AN1514
Application note

VIPower: double output buck or buck-boost converter using VIPer12A-E/22A-E

Introduction

This paper introduces two double output off-line non isolated SMPS based on the VIPerX2A-E family. The first SMPS is a Buck converter with two positive outputs and the second one is a Buck-Boost converter with two negative outputs. The use of VIPer12A-E or VIPer22A-E in both converters depends on the output power specifications. The power supplies are operated in off-line mode with an extended wide range of the input voltage, from 80 to 285 Vac. The target applications are small loads, such as microcontrollers, motors, displays and peripherals in several industrial and home appliances.

Two converter topologies are introduced in this paper. The considered double output converters are based on the VIPerX2A-E device family and are suitable for non isolated off-line applications. VIPerX2A-E is a low cost monolithic smart power with a PWM controller, start-up circuit and protection integrated on the same chip. The power stage consists of a vertical Power MOSFET with 730 V breakdown voltage and 0.32 A for VIPer12A-E or 0.56 A for VIPer22A-E maximum drain current with internal limitation.

The use of a VIPower device makes the design very simple and easy, since several features are integrated in the smart power IC. The first SMPS is a Buck converter with two positive outputs and the second one is a Buck-Boost converter with two negative outputs. The use of VIPer12A-E or VIPer22A-E in both converters depends on the output power specifications.

The power supplies are operated in off-line mode with an extended wide range of the input voltage, from 80 to 285 Vac.

The target applications are small loads, such as microcontrollers, motors, displays and peripherals in several industrial and home appliances with power level up to 6-8 W.

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1 Off-line double output converters

In these circuits the first output is obtained using the standard buck or buck-boost topology, while the second output is obtained by means of a second winding on the main inductor. This output is directly coupled with the first one in flyback mode and its value is given by the turns ratio n. The inductor is still low cost since a drum core can be used and the coupling between the two windings is not as critical as in a flyback converter. The electrical schematics of both configurations are shown in *Figure 1* and *Figure 2*.

2 VIPer application examples

In this section two VIPerX2A-E application examples are introduced:

1. Double output buck converter 24 V at 30 mA, 5 V at 50 mA
2. Double output buck-boost converter (-24 V) at 250 mA, (-5 V) at 70 mA.

Figure 1. Double output buck topology

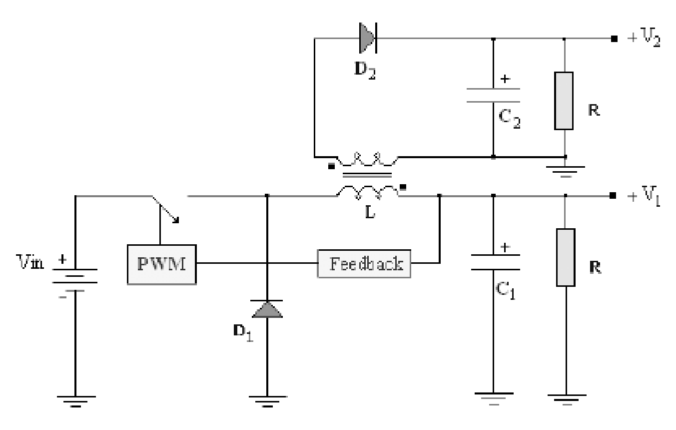
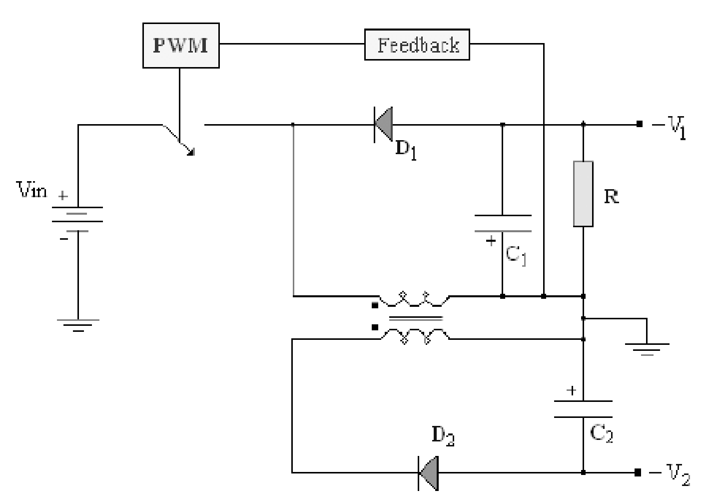


