AN5030
Application note

16 W, triple output, quasi-resonant flyback converter for air conditioning applications using VIPerPlus – VIPER35LD

Introduction

The STEVAL-ISA183V1 evaluation board implements a 16 W triple output power supply designed in quasi-resonant flyback topology, specifically designed as an auxiliary PSU for air conditioning systems.

The core of the application is the VIPER35LD high voltage converter from the VIPerPlus product family which integrates an 800 V rugged power MOSFET with a quasi-resonant PWM current-mode control.

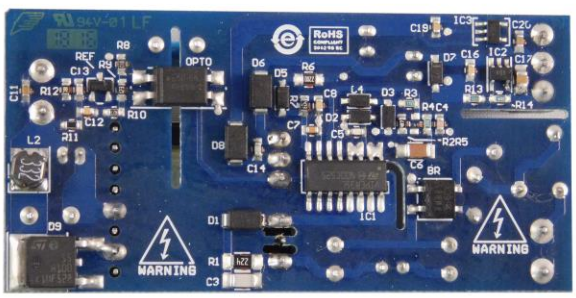
The power supply provides an isolated 12 V/1 A output a two non-isolated outputs, 15 V/200 mA and 5 V/200 mA respectively.

The board features:

- AC main input voltage range : 175 V_{AC} to 275 V_{AC}
- Triple output voltages: 12 V-1 A (Isolated), 15 V-200 mA (non-isolated), 5 V-200 mA (non-isolated), continuous operation
- High performance at low load conditions: < 50 mW at no-load condition and < 1.5 W input power at minimum operative output power (0.91 W)
- Efficiency at full load: > 81%
- EN55022 Class B conducted EMI compliant, using a low cost input filter
- RoHS compliant

Figure 1: STEVAL-ISA183V1 evaluation board (top view)

Figure 2: STEVAL-ISA183V1 evaluation board (bottom view)



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1 Electrical specifications and cross regulation

Table 1: STEVAL-ISA183V1 electrical specifications

Parameter	Min.	Typ.	Max.
AC Main Input voltage	175 V_{AC}		275 V_{AC}
Mains frequency (f_L)	50 Hz		60 Hz
Output Voltage 1 (isolated)	11.4 V	12 V	12.6 V
Output Current 1	30 mA		1 A
Output voltage 1 ripple			240 mVpp
Output Voltage 2 (non-isolated)	14.25 V	15 V	15.75 V
Output Current 2	30 mA		200 mA
Output voltage 2 ripple			300 mVpp
Output Voltage 3 (non-isolated)	4.9 V	5 V	5.1 V
Output Current 3	20 mA		200 mA
Output voltage 3 ripple			50 mVpp
Rated output power	0.96 W		16 W
Efficiency at full load	81 %		
Input power at minimum load			1.5 W
Input power in standby			50 mW
Secondary overvoltage protection			15.5 V
Ambient operating temperature	-25 °C		70 °C

As shown in the table above, a minimum load is required for each output to ensure proper regulation.

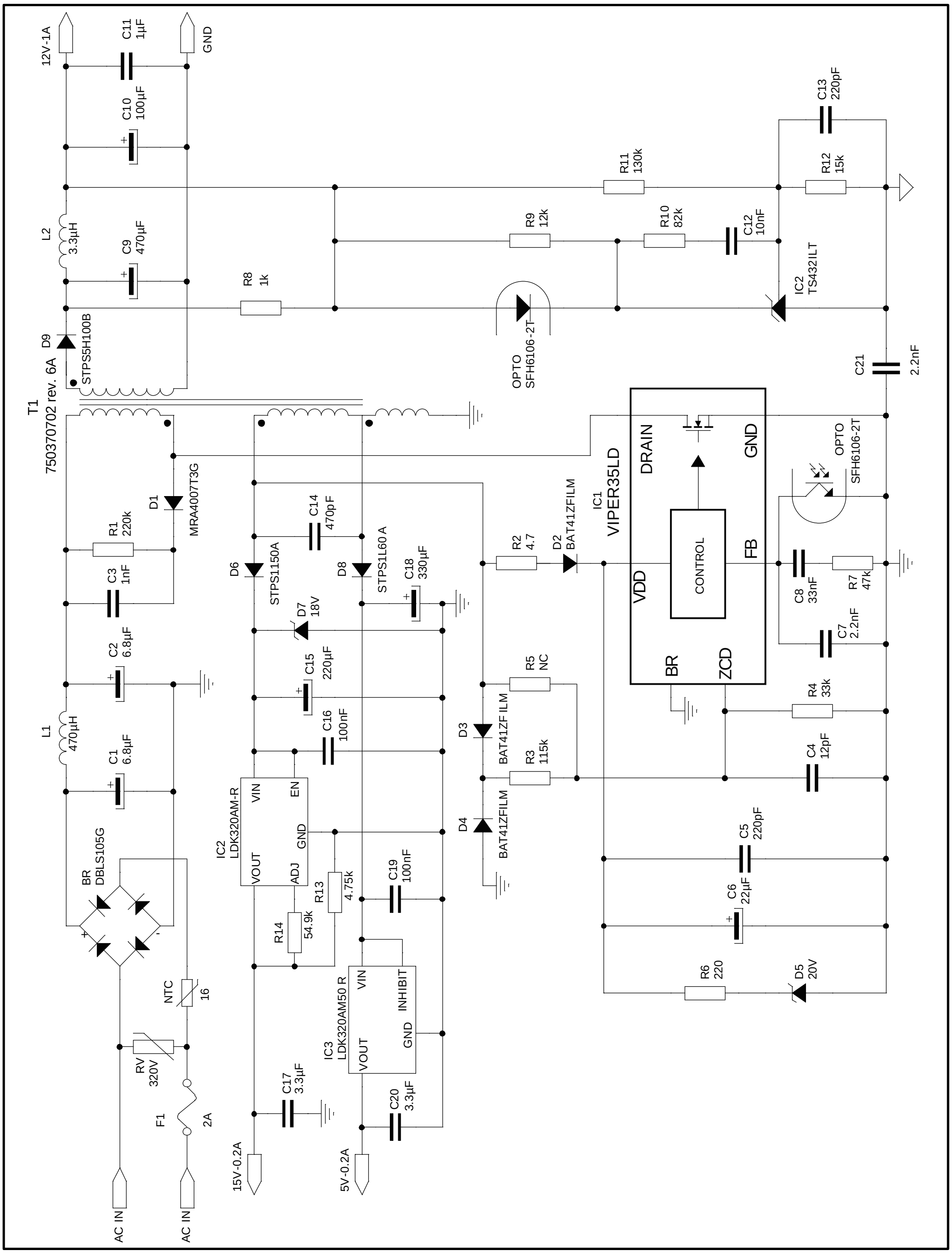
Table 2: Cross regulation

Test condition	Output 1	Output 2	Output 3
N. 1	30 mA	150 mA	150 mA
N. 2	700 mA	30 mA	150 mA
N. 3	700 mA	150 mA	20 mA

In all the test conditions shown in *Table 2: "Cross regulation"*, the output voltages must be within the limits shown in *Table 1: "STEVAL-ISA183V1 electrical specifications"*.

