The STEVAL-ISA081V1 SMPS generates 12 V nominal output voltage using primary regulation. This board is based on VIPer™26LD - a monolithic converter integrating a high voltage MOSFET and PWM controller in one package.

This document contains a fundamental technical description of the demonstration board (schematic diagram, PCB details, and bill of materials) as well as basic measurements (load regulation, efficiency, standby behavior, EMI and thermal behavior data).

The last section of this document contains short recommendations on how to set different output voltages in the range of 10 to 18 V and how to improve efficiency up to 86%.

Figure 1. Demonstration board STEVAL-ISA081V1



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1 Main characteristics

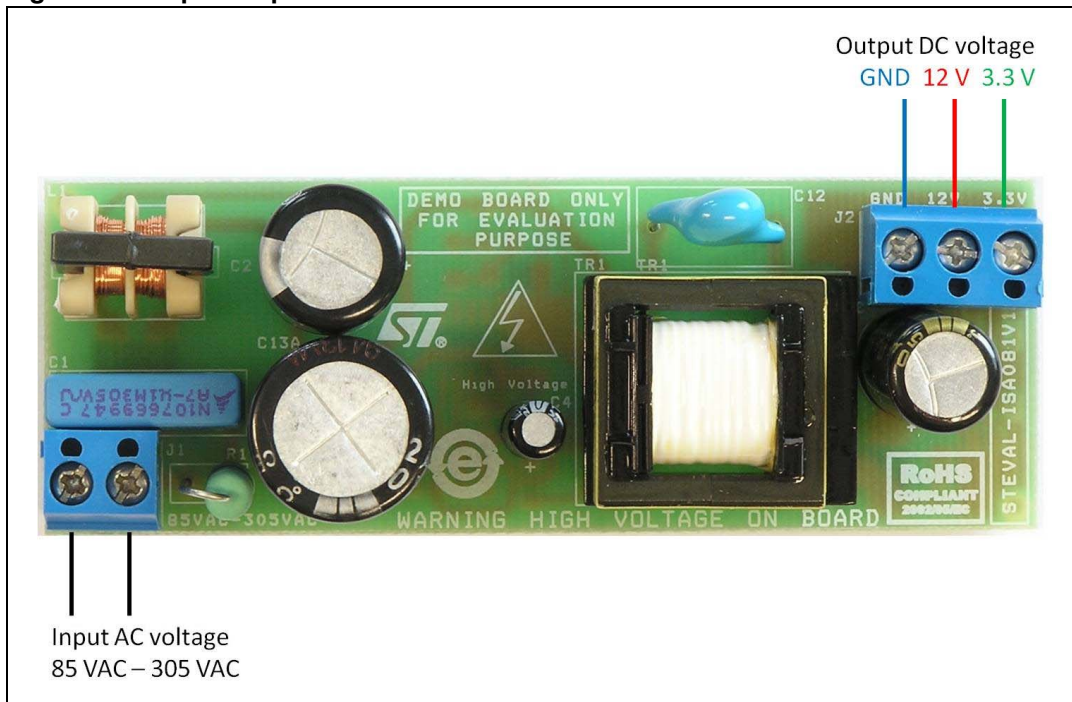
The main characteristics of the SMPS are listed below

- Input:
 - V_{IN} : 85 ~ 305 Vrms
 - frequency: 45 ~ 66 Hz
- Output:
 - 12 VDC $\pm$ 10%, 1 A (at 3.3 V not loaded)
 - 3.3 VDC $\pm$ 4%, 100 mA
 - Maximum total output current of 1 A
- Standby < 120 mW at 230 VAC
- Short-circuit: protected
- PCB type and size:
 - FR4
 - Single-sided 35 μ m
 - 32 x 90 mm
- Isolation: isolated 4 kV / 8 mm
- EMI: according to EN55022 Class B

2 Board connection

The STEVAL-ISA081V1 demonstration board is shown in [Figure 2](#) below, with input and output locations.