Figure 2. Double output buck-boost topology



2.1 Double output buck converter using VIPer12A-E

The proposed power supply, shown in *Figure 3*, is based on VIPer12A-E. The specifications of the converter are listed in *Table 1*. The input section consists of a resistor as a fuse, a single diode rectifier, and an input LC filter. Such a filter provides both DC voltage stabilization and improved EMI performance (compliant with EN55022 Class B standard). The capacitor Cin1 could be connected to provide further reduction of conducted EMI, if required.

The switching frequency is 60 kHz, given by the integrated oscillator of the VIPer12A-E.

Figure 3. Converter schematic

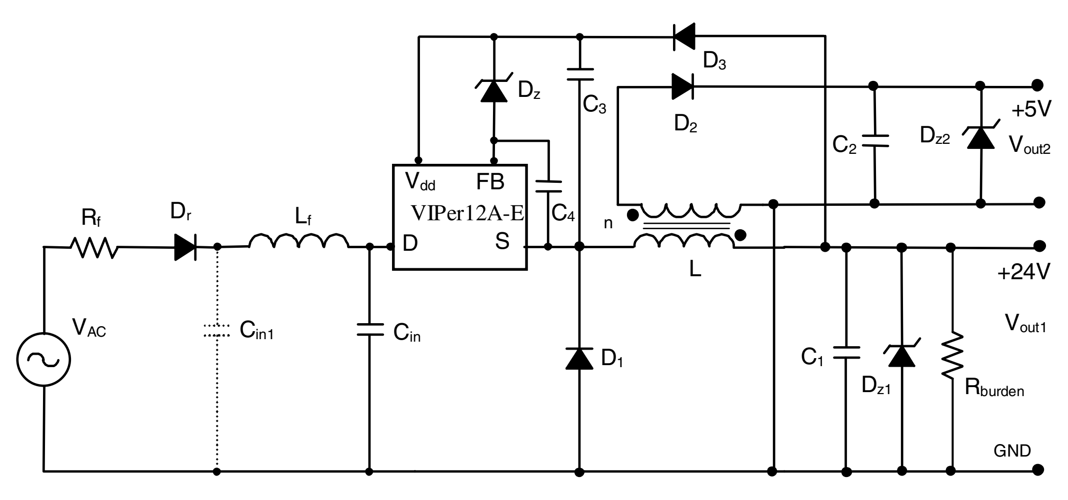


Table 1. Buck converter specifications

Parameter	Value
AC input voltage V_{inac}	80 - 285 Vac
Output current I_{out}	30 mA
Output current I_{out2}	50 mA
Output voltage V_{out1}	+24±10%V
Output voltage V_{out2}	+5 V±5%
Switching frequency	60 kHz
Output power	~ 1 W

The two outputs are provided using a buck converter for the 24 V output, named "V_{out1}", and a coupled inductor in flyback mode for the 5 V output, named "V_{out2}". The regulation feedback is connected to "V_{out1}" as well as the supply circuit of the VIPer12A-E. Doing so, only one high voltage diode and one capacitor are needed, i.e. D3 and C3 in *Figure 3*, reducing the complexity and the cost of the circuit.

The output inductor, L, has two coupled windings on the same ferrite core, with a proper turn ratio and coupling factor in order to get the correct output voltage. In particular, 1.5 mH inductor is used, with N1=200t - wound on the ferrite core of "PANASONIC ELC10D152E" inductor - and N2=60t. Zener diodes, Dz1 and Dz2 protect both outputs against overvoltage.

A burden resistor is connected across V_{out1} in order to perform the regulation on V_{out2} when V_{out1} is in open load condition. Such a resistor greatly improves the regulation with a slight impact on the efficiency.

The output rectifier diodes are both fast diodes: D1 is a high voltage diode since it has to sustain a reverse voltage given by the input DC bus voltage while D2 is a low voltage diode. The part list of the proposed circuit is given in *Table 2*. In *Figure 4* the board layout is shown and *Figure 5* shows the lab prototype.