2 Schematic diagram

Figure 3: STEVAL-ISA183V1 circuit schematic



3 Bill of materials

Table 3: STEVAL-ISA183V1 bill of materials

Item	Q.ty	Ref.	Part/ Value	Description	Manufacturer	Order code
1	1	IN		Input connector	TE Connectivity	282837-2
2	1	OUT_PRI		Secondary output connector	TE Connectivity	282837-2
3	1	OUT_SEC		Primary input connector	Wurth Elektronik	691214110003
4	1	RV		MOV	EPCOS	B72210S0321K101
5	1	BR	SOIC4	Bridge rectifier	Taiwan Semiconductor	RMB6S
6	1	F1	2.5 A	Fuse	Cooper Bussmann	SS-5F-2-5A-BK
7	1	NTC	20 Ω, 2 A		Ametherm	SL08 20002
8	2	C1, C2	6.8 µF, 400 V	Electrolityc capacitor	Rubycon	400AX6R8MEFC8X1 0.8
9	1	C3	1 nF, 630 V, 1206	MLCC capacitor	TDK	C3216C0G2J102JT
10	1	C4	12 pF, 50 V, 0603	MLCC capacitor	Murata	GRM1885C1H120JA 01D
11	2	C5, C13	220 pF, 16 V, 0603	MLCC capacitor	Murata	GRM188R71H221KA 01D
12	1	C6	22 µF, 35 V, 1206	MLCC capacitor	TDK	C3216X5R1V226M1 60AC
13	1	C7	2.2 nF, 50 V, 0603	MLCC capacitor	Murata	GRM1885C1H222FA 01D
14	1	C8	33 nF, 16 V, 0603	MLCC capacitor	Murata	GRM188R71H333KA 61D
15	1	C9	470 µF, 25 V	Electrolityc capacitor	Rubycon	25ZLH470MEFC10X 12.5
16	1	C10	100 µF, 25 V	Electrolityc capacitor	Rubycon	25YXJ100M5X11
17	1	C11	1 µF, 25 V, 0603	MLCC capacitor	Murata	GRM188C81E105KA ADD
18	1	C12	10 nF, 50 V, 0603	MLCC capacitor	Murata	GRM188R71H103KA 01D
19	1	C14	470 pF, 50 V, 0603	MLCC capacitor	Murata	GRM188R71H471KA 01D

Item	Q.ty	Ref.	Part/ Value	Description	Manufacturer	Order code
20	1	C15	220 µF, 25 V	Electrolityc capacitor	Rubycon	25YXJ220M6.3X11
21	2	C16, C19	100 nF, 50 V, 0603	MLCC capacitor	Murata	GCM188R71H104KA 43D
22	1	C17	3.3 µF, 25 V, 0805	MLCC capacitor	Murata	GRM21BR61E335K A12L
23	1	C18	330 µF, 10 V	Electrolityc capacitor	Rubycon	10ZLH330MEFC6.3X 11
24	1	C20	3.3 µF, 10 V, 0603	MLCC capacitor	Murata	GRM188R61A335KE 15D
25	1	C21	2.2 nF, 250 Vac	Ceramic X1/Y1 capacitor	Murata	DE2E3KY222MA2B M01
26	1	R1	220 kΩ ±5%, 0.33 W, 200 V, 1206	Resistor	Panasonic	ERJ-P08J224V
27	1	R2	4.7 Ω±1%, 0.1 W, 0603	Resistor	Panasonic	ERJ3RQF4R7V
28	1	R3	115 kΩ±0.1% , 0.1 W, 0603	Resistor	Panasonic	ERA3AEB1153V
29	1	R4	33 kΩ±0.1% , 0.1 W, 0603	Resistor	Panasonic	ERA3AEB333V
30	1	R5				DNM
31	1	R6	220 Ω±5%, 0.25 W, 0805	Resistor	Panasonic	ERJT06J221V
32	1	R7	47 kΩ±1%, 0.1 W, 0603	Resistor	Panasonic	ERJ-3EKF4702V
33	1	R8	1 kΩ±5%, 0.1 W, 0603	Resistor	Panasonic	ERJ3GEYJ102V

Item	Q.ty	Ref.	Part/ Value	Description	Manufacturer	Order code
34	1	R9	12 kΩ±5%, 0.1 W, 0603	Resistor	Panasonic	ERJ3GEYJ123V
35	1	R10	82 kΩ±5%, 0.1 W, 0603	Resistor	Panasonic	ERJ3GEYJ823V
36	1	R11	130 kΩ±1%, 0.2 W, 0603	Resistor	Panasonic	ERJP03F1303V
37	1	R12	15 kΩ±1%, 0.2 W, 0603	Resistor	Panasonic	ERJP03F1502V
38	3	D2, D3, D4	0.15 A, 100 V, SOD-123	Signal Schottky	STMictroelectronics	BAT41ZFILM
39	1	D5	20 V±5%, 0.5 W, SOD-123	Zener diode	Vishay	MMSZ5250BT1G
40	1	D6	150 V, 1 A, SMA	Power Schottky	STMictroelectronics	STPS1150A
41	1	D7	18 V±5%, 0.5 W, SOD-123	Zener diode	ONSemiconductors	MMSZ5248BT1G
42	1	D8	60 V, 1 A, SMA	Power Schottky	STMictroelectronics	STPS1L60A
43	1	D9	100 V, 5 A, DPACK	Power Schottky	STMictroelectronics	STPS5H100B
44	1	L1	470 µH	Radial inductor	Wurth Elektronik	7447462471
45	1	L2	3.3 µH		Coilcraft	SD43-332ML
46	1	IC1	SO16	HV converter	STMictroelectronics	VIPER35LD
47	1	IC2	SOT23-5L	Adjustable LDO	STMictroelectronics	LDK320AM-R
48	1	IC3	5 V, SOT23-5L	LDO	STMictroelectronics	LDK320AM50R
49	1	REF	SOT23	Reference	STMictroelectronics	TS432ILT
50	1	OPT	SMD4	Optocoupler	Vishay	SFH6106-2T
51	1	T1	EF20	Flyback transformer	Wurth Elektronik	750370702 rev. 6A

4 Transformer

Table 4: Transformer characteristics

Parameter	Value
Manufacturer	Wurth Elektronik
Order code	750370702 rev. 6A
Core	EE20/10/6
Primary inductance	1.5 mH ±10%
Leakage inductance	30 µH max.
Saturation current	1.2 A
Primary to secondary turn ratio	5.6:1, ±1%
Primary to auxiliary 1 turn ratio	10.77:1, ±1%
Primary to auxiliary 2 turn ratio	7:1, ±1%
Primary 1 to primary 2 turn ratio	1:1, ±1%