Figure 2. Input/output connection of SMPS

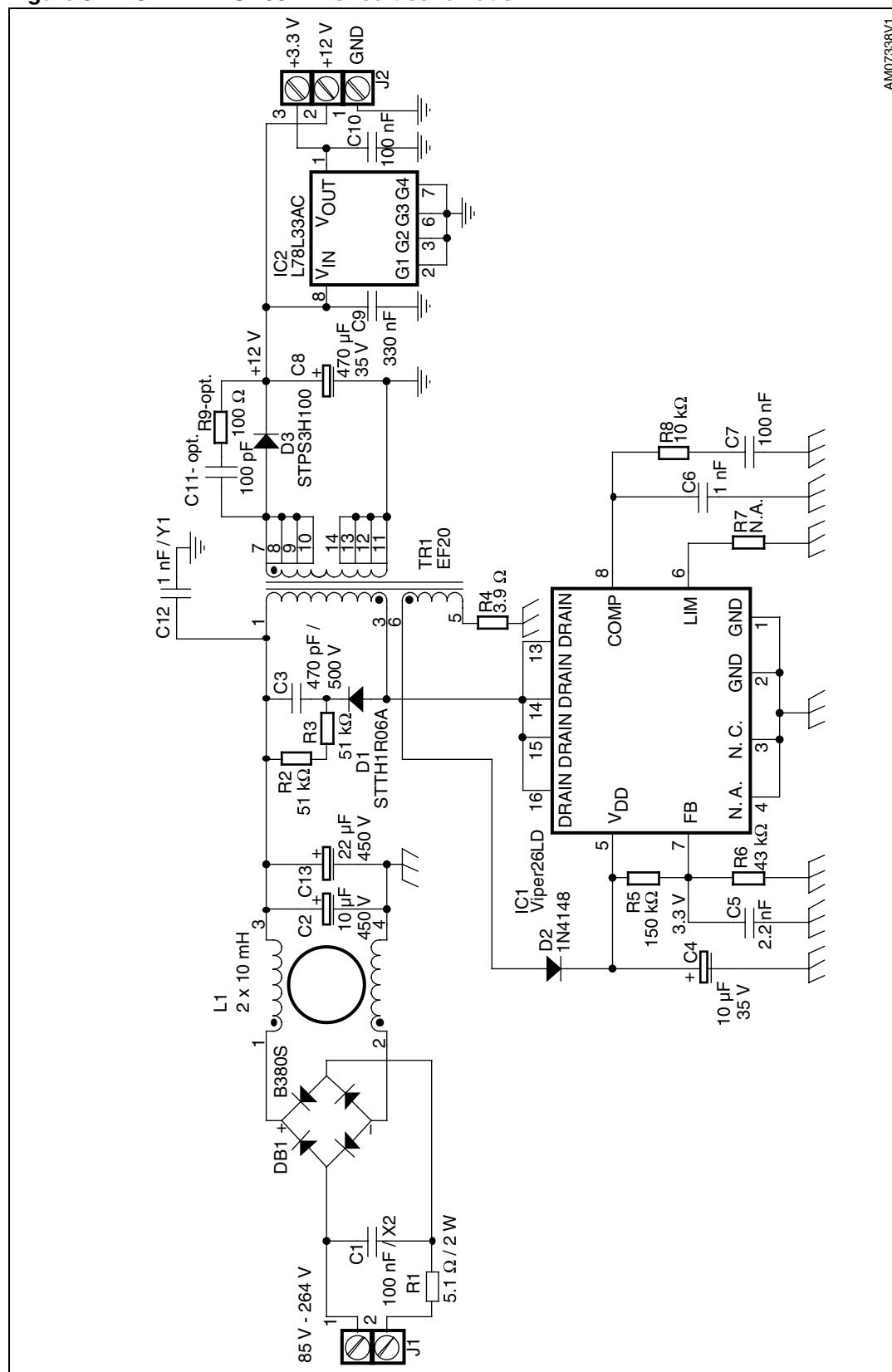


3 Board description

3.1 Schematic

A schematic diagram of the isolated flyback converter board prototype based on the VIPER26LD is provided in [Figure 3 on page 8](#).

Figure 3. STEVAL-ISA081V1 circuit schematic



3.2 Description of main components

The complete converter application consists of an input section and the flyback converter itself.

3.2.1 The input section contains

Bridge diode rectifier (DB1)

The bridge diode rectifier is used to reduce the size of the input bulk capacitor.

Inrush current limiter (R1)

This component reduces the inrush current caused by the connection of the SMPS to the mains (charging current of bulk capacitors) or by surge pulses. It is recommended to use a wirewound resistor to get higher immunity against current spikes.

EMI filter (L1, C1, C2, C13)

This basic EMI pi-filter uses an X2 foil capacitor (C1), bulk capacitors (C2, C13) and a CMC inductor (L1).

Input bulk capacitors (C2, C13)

These capacitors store energy when the input AC voltage is low. Their value respects the minimum input voltage and output power. The maximum voltage of these capacitors is 450 V for this design because the maximum input voltage is specified up to 305 VAC. If the maximum input voltage of the application is lower (more often the value is 265 VAC), 400 V capacitors can be used.

3.2.2 The flyback converter consists of

VIPER26LD (IC1)

This device integrates a controller and high voltage power MOSFET in one package. The controller works in current mode with a fixed frequency and in discontinuous mode even at the lowest input voltage. Thanks to the built-in error amplifier, the VIPER26LD can directly sense the auxiliary voltage via a voltage divider (R5, R6). Thanks to good coupling of the auxiliary and secondary windings, the auxiliary voltage corresponds well with the secondary voltage and can be used for feedback regulation. Mandatory components for proper operation of the VIPer26 are V_{DD} capacitor C4 and compensation network R8, C6 and C7. Diode D2 provides auxiliary voltage to C4 and the feedback voltage divider.

Note: The voltage divider collecting feedback information for the FB pin is connected to the V_{DD} pin. The total resistance of this voltage divider has to be designed with respect to the minimum charging current during startup and additional possible leakage currents (V_{DD} capacitor). The minimum charging current is 600 μ A, the maximum leakage current through the V_{DD} capacitor can be theoretically in the range of several tens of μ A. The total current through the voltage divider is therefore set to 150 μ A to guarantee enough margin for the startup circuit.

Peak clamp (D1, R2, R3, C3)

This circuit absorbs energy from the voltage spike present after MOSFET turn-off. This spike is generated by leakage inductance of the transformer. Alternatively, a Transil™-based peak clamp can be used - for instance PKC-136. The application of this device allows reducing standby consumption and it can also save some space on the board.

Secondary side (D3, C8, C11, R9, C9, IC2, C10)

The main secondary part is a rectifier consisting of D3 and C8. The C8 capacitor is stressed by a high level peak current and therefore a low ESR capacitor is used. The snubber circuit (optional) of D3 consists of C11 and R9. Thanks to the primary regulation, no additional components are required.

A simple linear regulator to generate 3.3 V on the output can also be implemented. The regulator (IC2) plays also the role of a bleeder - partly loading the output and keeping the output voltage below limits at no load. In case IC2 is not assembled, some type of bleeder (either a Zener diode or resistor) has to be applied in order to limit the maximum output voltage at no load.

Note: Components C13, DB1 and D3 appear with a suffix "A" on the PCB. This signifies that there is an assembled alternative package on the board. The functionality of such a component is the same as the basic component and therefore these components are not indicated in the schematic visible in [Figure 3](#).

3.3 Transformer

The transformer construction is designed in order to get good coupling between the auxiliary and secondary to reach applicable load regulation even when the primary regulation is used.