Table 2. Component list

Reference	Value	Description
R_r	10 Ω 1/2 W	
R_f	10 KΩ 1/4 W	
Rburden	4.7 KΩ 1/4 W	
C_{in}	4.7 µF, 450 V	Electrolytic capacitor
C_1	33 µF, 50 V	Electrolytic capacitor
C_2	100 µF, 16 V	Electrolytic capacitor
C_3	1 µF, 25 V	Electrolytic capacitor
C_4	22 nF	Ceramic capacitor
D_r		Diode 1N4007
D_1		Diode BA159 (fast)
D_2		Diode 1N4148 (fast)
D_3		Diode 1N4004
D_Z		22 V Zener
D_{Z1}		27 V Zener
D_{Z2}		5.6 V Zener
L	1.5 mH	
L_f	470 µH	Inductor
IC1		STMicroelectronics VIPer12A-E

Figure 4. **Board layout**

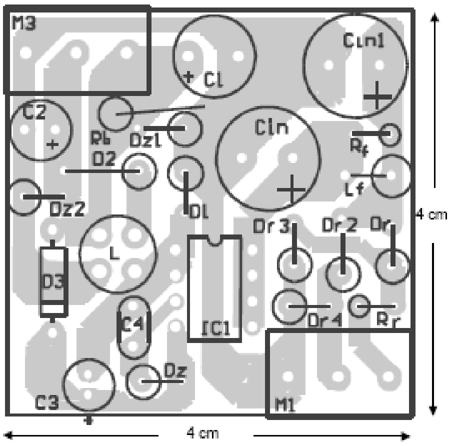
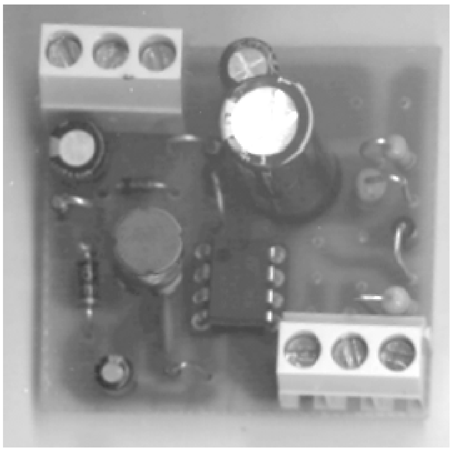


Figure 5. **Board prototype**



2.1.1 Experimental results

In this section the characterization of the circuit is given. Four load conditions have been considered:

1. Output1 = open load - output2 = open load
2. Output1 = full load - output2 = open load
3. Output1 = open load - output2 = full load
4. Output1 = full load - output2 = full load

In *Table 3* and *Table 4* the experimental results are listed, with 80 V and 285 V input voltage respectively. In all the considered operating conditions the proposed power supply meets the given specifications. The efficiency has been evaluated and is shown in *Figure 6*, where the output power P_{out} is given by (*Equation 1*).

Equation 1

$$P_{out} = P_{out1} + P_{out2}$$

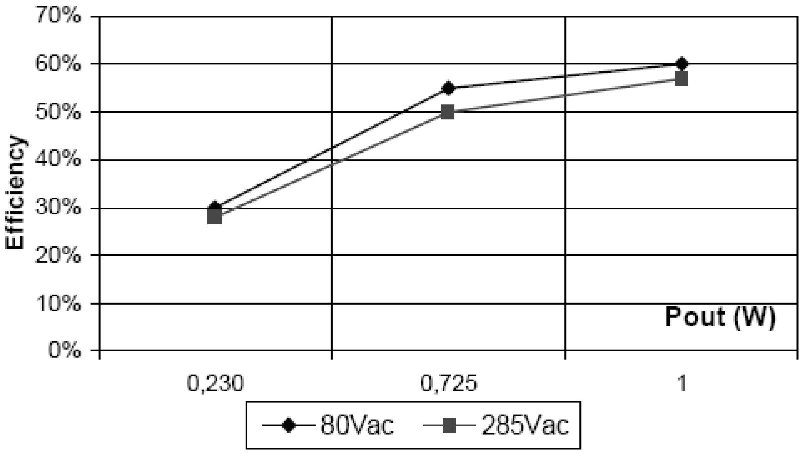
Table 3. Load regulation at V_{in}=80V_{acrms}