Figure 4: Transformer electrical and pin pattern diagram

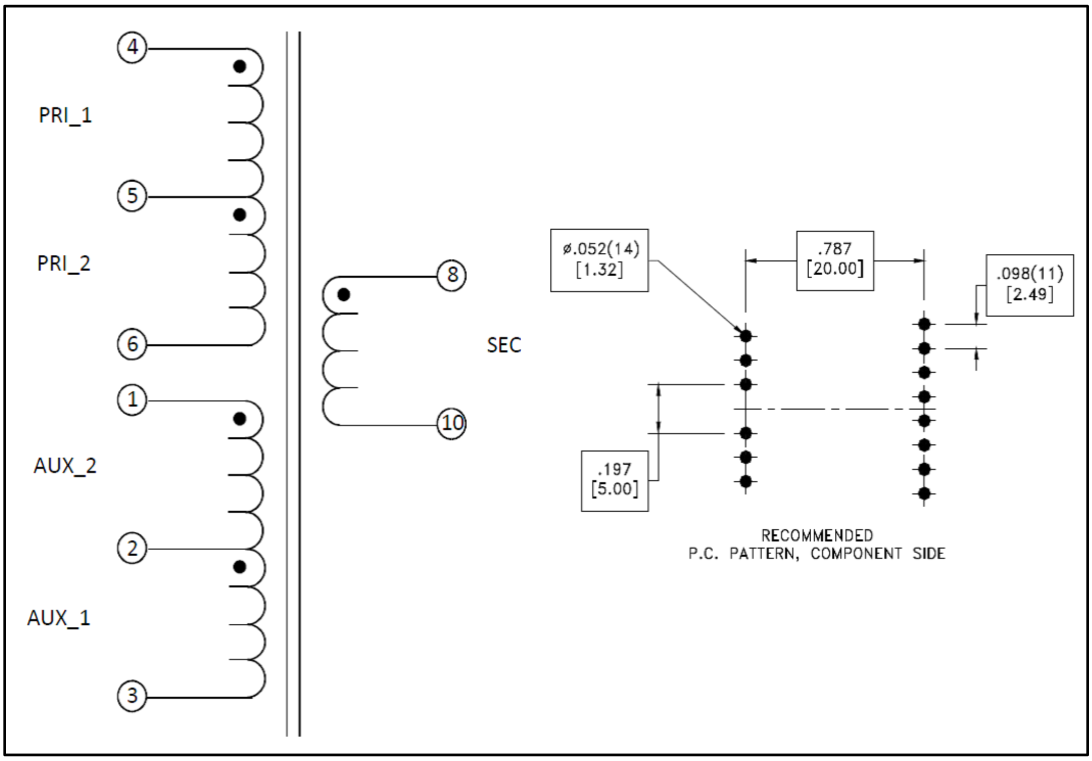
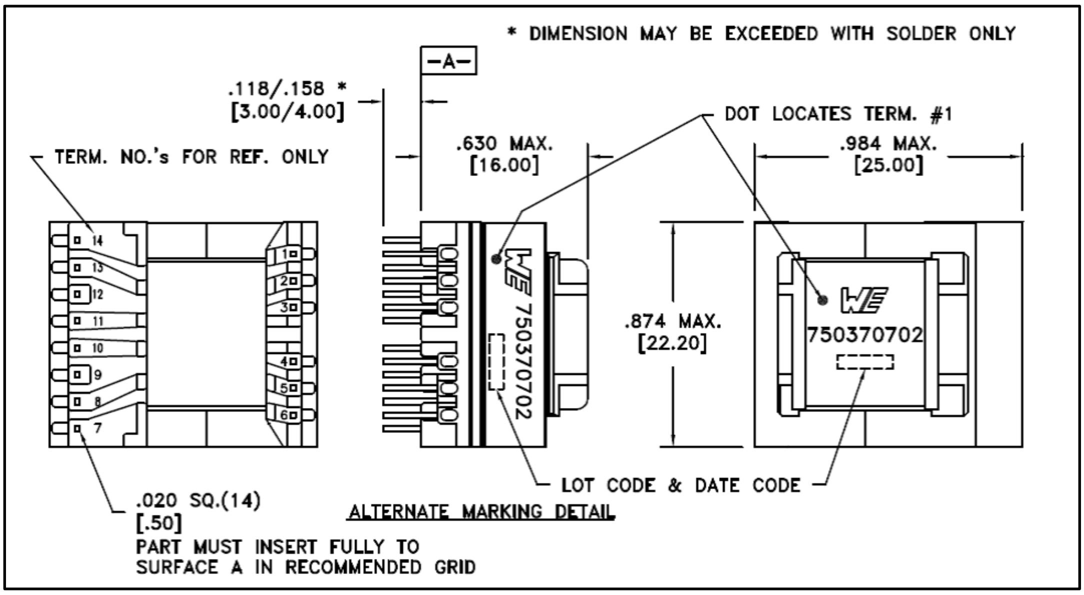


Figure 5: Transformer size and dot location



5 Performance data

5.1 Output voltage characteristics

The following tables show the STEVAL-ISA183V1 line and load regulation, measured at the PCB output connectors at 230 V_{AC}.

Table 5: Load regulation

I_{OUT1}[A]	I_{OUT2}[mA]	I_{OUT3}[mA]	V_{OUT1}[V]	V_{OUT2}[V]	V_{OUT3}[V]
0.03	20	30	12.04	5.02	14.90
0.03	20	200	12.04	5.02	14.65
0.03	200	30	12.04	5.02	14.90
0.03	200	200	12.02	5.02	14.45
1	20	30	12.02	5.02	14.90
1	20	200	12.02	5.02	14.90
1	200	30	12.02	5.02	14.90
1	200	200	12.02	5.02	14.90

Table 6: Cross regulation results

I_{OUT1}[A]	I_{OUT2}[mA]	I_{OUT3}[mA]	V_{OUT1}[V]	V_{OUT2}[V]	V_{OUT3}[V]
30	150	150	12.04	5.02	14.76
700	20	150	12.04	5.02	14.90
700	150	30	12.04	5.02	14.90

5.2 Efficiency and light load measurements

The efficiency at full load and the converter consumption at low and light load are measured at the entire input voltage range.