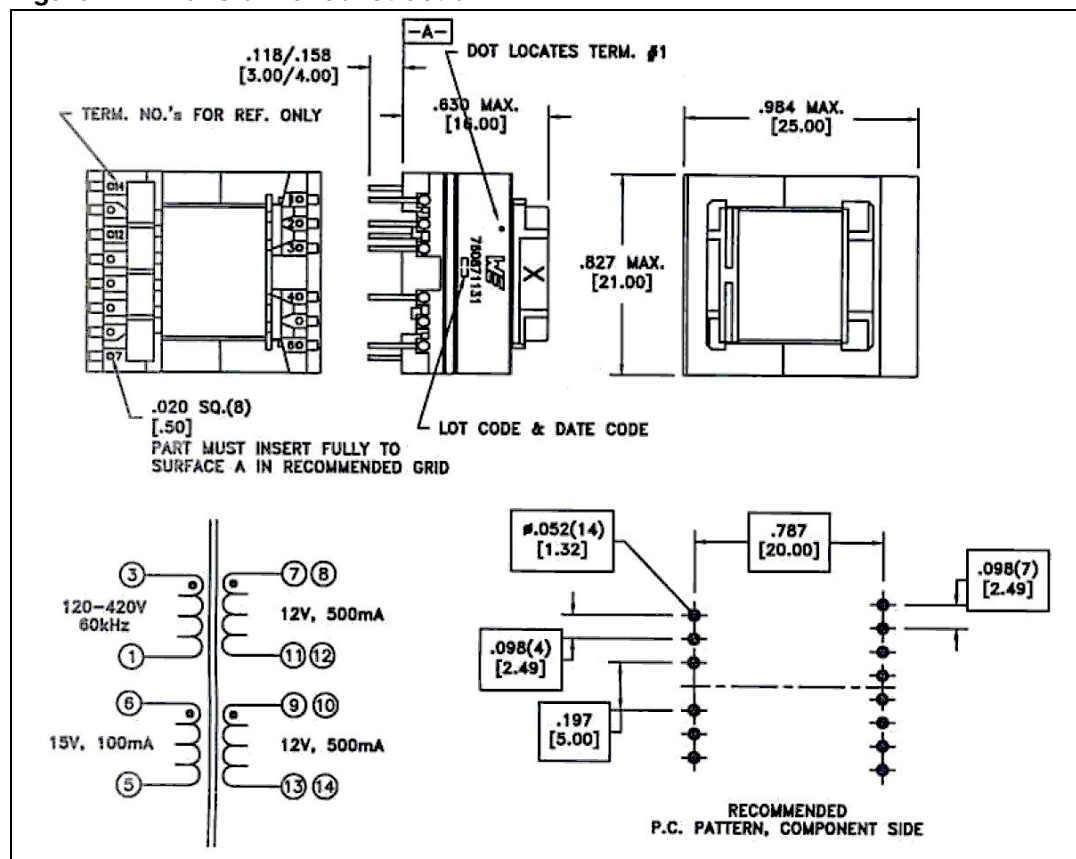
The transformer was developed in cooperation with WÜRTH ELEKTRONIK company and is available under order number **760871131**. The transformer specifications are as follows:

- E20/10/6 - 60 kHz, voltage range 85 - 305 VAC
- Core shape E20/10/6
- Core Al 150 nH
- Primary to secondary isolation 4 kV AC

Table 1. Transformer windings

Layer	Start pin	Stop pin	Number of turns	Wire number	Wire diameter (mm)	Wire material	Inductance (μH)	Position
1	3	1	96	2	0.2	Cu2I	1394	Primary
2	7, 8, 9, 10	11, 12, 13, 14	10	4	0.3	TeX	15	12 V / 1 A
3	6	5	12	1	0.2	Cu2I	22	14.5 V / aux.

Figure 4. Transformer construction



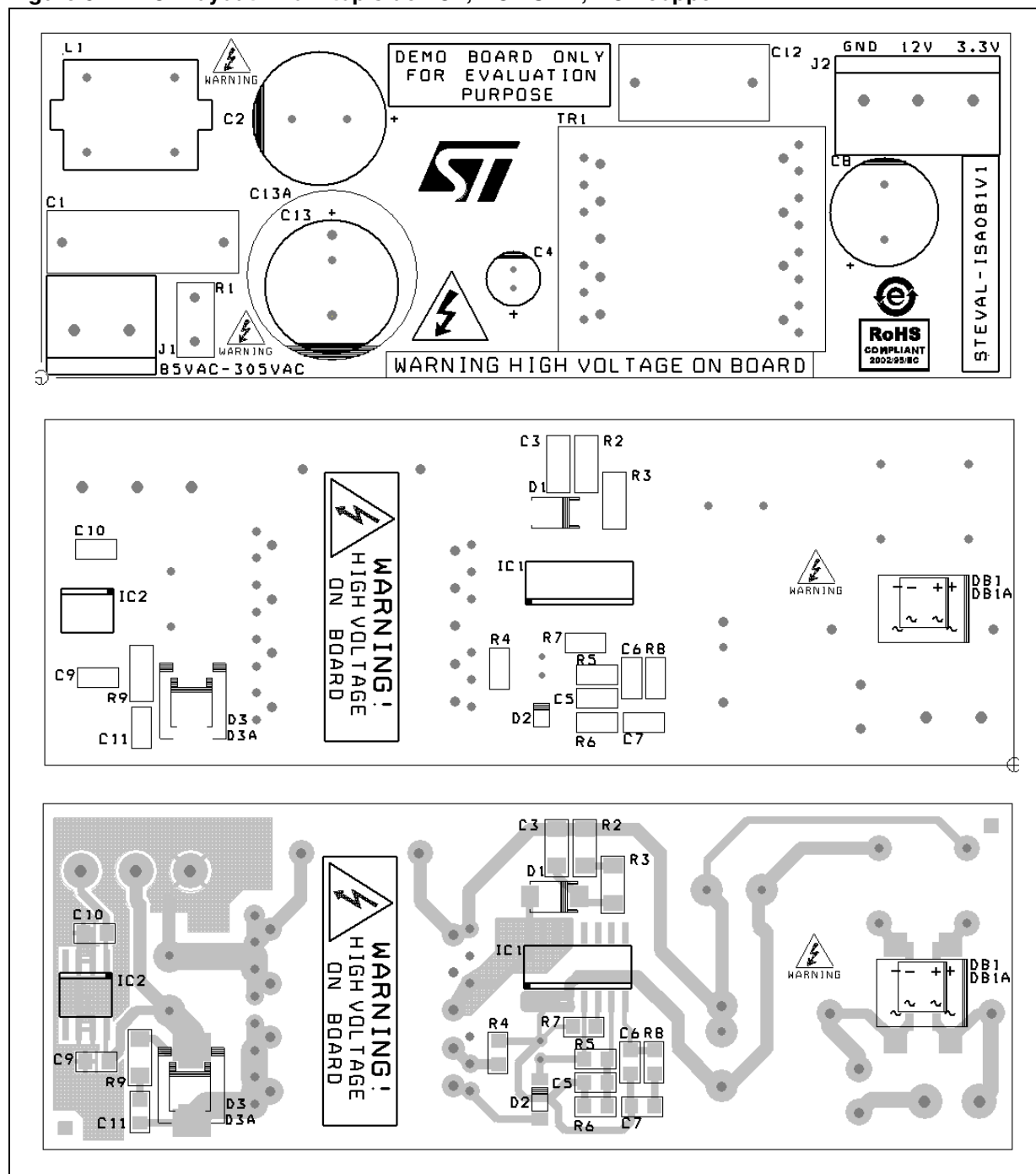
3.4 Layout

The layout of the PCB is based on a single-sided FR4, with 35 μm thickness. The size of the PCB is 32 x 90 mm. The distance between the primary and secondary side is higher than 8 mm, respecting the safety requirements for all standard applications. The layout of the PCB is provided in [Figure 5](#).

The layout was designed with respect to the following rules to achieve stable operation, good efficiency and reduce EMI noise.