V_{in}=80Vac	V_{out1}(V)	I_{out1}(mA)	V_{out2}(V)	I_{out2}(mA)
1	24.95	5	5.58	0
2	26.16	30	5.58	0
3	26.98	5	4.90	50
4	24.02	30	5.06	50

Table 4. Load regulation at V_{in}=285V_{acrms}

V_{in}=285Vac	V_{out1}(V)	I_{out1}(mA)	V_{out2}(V)	I_{out2}(mA)
1	24.95	5	5.58	0
2	24.39	30	5.58	0
3	24.86	5	4.75	50
4	24.39	30	5.20	50

Figure 6. Efficiency vs. output power



2.2 Double output buck-boost converter using VIPer22A-E

The proposed power supply, shown in *Figure 7*, is based on VIPer22A-E. It delivers maximum 7 W output power in wide range, according to *Table 5* which lists the main specifications of the converter. This topology is used to supply negative output voltage referred to neutral in non isolated applications. The input stage is similar to the Buck based application but requires a larger bulk capacitor due to the higher power level, as shown in *Table 6*.

Table 5. Buck-boost converter specifications

Parameter	Value
AC input voltage V_{inac}	80 - 285 Vac
Output current I_{out1}	250 mA
Output current I_{out2}	70 mA
Output voltage V_{out1}	-24±10%V
Output voltage V_{out2}	-5 V±5%
Switching frequency	60 kHz
Output power	~ 7 W

The two outputs are provided using a Buck-Boost converter for the -24 V output, named "V_{out1}", and a coupled inductor in flyback mode for the -5 V output, named "V_{out2}". The regulation feedback is connected to "V_{out1}" as well as the supply circuit of the Viper22A-E. Doing so, only one high voltage diode and one capacitor are needed, i.e. D2 and C3 in *Figure 7*, reducing the complexity and the cost of the circuit.

The output inductor, L, has two coupled windings on the same ferrite core, with a proper turn ratio and coupling factor in order to get the correct output voltage. In particular, 1 mH inductor "PANASONIC ELC08D102E" is used with a second winding (N2=45 turns) in order to obtain the secondary output.

Zener diode Dz2 protects the Out2 against overvoltage, but this protection is not needed in Out1. A burden resistor (R_b) is connected across V_{out1} in order to perform the regulation on Vout2 when Vout1 is in open load condition. The output rectifier diodes are both ultrafast diodes: D3 is a high voltage diode since it has to sustain a reverse voltage given by the input DC bus voltage while D4 is a low voltage diode. The part list of the proposed circuit is given in *Table 6*.