Figure 6: No load consumption vs. input voltage

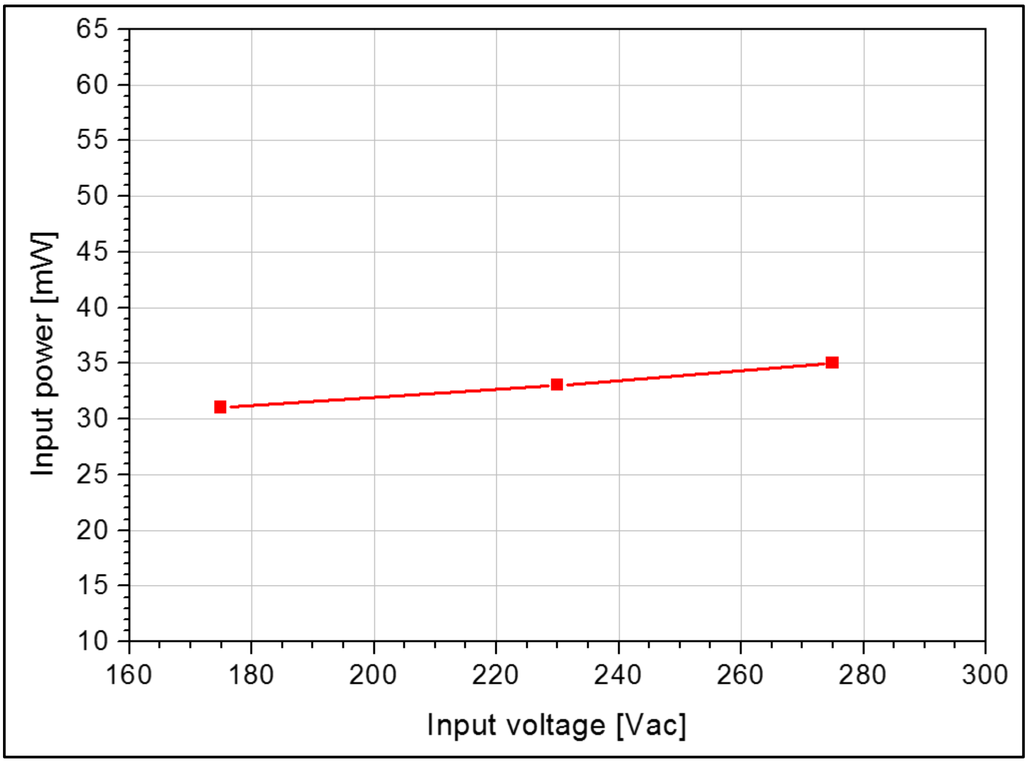


Figure 7: Consumption at minimum load vs. input voltage

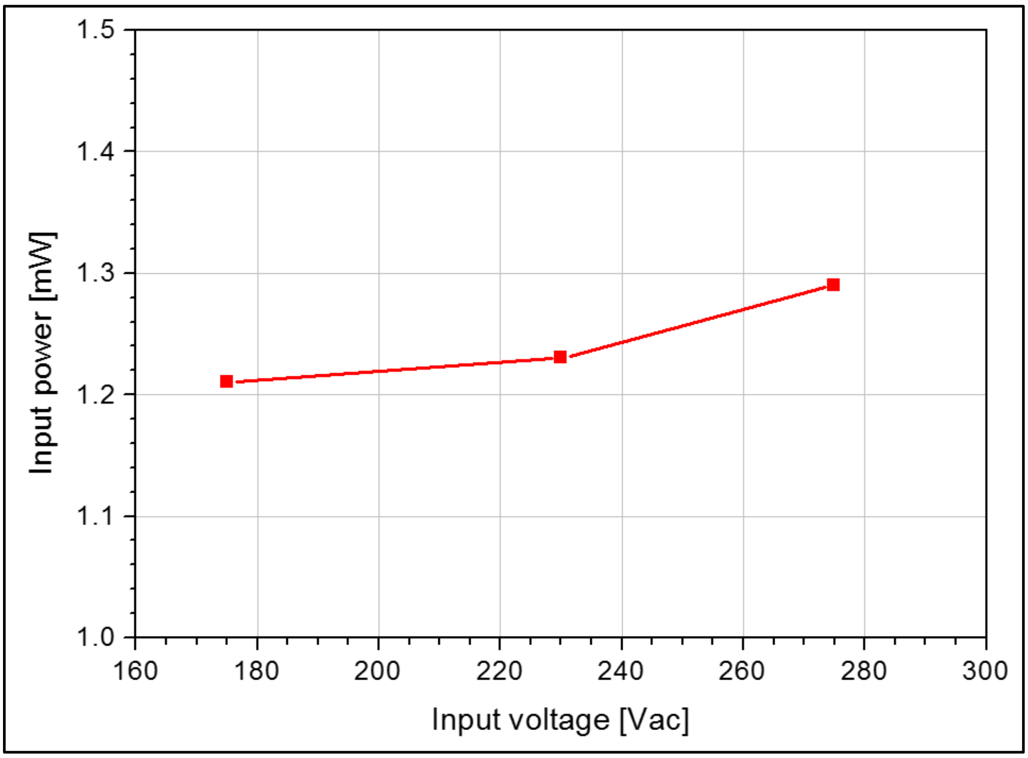
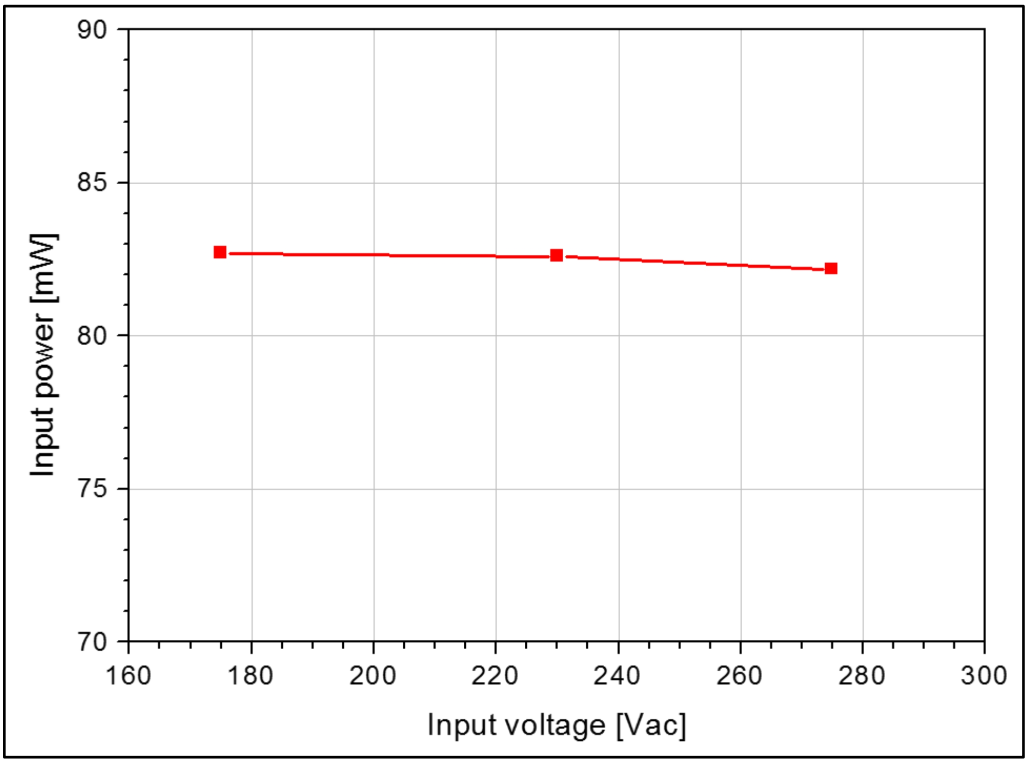


Figure 8: Efficiency vs. input voltage



6 Typical waveforms

This section shows typical waveforms during normal operations and during start-up.

The drain voltage, drain current and supply V_{DD} voltage waveforms are shown at the nominal input voltages, at both minimum and full load (see *Figure 9: "Operation at minimum load at 230 VAC"*and *Figure 10: "Normal operations at full load and 230 VAC"*).

The output voltages are stable and clean with no abnormal oscillation or overshoot during startup and the drain voltage is well within the power section rate (see *Figure 11: "Normal operations at full load and 274VAC"* and *Figure 12: "Startup at full load and 230VAC"*).

The output voltage ripple at 12 V output, nominal input voltage and full load is also measured, resulting within the specifications (see *Figure 13: "Startup at full load and 274VAC"*).