- The power HF tracks are wide and short:
 - Transformer to IC1
 - Transformer to C13
 - IC1 to C13
 - Transformer to C8
 - C8 to D3
 - Transformer to D3
 - Peak clamp loop
- The power and signal GND of VIPER26LD are separated and connected only in one point close to the source pins
- The EMI filter has been placed far from the transformer to avoid possible crosstalk of EMI noise

Figure 5. PCB layout - from top side TOP, BOT SMD, BOT copper



3.5 BOM

Table 2. Bill of materials

Index	Quantity	Ref.	Value / generic part number	Package / class	Manufacturer
1	1	R1	5.1 Ω / 2 W	Wirewound	
	or		4.7 Ω / 2 W	Wirewound	
2	2	R2, R3	51 k Ω / 5% / 0.25 W	1206	
3	1	R4	3.9 Ω / 5% / 0.1 W	0805	
4	1	R5	150 k Ω / 1% / 0.1 W	0805	
5	1	R6	43 k Ω / 1% / 0.1 W	0805	
6	0	R7	Not assembled		
7	1	R8	10 k Ω / 5% / 0.1 W	0805	
8	0	R9	Not assembled		
9	1	C1	100 nF / 305 VAC / X2	18 x 5 x 11 RM 15	EPCOS
10	1	C2	10 μ F / 450 V	D12.5 x 20 RM 5	
11	1	C3	470 pF / 200 V	1206	
12	1	C4	10 μ F / 35 V / 105 $^{\circ}$ C	D5 x 11 RM 2	
13	1	C5	2.2 nF / 50 V	0805	
14	1	C6	1 nF / 50 V	0805	
15	2	C7, C10	100 nF / 50 V	0805	
16	1	C8	470 μ F / 35 V / low ESR	D10 x 20 RM 5	
17	1	C9	330 nF / 50 V	0805	
18	0	C11	Not assembled		
19	1	C12	1 nF / 250 VAC / 4 kV / Y1	RM 12	
20	0	C13	Not assembled		
21	1	C13A	22 μ F / 450 V	D16 x 20 RM 5	
22	1	L1	CMC 2 x 10 mH	UU9.8, RM 8 x 7	EPCOS
23	1	T1	EF20 - 1.41 mH	EF20	WÜRTH ELEKTRONIK
24	0	DB1	Not assembled		
25	1	DB1A	1 A / 800 V / bridge	SO-DIL	
26	1	D1	STTH1R06A	SMA	STMicroelectronics™
27	1	D2	1N4148	MINIMELF / SOD80	
28	0	D3	Not assembled		
29	1	D3A	STPS2H100U	SMB	STMicroelectronics
30	1	IC1	VIPER26LN	SO16N	STMicroelectronics
31	1	IC2	L78L33AC	SO8N	STMicroelectronics

Table 2. Bill of materials (continued)

Index	Quantity	Ref.	Value / generic part number	Package / class	Manufacturer
32	1	J1	Screw terminal 2 pos.	RM 5 mm	
33	1	J2	Screw terminal 3 pos.	RM 5 mm	

4 Measurements

4.1 Efficiency

Figure 6. Efficiency at 120 VAC and 230 VAC vs. output current

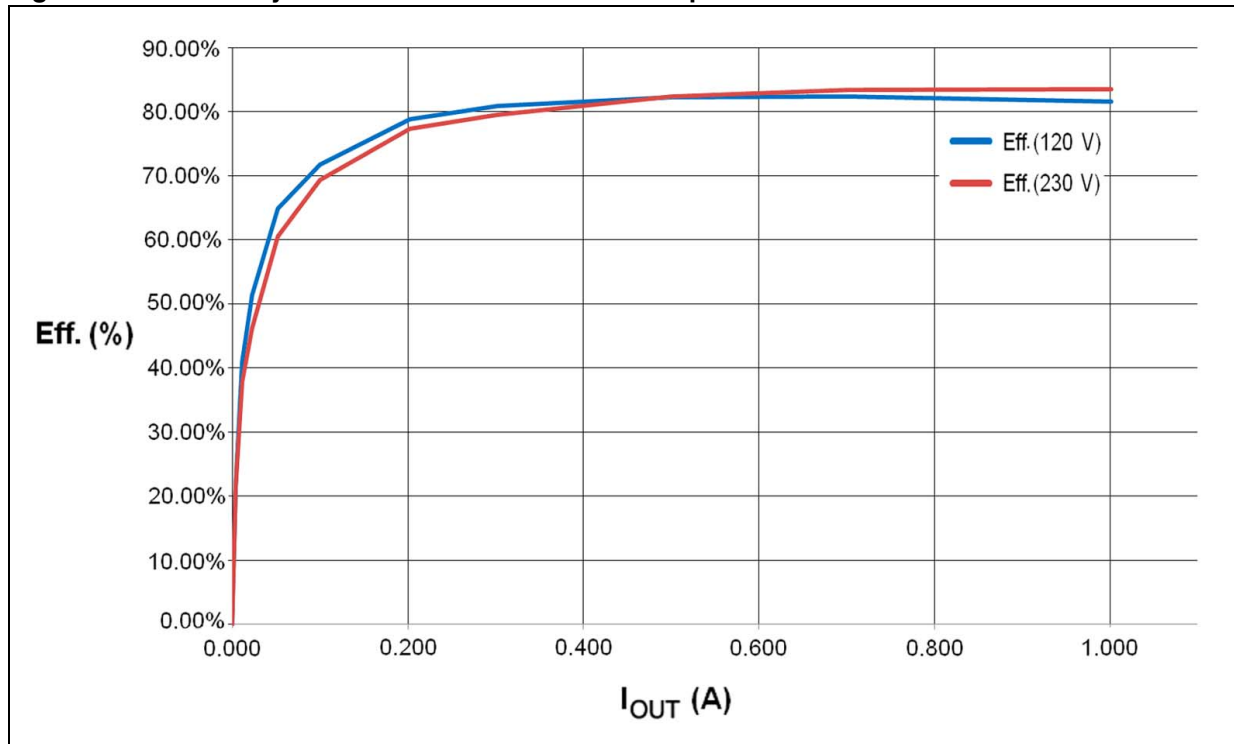
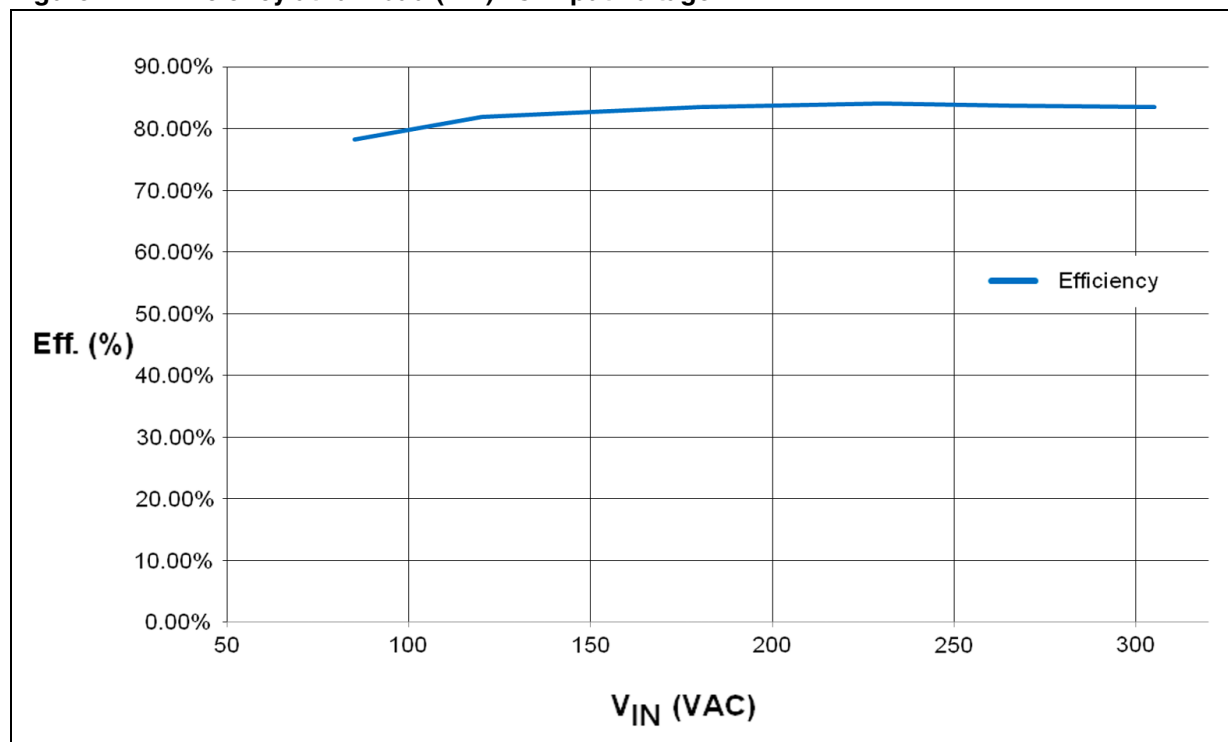