Figure 7. Converter schematic

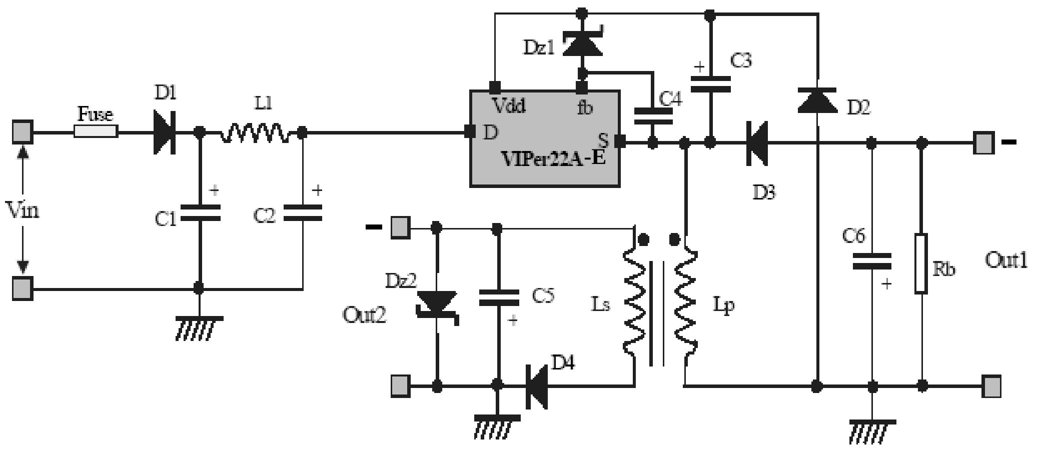


Table 6. Component list

Reference	Value	Description
R_f(Fuse)	10 Ω1/2 W	
Rb	1.5 kΩ1/2 W	
C_1	10 µF, 400 V	Electrolytic capacitor
C_2	10 µF, 400 V	Electrolytic capacitor
C_3	10 µF, 25 V	Electrolytic capacitor
C_4	100 nF	Ceramic capacitor
C_5	220 µF,16 V	Electrolytic capacitor
C_6	220 µF,25 V	Electrolytic capacitor
D_1		Diode 1N4007
D_2		Diode BYT400 (fast)
D_3		Diode STTA106 (Turbosw.)
D_4		Diode STTA102 (200V)
D_{Z1}		24V Zener
D_{Z2}		5.6V Zener
L_p	1mH	
L_s		45 turns
IC1		STMicroelectronics VIPer22ADIP-E

2.2.1 Experimental results

In this section the characterization of the circuit is given. Four load conditions have been considered:

1. Output1 = open load - output2 = open load
2. Output1 = full load - output2 = open load
3. Output1 = open load - output2 = full load
4. Output1 = full load - output2 = full load

The experimental results are listed in *Table 7* and *Table 8*, with 80 V and 285 V input voltage respectively. In all the considered operating conditions the proposed power supply meets the given specifications. The efficiency has been evaluated and is shown in *Figure 8*, where the output power P_{out} is given by (*Equation 1*).

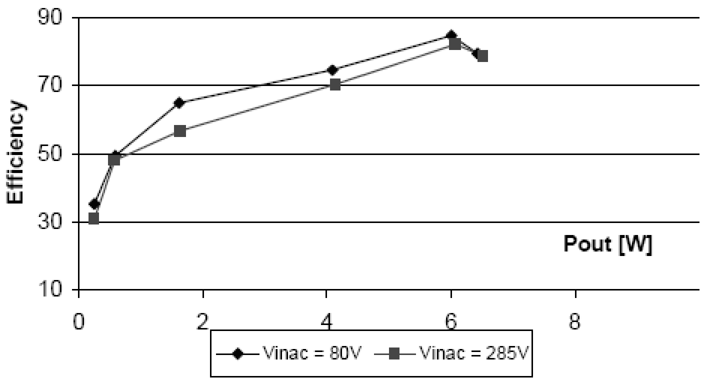
Table 7. Load regulation at V_{in}=80V_{acrms}

V_{in}=80Vac	V_{out1}(V)	I_{out1}(mA)	V_{out2}(V)	I_{out2}(mA)
1	-24.72	10	- 4.85	0
2	-23.86	250	- 5.54	0
3	-24.7	10	- 4.59	70
4.	-23.7	250	- 4.88	70

Table 8. Load regulation at V_{in}=285V_{acrms}

V_{in}=285Vac	V_{out1}(V)	I_{out1}(mA)	V_{out2}(V)	I_{out2}(mA)
1	-24.67	10	- 4.98	0
2	-24.1	250	- 5.61	0
3	-24.7	10	- 4.62	70
4	-24	250	- 5.03	70

Figure 8. Efficiency vs. output power



2.2.2 Thermal measurements

Due to the higher power level of such a non isolated converter, thermal constraints have to be evaluated in order to allow proper system operation. The main issue is related to parasitic effects that can lead to higher power dissipation in the device and consequently a higher working temperature. For example, if a fast diode is used, the recovery of charge generates a current spike in the device increasing the switching losses, as shown in *Figure 9* and *Figure 10* for V_{in}=80 V and V_{in}=285 V respectively. The device is forced to operate at high temperature as shown in *Figure 11*.

Figure 9. V_{in}=80V_{acrms}, I_{out2}=75 mA, CH1=V_{out1}, CH2=I_{out1}, CH3=I_{Lp}, CH4=V_{out2}