Figure 9: Operation at minimum load at 230 V_{AC}

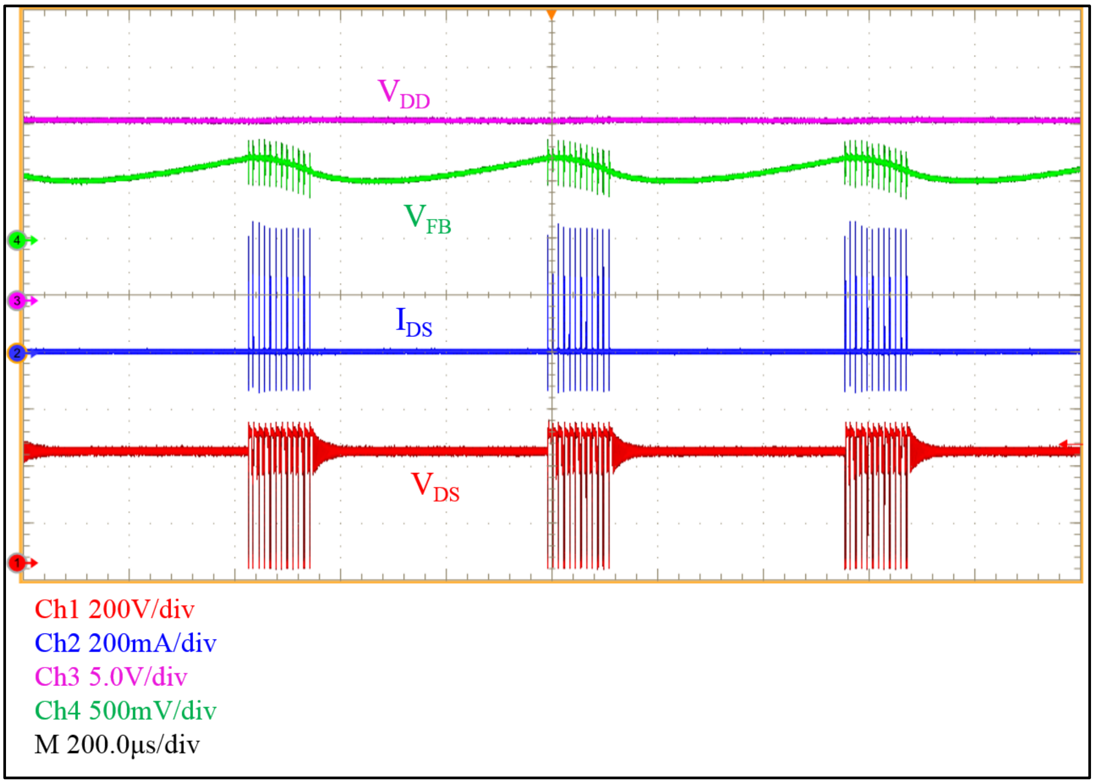


Figure 10: Normal operations at full load and 230 V_{AC}

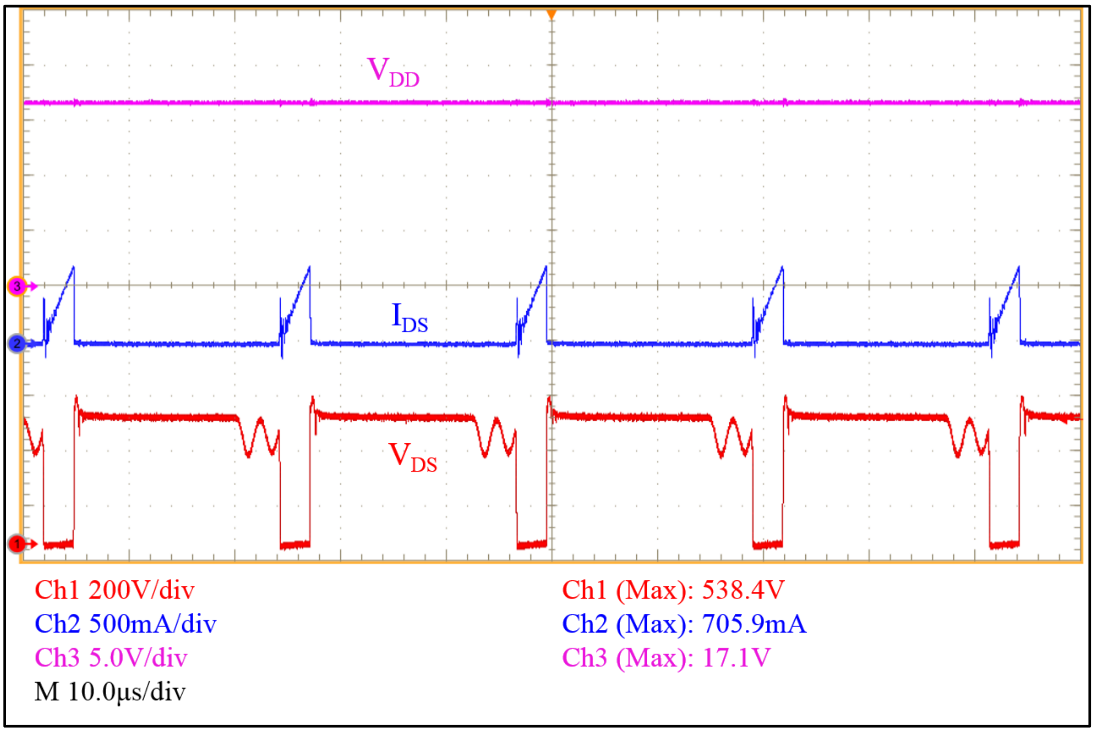