Figure 7. Efficiency at full load (1 A) vs. input voltage

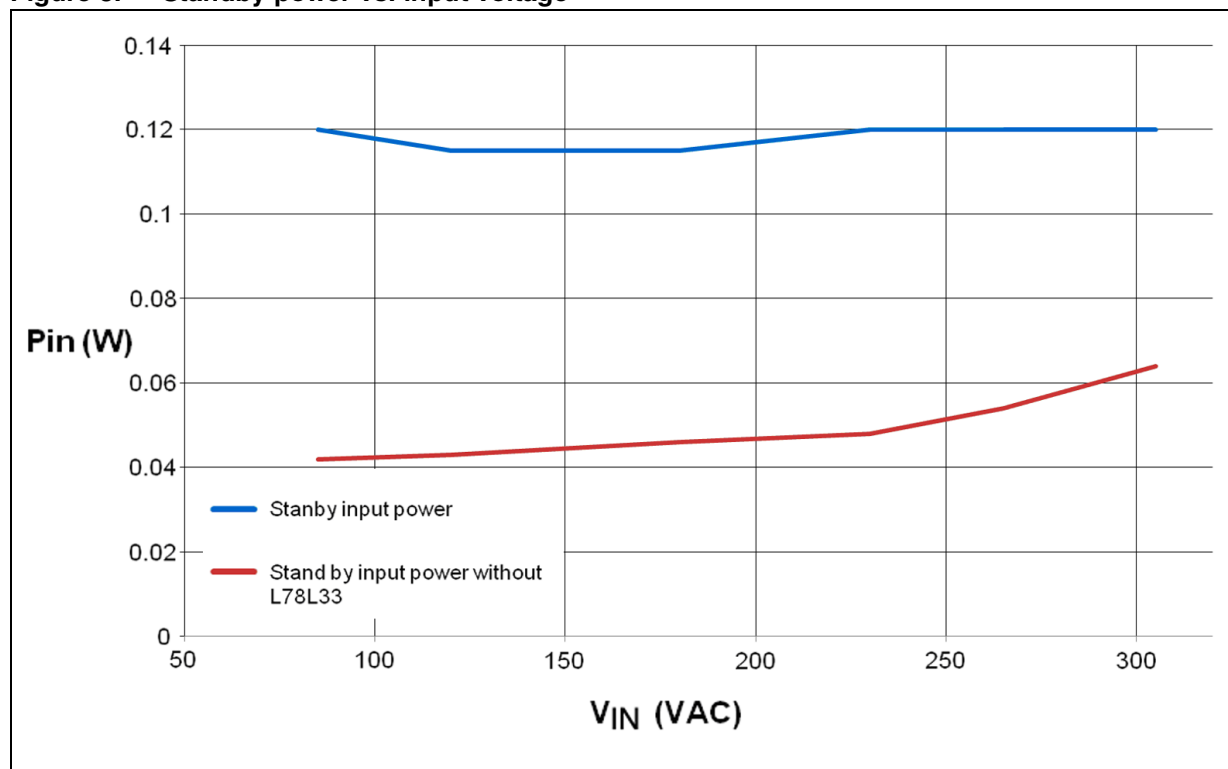
The output voltage efficiency depending on the output current of the 12 V output is displayed in [Figure 6](#). The 3.3 V output was not loaded for this measurement.

[Figure 7](#) shows the efficiency of the SMPS at full load applied on the 12 V output (1 A, 3.3 V output not loaded) depending on the different input voltages. A drop of efficiency at low input voltage is mainly caused by an increase of the losses of the input inrush resistor and CMC.

The efficiency was calculated as the ratio between the output power and input power. The input power was directly measured by power analyzer NORMA 4000. The output power was calculated as the product of the output current and output voltage. The output voltage was measured on the output connector by multimeter KEITHLEY 2000 and the current was measured by multimeter FLUKE 189.

