AN1698
APPLICATION NOTE

VIPower: DIGITAL TV RECEIVER POWER SUPPLY WITH VIPer22A

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Many new video channels have been provided to the end user in the past few years: on top of the conventional terrestrial analog broadcast and everyones' videorecorder, one can get images from cable, satellites and more recently from terrestrial digital broadcast systems. The TV set tends to become more and more a monitor with numerous input sockets able to connect to various external equipments (Set top boxes) which all require an off line power supply.

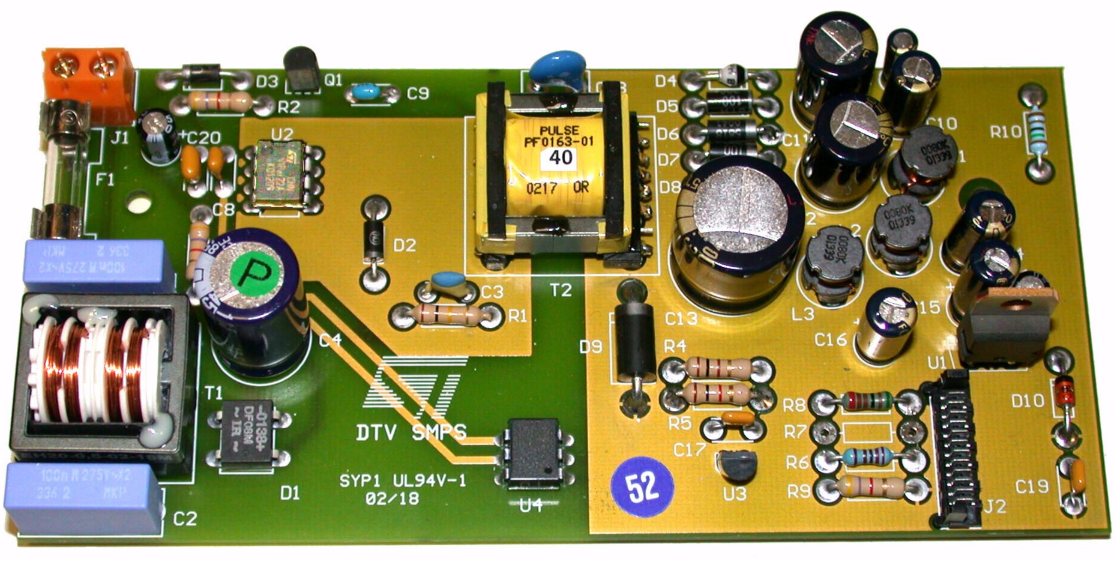
One of the smallest power required is represented by the digital TV receiver which operates with less than 6 Watt and multiple output voltages. This document describes an application with VIPer22A satisfying the specification shown in table 1.

Table 1: Output Voltage Specification

INPUT	OUTPUT 1	OUTPUT 2	OUTPUT 3	OUTPUT 4	OUTPUT 5	OUTPUT 6
European mains line	1.8 V +/- 5% (See note 1)	2.5 V +/- 5% (See note 1)	3.3 V +/- 5% (See note 1)	5 V +/- 5% (See note 1)	12 V +/- 5%	30 V +/- 5%
Min: 176 Vac Max: 264 Vac	Imin: 32 mA Imax: 0.28 A	Imin: 23 mA Imax: 0.67 A	Imin: 20 mA Imax: 0.12 A	Imin: 0.4 A Imax: 0.44 A	Imin: 7 mA Imax: 20 mA	Imin: 0 mA Imax: 5 mA

Note 1: The accuracy of +/-5% is reached only for a certain range of loads combination. See paragraph 2.2 for cross regulation results.

BOARD LAYOUT



1. VIPerX2A DESCRIPTION

The VIPer12A and VIPer22A devices are high voltage integrated circuits, intended to be used in off line switching power supplies taking advantage from minimized part count, reduced size (SO-8 package available) and consumption: They are able to meet the new Eco Standards with cost effectiveness.

1.1. General features

The VIPerX2A family is a range of PWM controller IC together with a high voltage power MOSFET housed in the DIP-8 and the small SMD SO-8 packages. The features of these devices allow to reduce the overall parts count, leading to compacity and higher reliability which is also reinforced by the automatic thermal shutdown, thanks to the monolithic structure.

The VIPerX2A family devices address low power applications, as shown in tables 2 and 3. Note that these power capabilities can be achieved with adequate thermal configuration, such as sufficient copper plane area connected to the drain pins on the printed circuit board.