Figure 11: Normal operations at full load and 274 V_{AC}

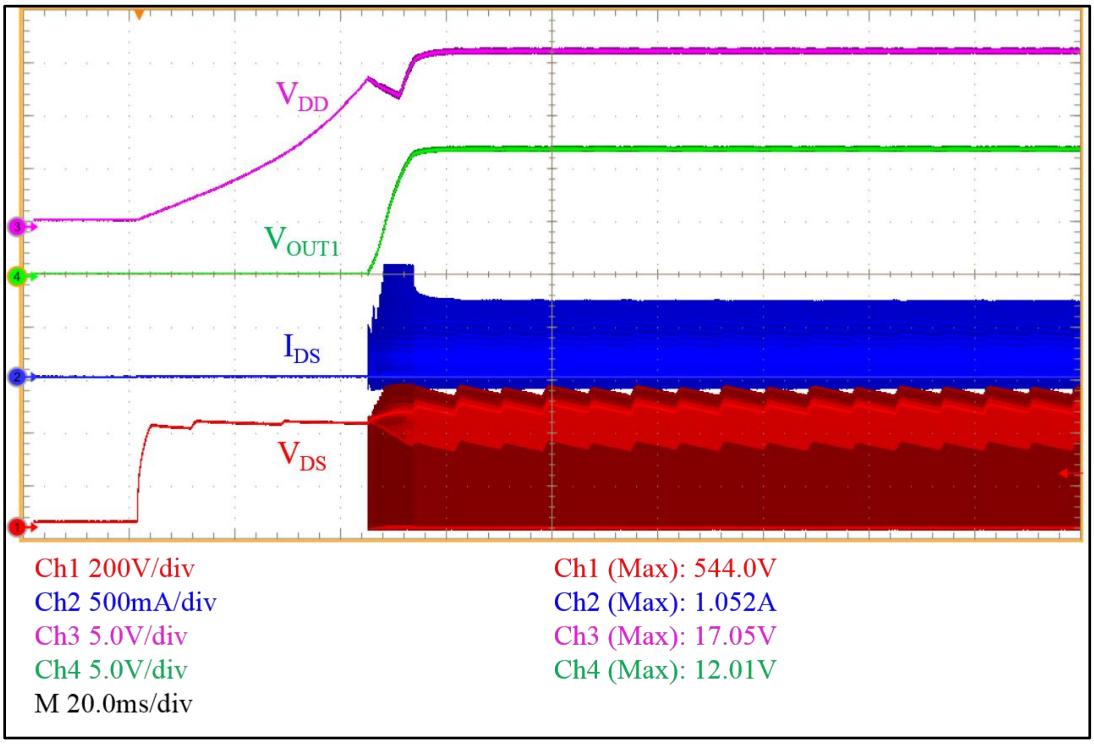


Figure 12: Startup at full load and 230 V_{AC}

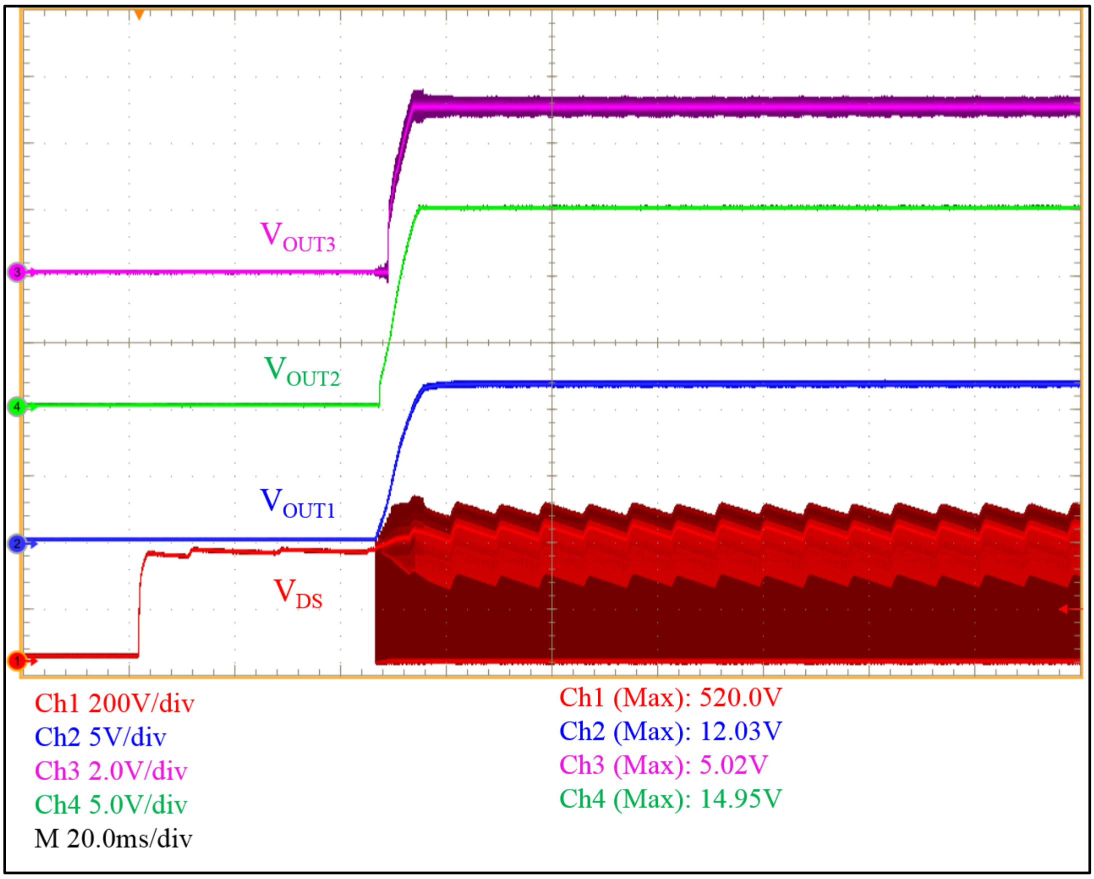
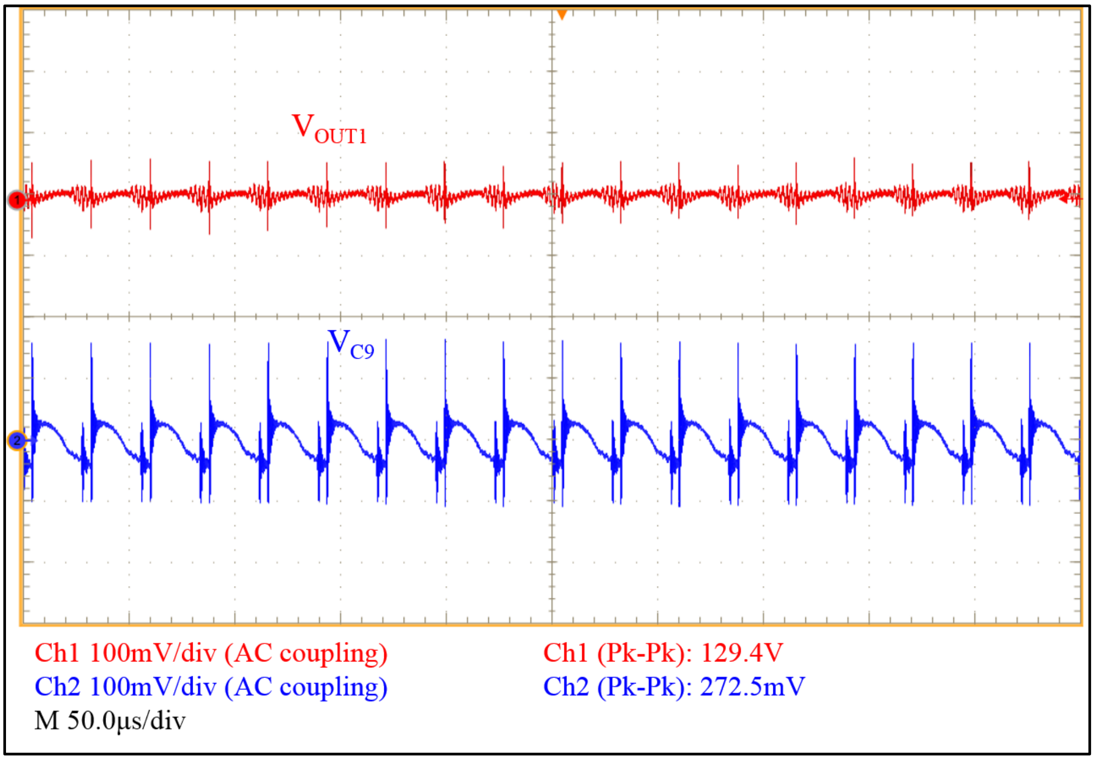