4.2 Standby

Figure 8. Standby power vs. input voltage

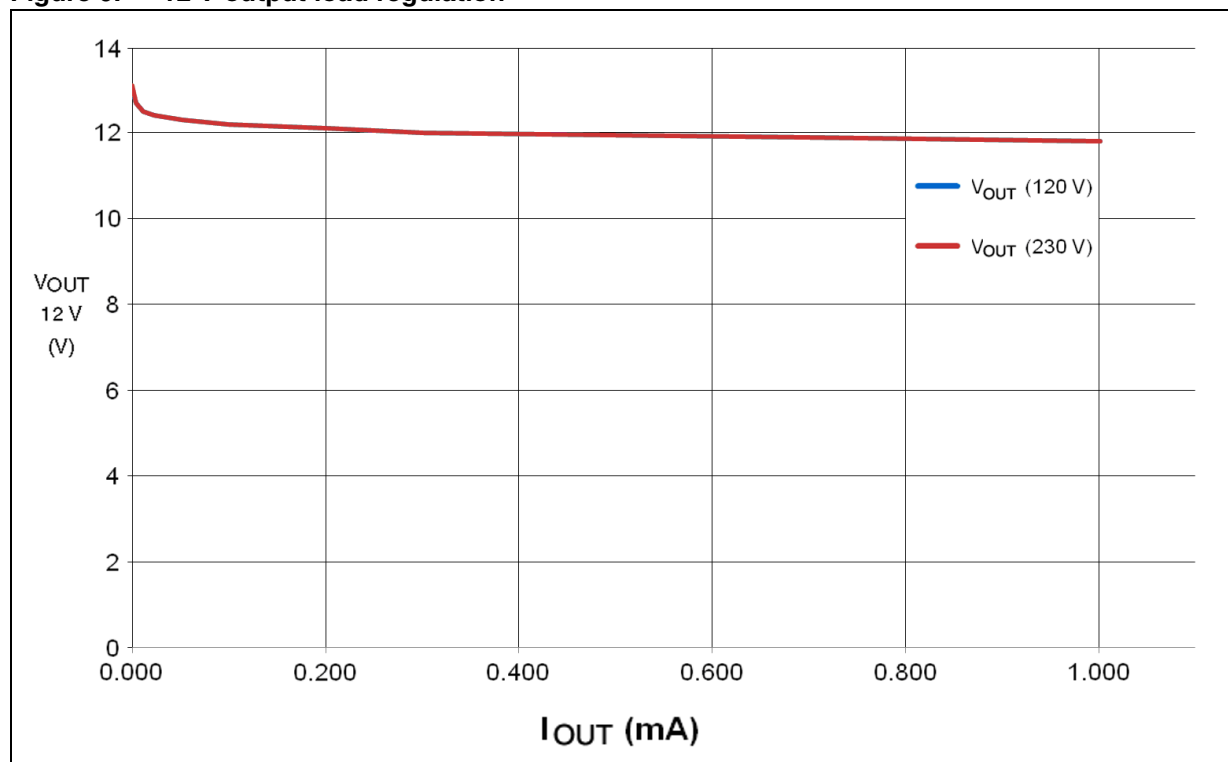


The standby behavior of the board is displayed in [Figure 8](#). The blue line is the standby input power of the fully assembled board. The red line is the standby input power of the board without linear regulator L78L33 and with a 15 V Zener diode applied as a bleeder. The typical input current of L78L33 is 3.5 mA which is approximately 40 mW of load present on the secondary side.

The standby input power was directly measured by power analyzer NORMA 4000. The output connection was kept open during the measurement.