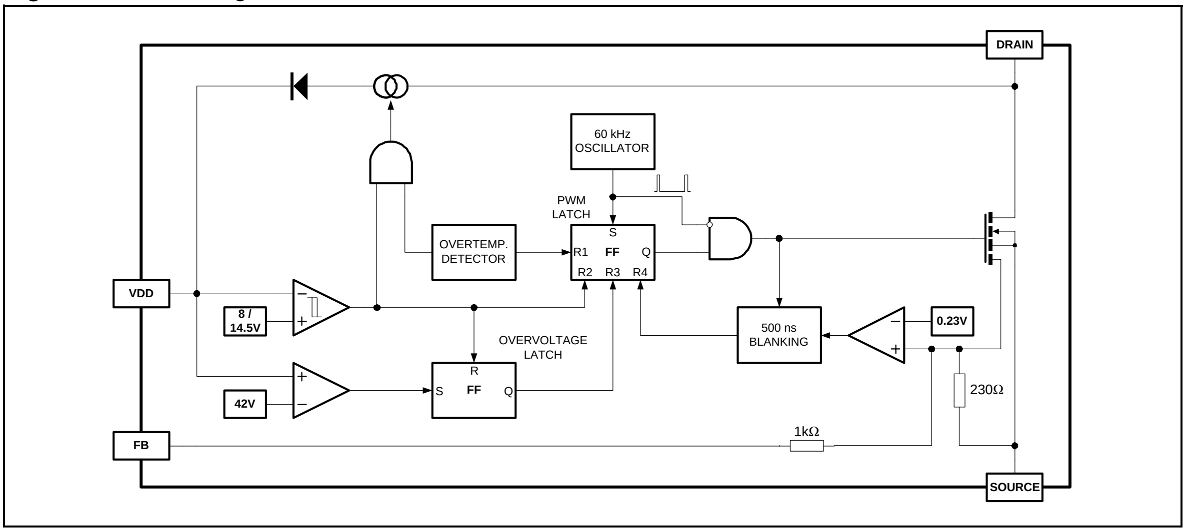
Table 2 : Power capability with wide input voltage range (85 - 265 Vac)

Package / Device	SO-8	DIP-8
VIPer12A	5 W	8 W
VIPer22A	7 W	12 W

Table 3: Power capability with European input voltage range (180 - 265 Vac)

Package / Device	SO-8	DIP-8
VIPer12A	8 W	13 W
VIPer22A	12 W	20 W

Figure 1: Block diagram



1.2. Block diagram

Figure 1 presents the internal diagram of the VIPerX2A family.

The power section is a high voltage sense N type mosfet, of which the minimum guaranteed breakdown is 730V. It is driven with a current mode structure with a fast comparator using the current delivered by the Nmosfet sense, and filtered by a blanking time. The switching frequency is internally fixed at 60kHz.

All the internal signal circuits are supplied by a regulator able to accept a voltage in excess of 45V.

Various protections are implemented, as the overvoltage on the VDD pin at 42V, and the thermal shutdown at 170°C typical. As the control structure is a current mode, the drain current is limited cycle by cycle and has a maximum value corresponding to a FB pin held to ground. The feedback loop is implemented by driving this FB pin with an optocoupler connected to a positive voltage.

An hysteresis comparator monitors the VDD voltage to manage the start up current source. It is switched on to charge the VDD capacitor up to the start up threshold, and maintained in the off state during the normal switching operation to minimize the input power consumption.

1.3. Current mode structure and burst mode

A feedback pin controls the operation of the device. Unlike conventional PWM control circuits which use a voltage input (the inverted input of an operational amplifier), the FB pin is sensitive to current. Figure 2 presents the internal current mode structure.

The Power MOSFET delivers a sense current I_S proportional to the main current I_D. R2 receives this current and the current coming from the FB pin. The voltage across R2 is then compared to a fixed reference voltage of about 0.23V. The MOSFET is switched off when the following equation is reached:

$$R_2 \cdot (I_S + I_{FB}) = 0.23V$$

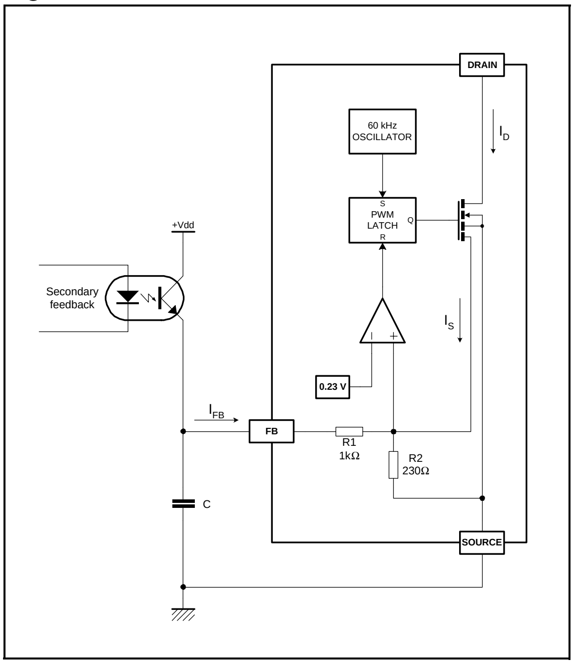
By extracting Is and introducing the sense mosfet ratio G_{ID}:

$$I_D = G_{ID} \cdot \left(\frac{0.23V}{R_2} - I_{FB}\right)$$

This formula demonstrates that the peak drain current depends linearly on the FB pin current, and that the feedback current must be increased for decreasing the drain current. For very low drain currents, it is valid as long as I_{FB} satisfies:

$$I_{FB} < I_{FBsd}$$

Figure 2: Feedback and current mode structure



Where I_{FBsd} is an internal threshold of the VIPerX2A. If I_{FB} exceeds this threshold, the device stops switching. This threshold on the FB pin corresponds to about 12% of the current limitation of the device, i.e. about 80mA for a VIPer22A.

When the output load is decreased and the regulation loop makes the FB pin reach the I_{FBsd} threshold, the device enters a burst mode operation by skipping switching cycles. This is especially important when the converter is lightly loaded, to achieve very low input power consumption. Values in the range of 100mW of input power can be reached with no load on the output.

2. DIGITAL TV APPLICATION

2.1. Schematics

The overall schematics is shown in figure 3.

A conventional flyback structure is used with the main transformer T2 insuring the isolation between primary and secondary side, and delivering all the output voltages, except the 1.8V one which is derived from the 3.3V through a serial regulator U1. This voltage is too low to be delivered directly from the transformer with the required accuracy, and it also simplifies the transformer design.

The secondary rectifying is made with shottky diodes for low output voltage values, and with silicon diodes for the two highest ones (12V and 30V). The diode in charge of the 2.5V rectification has been put in the transformer return line with the following benefits:

– The 2.5V output can be left unloaded without too much voltage variation, because C13 can be either charged or discharged by the other outputs as presented on figure 4.
– As D9 is always biased by the sum of all output currents, its forward voltage drop has less variation and the cross coupling between the 2.5V and the other outputs is improved.

See paragraph 2.2 for a comparison with the conventional configuration. The drawback of such a configuration is the dissipation of D9 which has to withstand the sum of all the output currents. This is acceptable for low output power converters.

The low voltage outputs are further filtered with an L-C network in order to reduce the output ripple to an acceptable value. The 30V output has a shunt regulation thanks to D10 and R10. This is necessary because of the very low current consumed on this output, which would not be sufficient to insure a correct voltage value on the transformer. D4 and C7 can be considered as a peak rectifier network when lightly loaded, and the output voltage is much higher than the one predicted by the turns ratio in this condition. Note that the shunt regulation imposes a constant