Figure 13: Startup at full load and 274 V_{AC}



6.1 Output overvoltage protection

The output overvoltage protection is tested by shorting the opto-diode. In this way, the converter operates in open loop and the power excess (with respect to the load) charges the output capacitance, increasing the output voltage as the OVP is tripped and the converter stops switching.

The figures below show the protection activation and the STEVAL-ISA183V1 restart.

Figure 14: OVP triggering

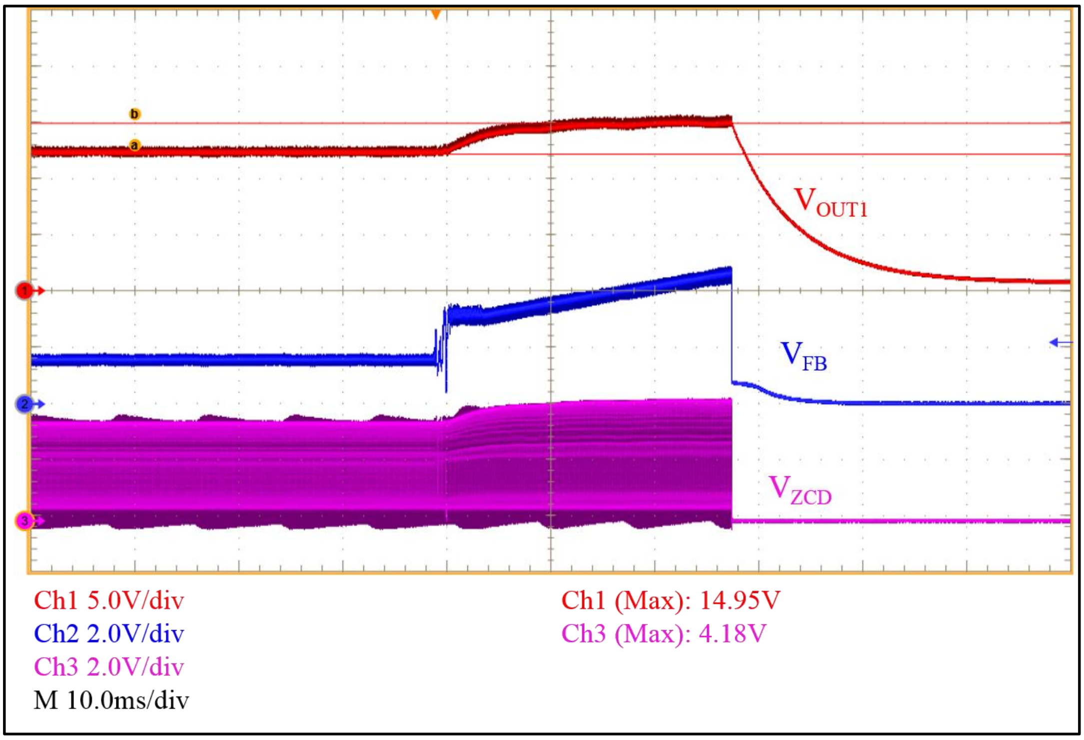


Figure 15: OVP triggering: zoom

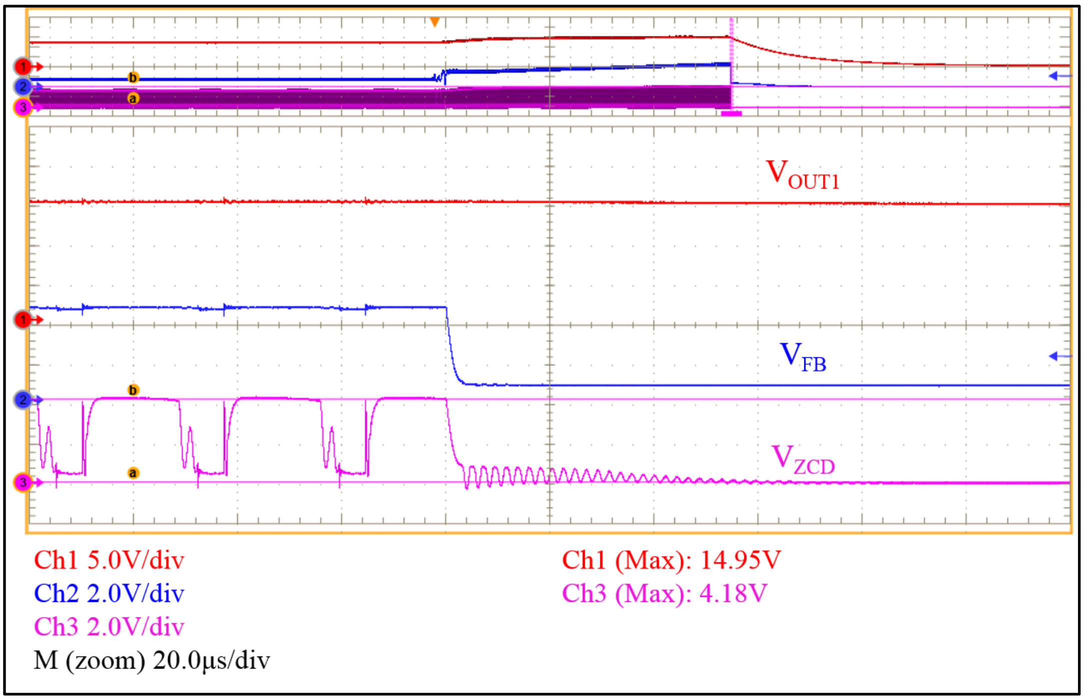
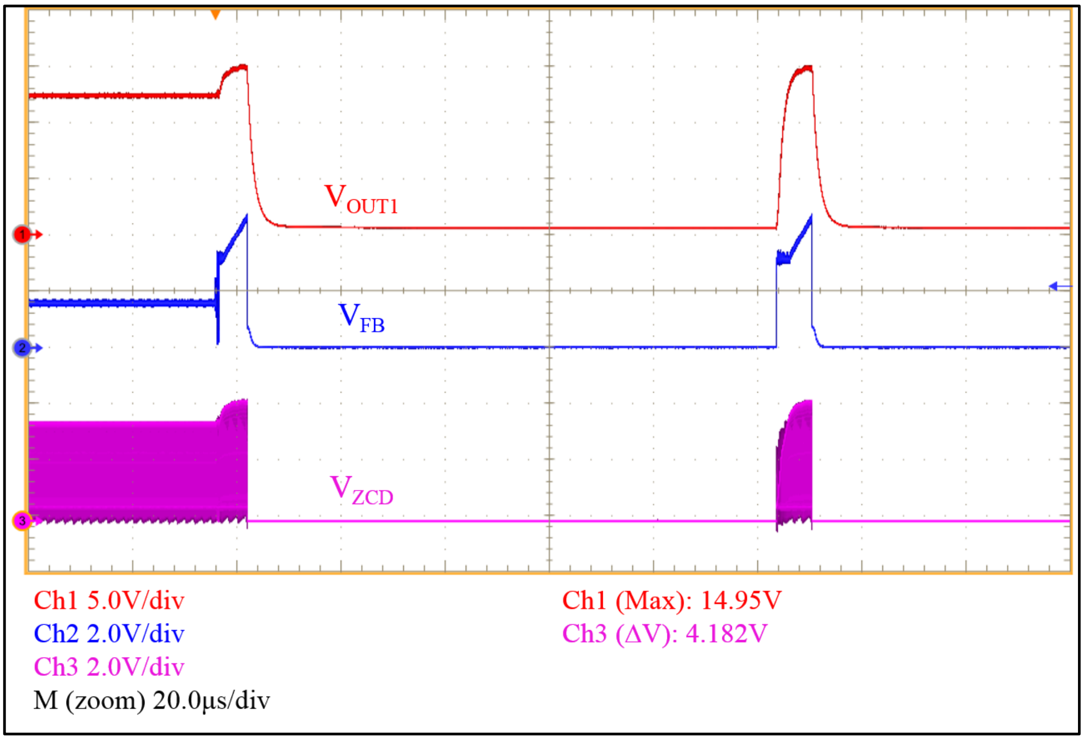


Figure 16: Restart after protection activation



7 Conducted noise measurements

A pre-compliant test of the conducted noise emissions according to EN55022 (Class B) European normative was performed using an average and a peak detector with max. hold function, at full load and nominal mains voltage.

In all test conditions, there is a good margin between the measurements and the corresponding limits. The results are shown in the following figures.

Figure 17: Average CE measurement at 230 V_{AC} and full load

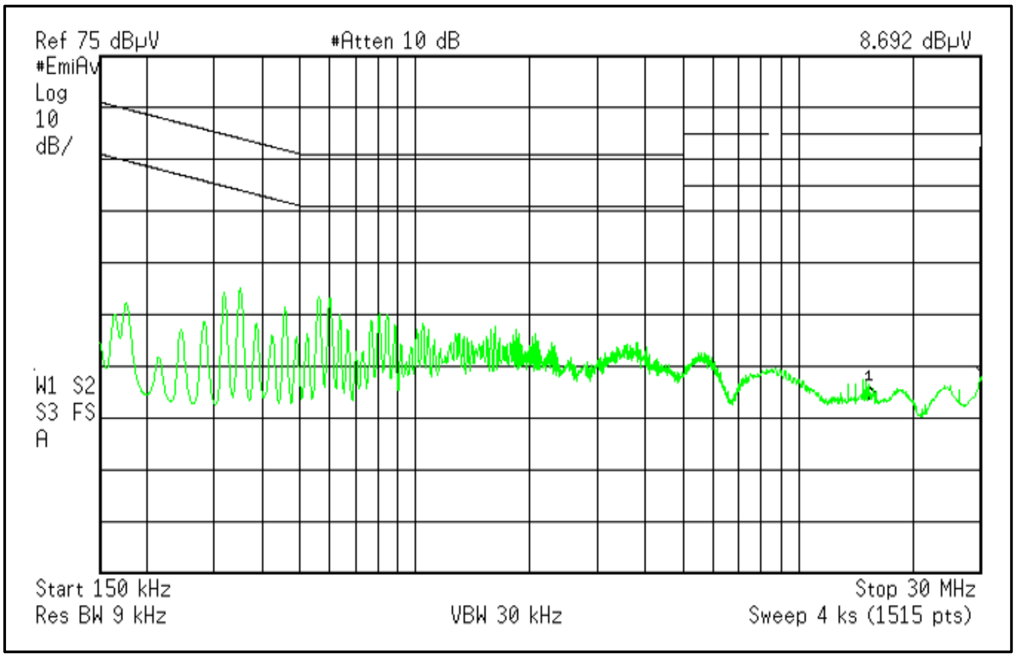
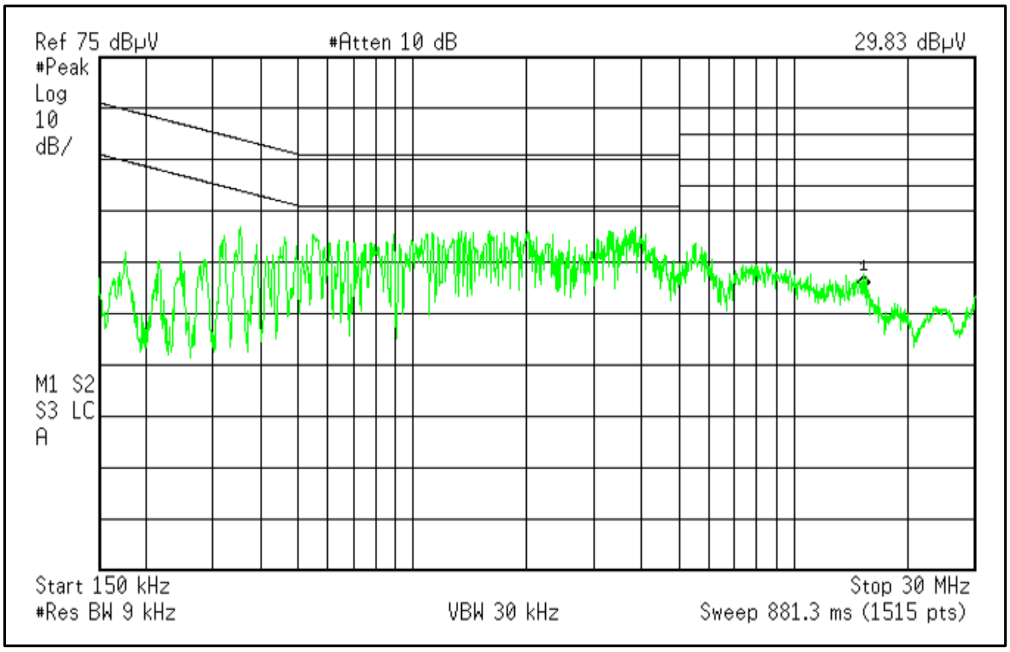


Figure 18: Peak CE measurement with max. hold function at 230 V_{AC} and full load



8 Immunity tests

The board was submitted to immunity tests according to IEC61000 and their results are classified according to the standard criteria:

- A: normal performance;
- B: temporary degradation or loss of function or performance, with automatic return to normal operation;
- C: temporary degradation or loss of function, with external intervention to recover normal operation
- D: degradation or loss of function, necessary substitution of damaged components to recover normal operation

8.1 ESD immunity test (IEC 61000-4-2)

The test was performed on a single test board. The input voltage was set to 230 V_{AC}, the output was loaded at full load and the proper operation was verified through a current probe connected to the output.