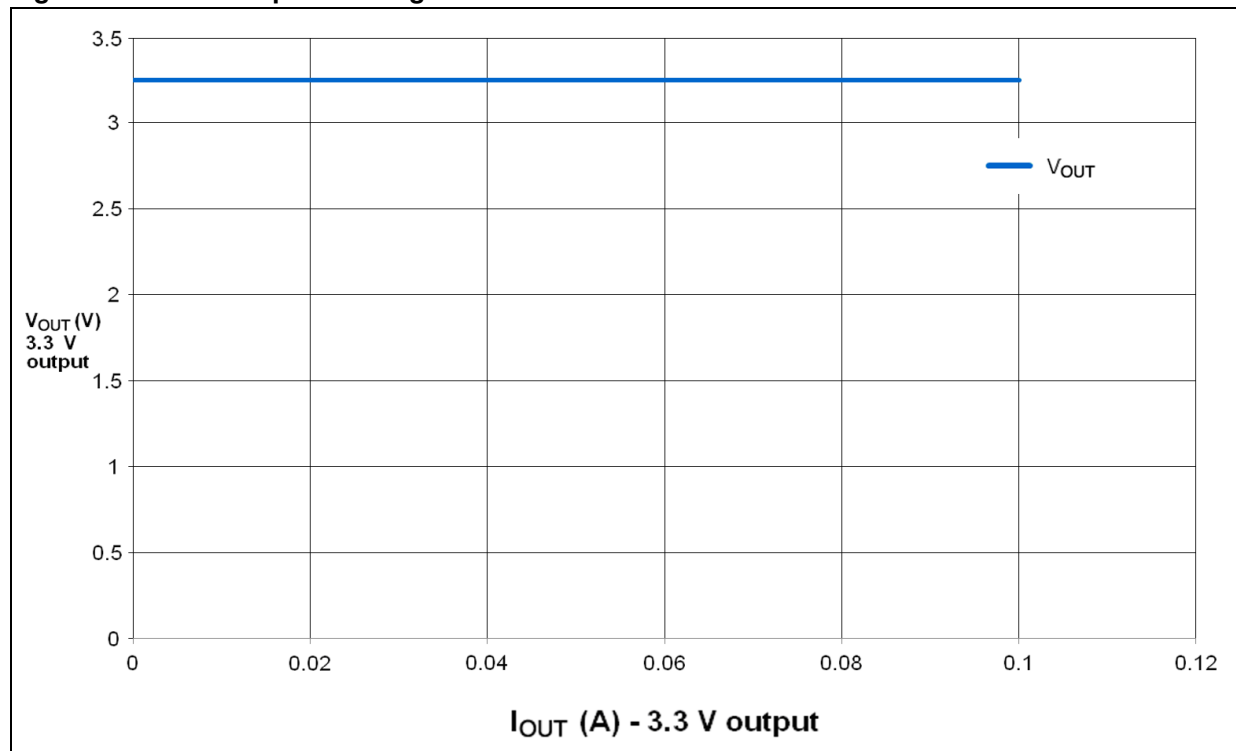
4.3 Load regulation

Figure 9. 12 V output load regulation

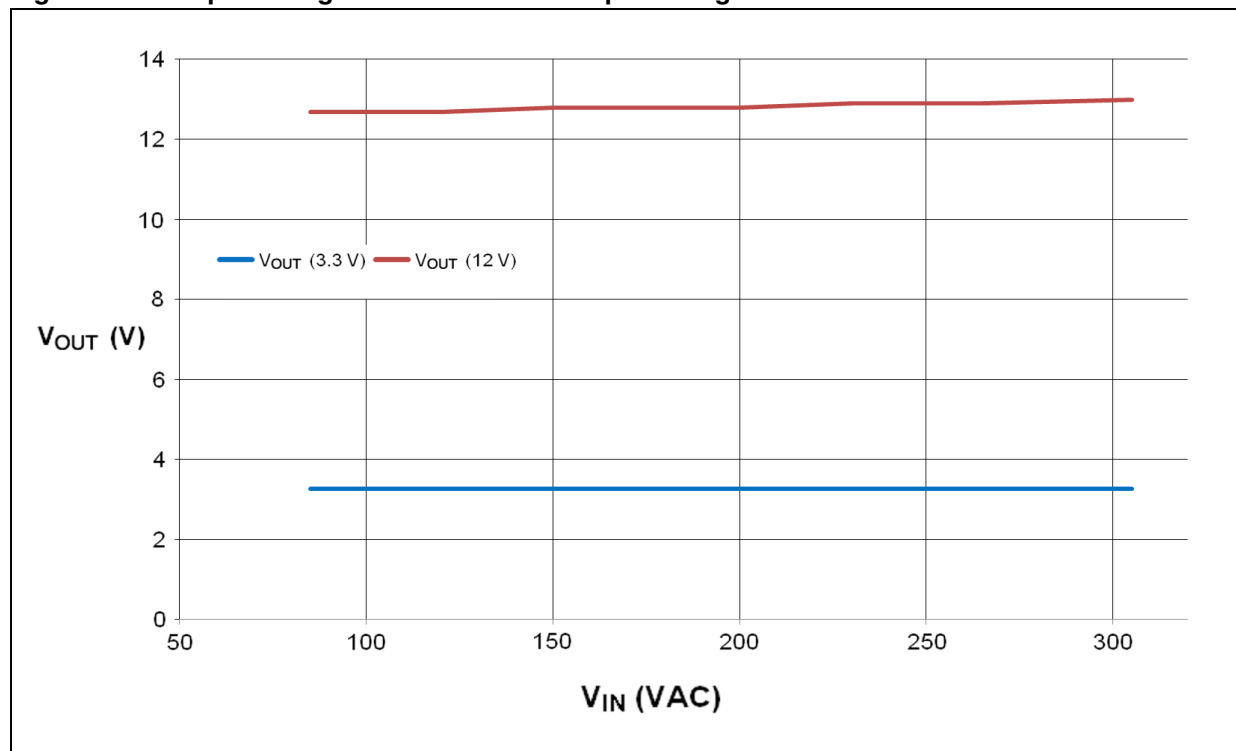


The load regulation of the 12 V output is displayed in [Figure 9](#). The output voltage at no output load is determined by the consumption of L78L33. If L78L33 is not implemented and no other bleeder (Zener diode or resistor) is used, the output voltage rises.

The load regulation of the 3.3 V output is visible in [Figure 10](#).

Figure 10. 3.3 V output load regulation

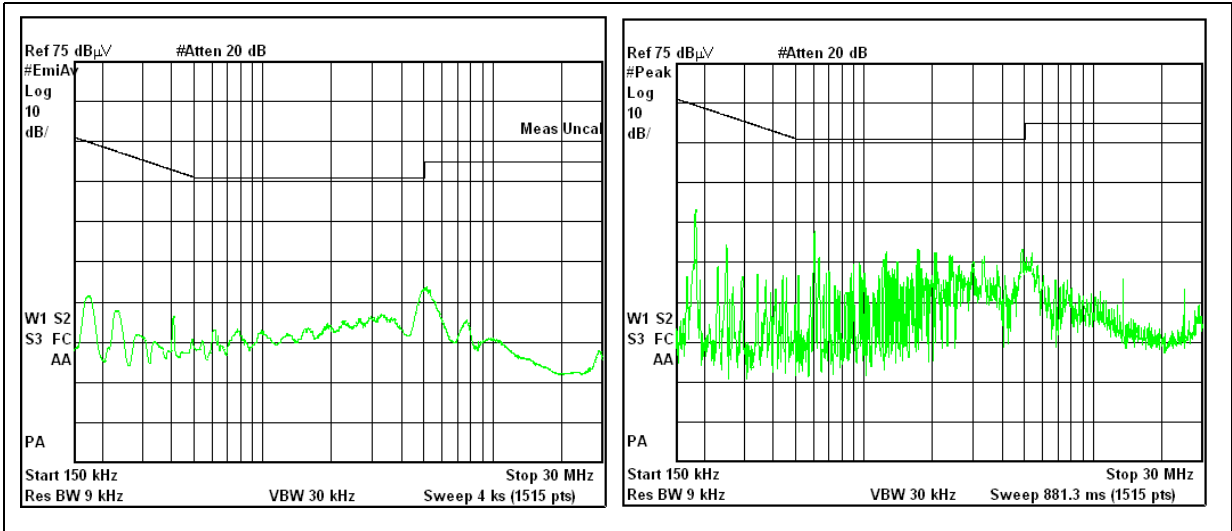
The output voltage of the 3.3 V and 12 V output at no load depending on the input voltage is visible in [Figure 11](#).

Figure 11. Output voltage at no load vs. the input voltage level

4.4 EMI

The conductive EMI test of the demonstration board is displayed in [Figure 12](#). The AVG detector is indicated on the left, the peak detector measurement is indicated on the right.

Figure 12. EMI measurement regarding EN55022 Class 2 - left peak detector, right AVG detector



4.5 Temperature

The thermal map at full load, measured at 305 VAC and at 85 VAC, is displayed in [Figure 13](#) and [Figure 14](#). The ambient temperature was 25 °C.