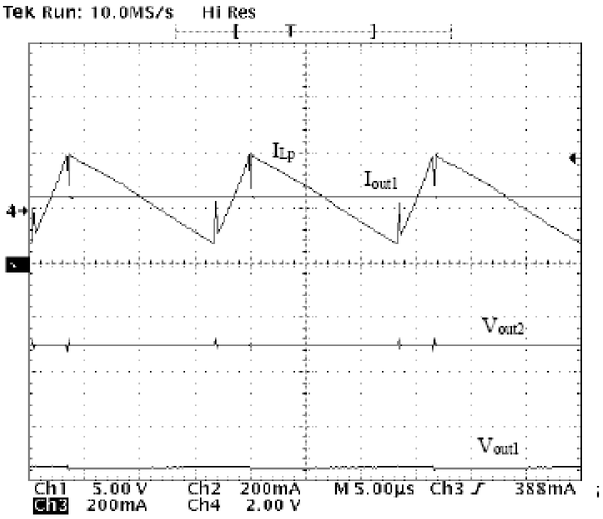


Figure 10. V_{in}=285V_{acrms}, I_{out2}=75 mA, CH1=V_{out1}, CH2=I_{out1}, CH3=I_{Lp}, CH4=V_{out2}

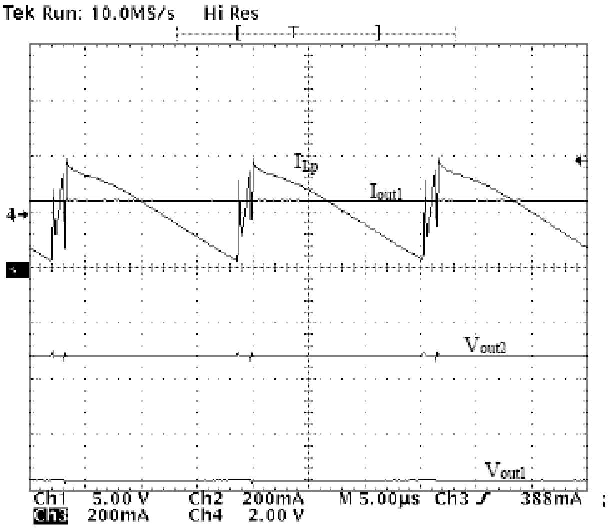
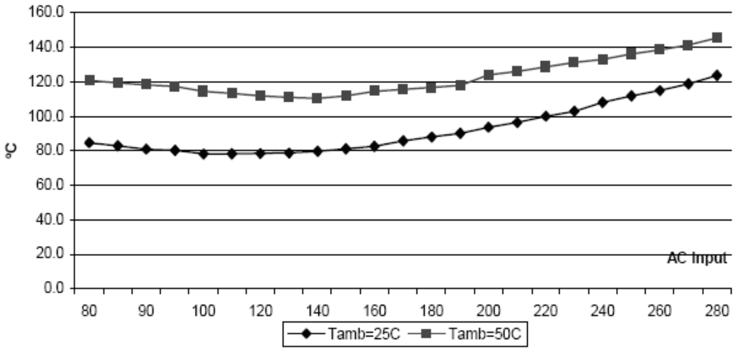


Figure 11. VIPer22A-E temperature at maximum load with parasitic capacitance



In this case the temperature of the device will be so high as to enable the thermal shutdown in a few minutes. If an ultra fast diode is used under the previous load condition, thermal measurements give lower temperature as listed in *Table 9*. In such a case the temperature increase is below 40°C increasing the efficiency of the system and allowing proper operation with ambient temperature up to 65°C with no heat sink.

The above considerations apply to other parasitic elements on the board, e.g. stray capacitance of the inductor, as shown in *Figure 12*. In this case a good inductor helps to limit the power dissipation in the device and then the operating temperature.

In *Figure 13* and *Figure 14* the EMI behavior of the power supply at full load is shown, using a 50 LISN according to EN550014 standard, for line and neutral respectively. Although the measurements have been performed using peak detector, the emission level is well below the Quasi-Peak (QP) limit, complying with the previously mentioned standard.

Table 9. Thermal characterization (package: DIP8; $R_{thj\text{-}lead}$=45 °C/W mounted by socket; T_{amb}=25°C)

V_{inac} (Vrms)	Pdiss (W)	ΔT (°C)	T (°C)
80	0.7	30.6	55.6°C
220	0.58	26.1	51.1
285	0.88	39	64°C