The test conditions are:

- contact discharge and air discharge methods
- discharge circuit150 pF/330 Ω
- polarity: positive/negative
- a two Y1 capacitor network connected to the AC line connector according to the norm.

The test results are shown in the following tables.

Table 7: ESD contact discharge test results

Noise injection	ESD level	Polarity	Result	Criterion
L vs. PE	10 kV	Positive	PASS	A
L vs. PE	10 kV	Negative	PASS	A
N vs. PE	10 kV	Positive	PASS	A
N vs. PE	10 kV	Negative	PASS	A

Table 8: ESD contact discharge test results with PE connected on secondary GND

Noise injection	ESD level	Polarity	Result	Criterion
L vs. GND	8 kV	Positive	PASS	A
L vs. GND	8 kV	Negative	PASS	A
N vs. GND	8 kV	Positive	PASS	A
N vs. GND	8 kV	Negative	PASS	A

Table 9: ESD air discharge test results

Noise injection	ESD level	Polarity	Result	Criterion
Horizontal coupling plane	20 kV	Positive	PASS	A
Horizontal coupling plane	20 kV	Negative	PASS	A
Vertical coupling plane	20 kV	Positive	PASS	A
Vertical coupling plane	20 kV	Negative	PASS	A

8.2 Surge immunity test (IEC 61000-4-5)

The test was performed on a single test board. The input voltage was set to 230 V_{AC}, the output was loaded at full load and the proper operation was verified through a current probe connected to the output.

The test conditions are:

- repetition rate: 30 seconds
- repetition number: 5 each
- applied to: input lines vs. EARTH – common mode
- applied to: both input lines (L vs. N) - differential mode
- a two Y1 capacitor network connected to the AC line connector according to the norm.

The test results are shown in the following tables.

Table 10: Common mode surge test results

Noise injection	Surge level	Polarity	Result	Criterion
L vs. PE	2 kV	Positive	PASS	A
N vs. PE	2 kV	Positive	PASS	A
L vs. PE	2 kV	Negative	PASS	A
N vs. PE	2 kV	Negative	PASS	A

Table 11: Differential mode surge test results

Noise injection	Surge level	Polarity	Result	Criterion
L vs. N	2 kV	Positive	PASS	A
L vs. N	2 kV	Negative	PASS	A

Performed tests show that the board withstands the lightning disturbances applied to input line in common mode and differential mode for each severity level.

According to the standard, the application can be classified as level 3.

8.3 Burst immunity test (IEC 61000-4-4)

The test was performed on a single test board. The input voltage was set to 230 V_{AC}, the output was loaded with 10 % of the rated power and the proper operation was verified by connecting a current probe to the output.

The test conditions are:

- polarity: positive/negative
- burst duration: 15 ms ±20 % at 5 kHz
- burst period: 300 ms ±20 %
- duration time: 1 minute
- applied to: AC lines through integrated capacitive coupling clamp.

The test results are shown in the following table.

Table 12: Burst test results

Noise injection	Burst level	Polarity	Result	Criterion
L	4 kV	Positive	PASS	A
N	4 kV	Positive	PASS	A
PE	4 kV	Positive	PASS	A
L/PE	4 kV	Positive	PASS	A
N/PE	4 kV	Positive	PASS	A
L/N	4 kV	Positive	PASS	B
L/N/PE	4 kV	Positive	PASS	A
L	4 kV	Negative	PASS	A
N	4 kV	Negative	PASS	A
PE	4 kV	Negative	PASS	A
L/PE	4 kV	Negative	PASS	A
N/PE	4 kV	Negative	PASS	A
L/N	4 kV	Negative	PASS	A
L/N/PE	4 kV	Negative	PASS	A

9 Thermal tests

A thermal analysis of the board was performed using an IR camera, under full load condition, at nominal input voltage. The thermal map was taken 30 minutes after the power on at an ambient temperature of 25 °C.

The results are shown in the following figures.

Figure 19: STEVAL-ISA183V1 thermal map at 230 V_{AC} and full load (top side)

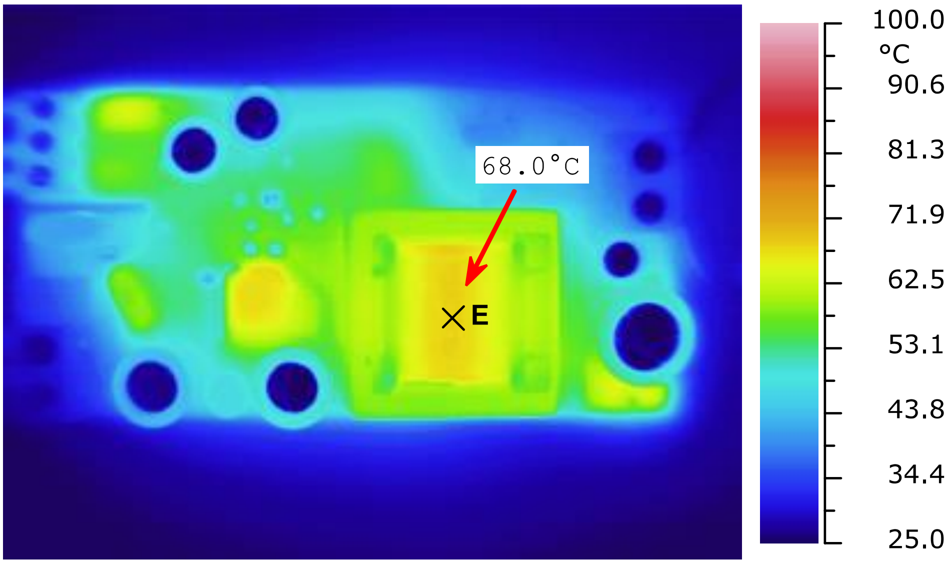
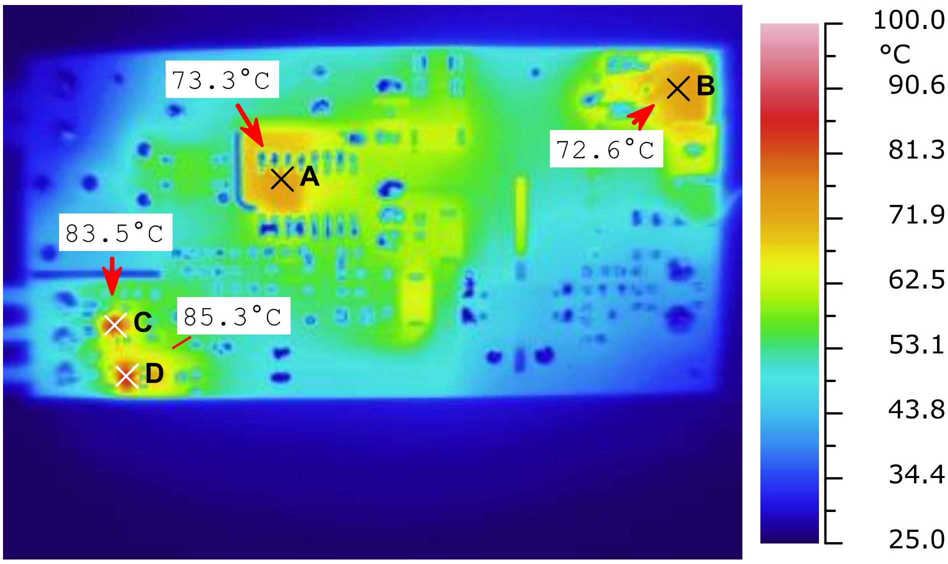


Figure 20: STEVAL-ISA183V1 thermal map at 230 V_{AC} and full load (bottom side)



10 Conclusions

A 16 W triple output power supply designed in quasi-resonant flyback topology, specifically designed to be used as an auxiliary PSU in an air conditioning system using the VIPer35LD, has been introduced and the test results shown.

The key features are the high conversion efficiency, the extremely low consumption at no-load and at minimum operative output condition and the excellent EMI performance using low cost input filter, even using a small PCB size and with a minimal bill of materials.

11 Revision history

Table 13: Document revision history

Date	Version	Changes
05-May-2017	1	Initial release