Figure 13. Thermal map of the board at 305 V AC on the input - left bottom side, right top side

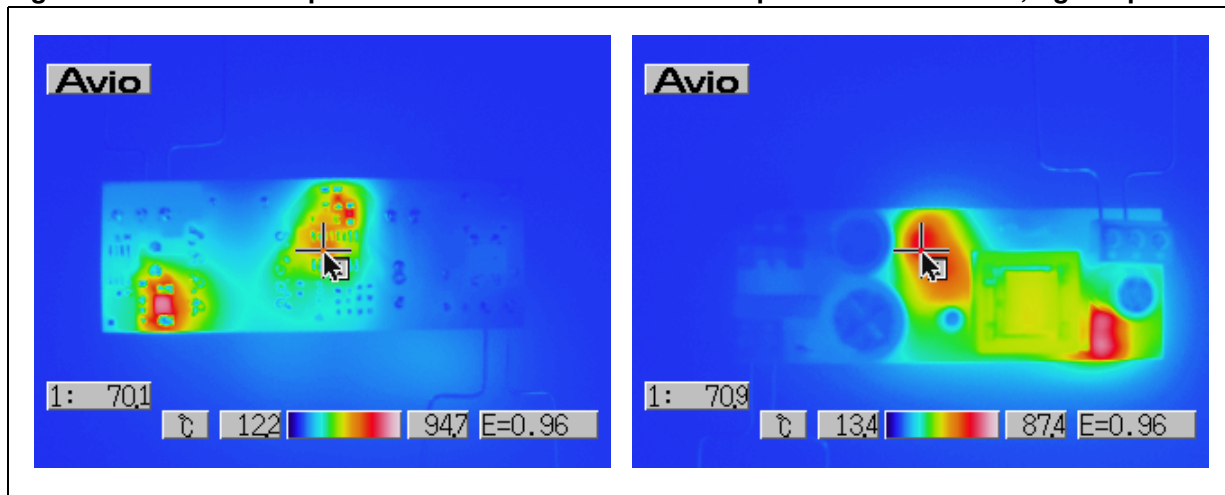
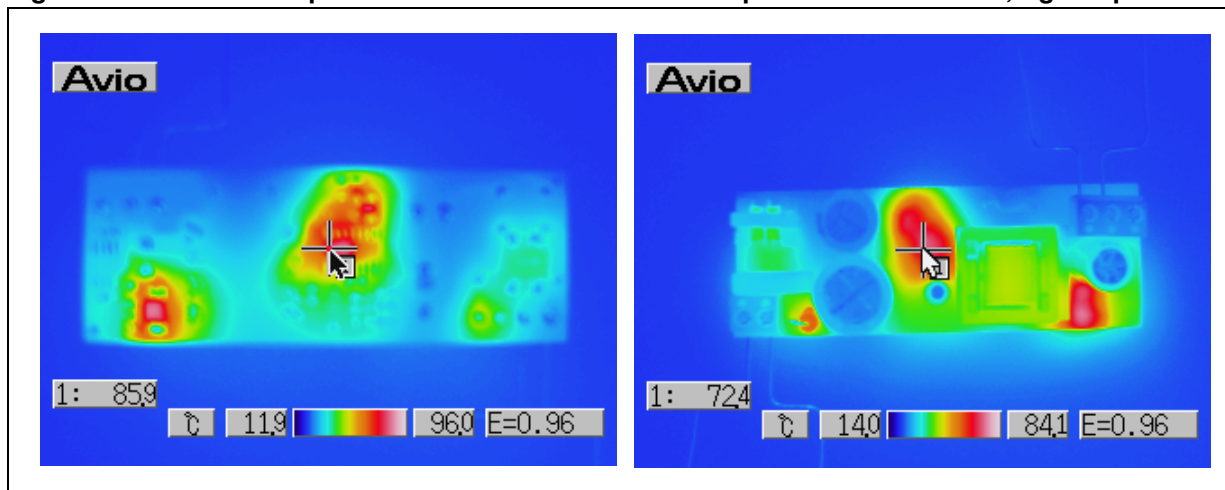


Figure 14. Thermal map of the board at 85 V AC on the input - left bottom side, right top side



5 Application recommendations

5.1 Output voltage operating range

The demonstration board STEVAL-ISA081V1 was originally designed for output specification 12 V / 1 A supplied from wide input range 85 to 305 VAC. With minimal changes of components it is possible to set a different output voltage in the nominal output voltage range of 10 to 18 V, keeping the output power capability. The only changes are in the values of voltage divider R5, R6. The other components including the transformer remain the same. [Table 3](#) shows applicable values of the voltage divider for different nominal output voltages. There is also visible an indicative value of output voltage at full and no load, standby consumption and efficiency at full load measured on one sample.

Table 3. Settings and performance of demonstration board for different output voltages

V _{OUT} (V) nominal value	R5 (kΩ)	R6 (kΩ)	V _{OUT} (V) no load	V _{OUT} (V) full load	I _{OUT} (A) at load	V _{AUX} (V)	P _{IN} (mW) no load	Eff. (%)
10	150	56	10.90	9.70	1.20	12.2	100	83.0
12	150	43	13.10	11.80	1.00	15.0	112	84.1
15	150	33	15.90	14.75	0.80	18.6	170	83.9
18	91	16	18.90	17.80	0.67	21.8	270	83.7

The major limitation regarding the setting of the output voltages is the VIPer26 supply range (V_{AUX} column) and transformer design.

The supply voltage of VIPer26 has to be in the range of 11.5 to 23.5 V which consequently limits the output voltage range using the same transformer.

There are theoretically several possible limiting factors caused by the transformer due primarily to the turns ratio. The consequence of using a transformer designed for 10 V output for an 18 V output voltage level is a higher voltage stress on the primary side switch. Thanks to the VIPer26 which has implemented an 800 V MOSFET, there is still enough margin even at 18 V on the output. The maximum drain source voltage measured at 305 VAC with 18 V set on the output was 700 V.

5.2 Improved efficiency

The measured efficiency is about 84% at full output load and 230 VAC. This value can be increased by simply changing the output Schottky diode. Please note that the original board contains an STPS3H100 - 3 A / 100 V Schottky diode. This diode is universal - applicable also up to 18 V output voltage. If only 12 V output is required, a 60 V Schottky diode can be used.

An STPS5L60 - 5 A / 60 V Schottky diode in the SMC package was tested. The result measured on one sample at 230 VAC is displayed in [Table 4](#).

Table 4. Efficiency using a 60 V Schottky diode

D3	V _{OUT} (V) full load	I _{OUT} (A) full load	Eff. (%)	VD3 (V) at 305 VAC
STPS3H100	11.80	1.00	84.1	56
STPS5L60	12.15	1.00	86.1	56

6 Revision history

Table 5. Document revision history

Date	Revision	Changes
25-Nov-2010	1	Initial release.
08-Jun-2012	2	Updated Figure 3 , minor text corrections throughout document.

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