Figure 12. V_{DS} and I_D at V_{in}=230V_{acrms}, I_{out}=250 mA

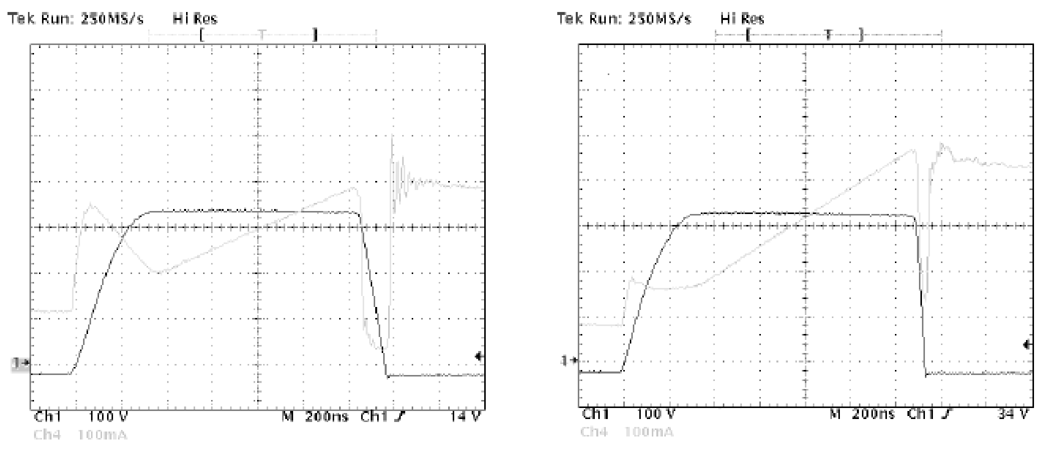


Figure 13. Conducted emissions at full load with EN55014 limits: line emissions

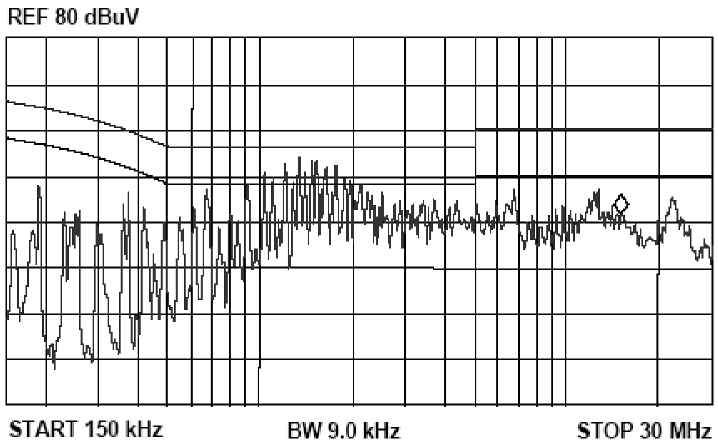
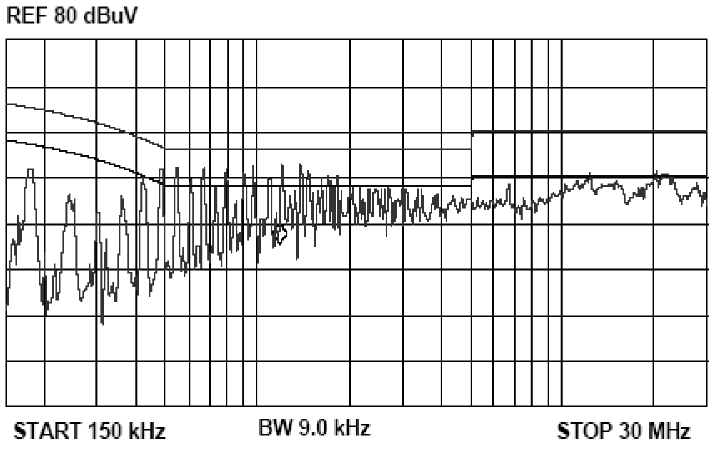


Figure 14. Conducted emissions at full load with EN55014 limits: neutral emissions



3 Conclusion

Very low cost power supplies based on STMicroelectronics VIPerX2A family have been proposed for low power applications where two non isolated voltages are required. Two application examples have been given with a full characterization. The converters show good performances in terms of electrical behavior, size and cost, confirming the suitability to industrial as well as home appliance applications of such a VIPower device.

4 Revision history

Table 10. Document revision history

Date	Revision	Changes
04-Jan-2005	1	Minor text changes
26-Sep-2007	2	– The document has been reformatted – VIPer12A becomes VIPer12A-E – VIPer22A becomes VIPer22A-E – VIPer22ADIP becomes VIPer22ADIP-E

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