Figure 3: Power Supply Schematics

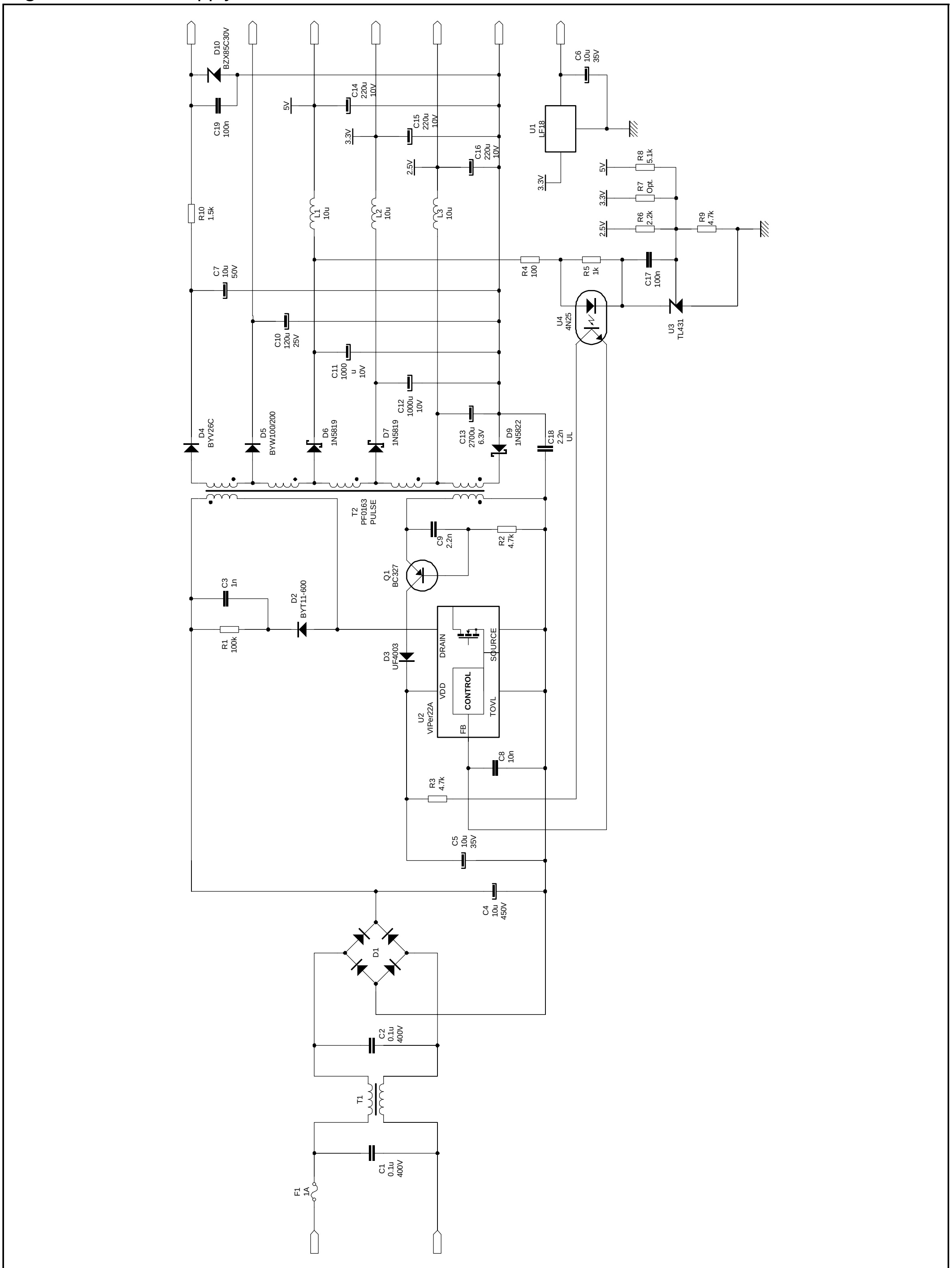
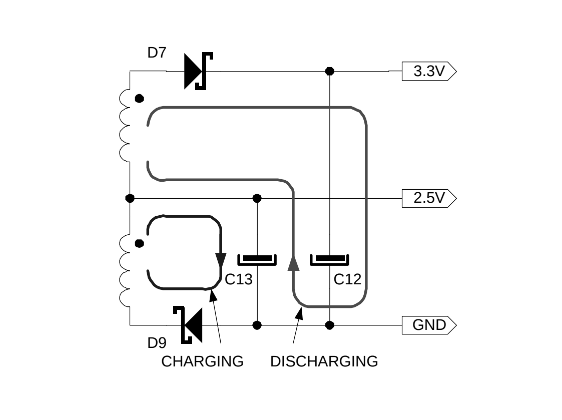


Figure 4: Current Flowing in 2.5V Capacitor



current flowing on this output, thus leading to controlled voltage value across C7.

The regulation is achieved from secondary with a conventional programmable zener of the TL431 type, together with a multiple input resistive divider R6 to R9. Actually, only the 2.5V and the 5V outputs provide the feedback through R6 and R8. This configuration allows to spread the voltage variations among all the outputs, instead of having one very well regulated output, and all the other ones with poor tolerances.

On primary side, a VIPer22A is used with some additional components: C5 insures a correct start up, C8 filters any high frequency noise on the FB pin, and R3 prevents U4 from discharging C5. This may occur in case of light load on the output, with a small overvoltage which lasts too long. In this condition, the system restarts endlessly, as C5 is always quickly discharged down to V_{DDoff} while waiting for the overvoltage to disappear, and the auxiliary winding to deliver some energy. R3 allows to keep a sufficient voltage on the VDD pin during that period of time.

An active filter has been used on the auxiliary winding in order to eliminate the spikes which always appear after the turn off of the VIPer22A main switch. This is especially important in short circuit conditions, where the auxiliary winding is supposed to decrease and the VDD voltage to reach VDDoff. The device then enters into an endless restart cycle (also called hiccup mode) with a low restart duty cycle. This operation mode allows to withstand indefinitely a short circuit on any output, without blowing up the rectifying diodes on secondary side.

The voltage on the drain is controlled by an RCD type clamper. This network dissipates the leakage energy of the transformer into R1. As the breakdown voltage of the VIPer22A is guaranteed to be higher than 730V, the R1 value can be set to a relatively high value, thus optimizing the leakage losses (the higher is the clamping voltage, and the lower is the dissipated energy).

2.2. Results

All measurements are made at ambient temperature (about 25°C), with an input voltage of 330VDC and a fixed load for the 12V (20mA) and the 30V (5mA) outputs.

In these conditions, the efficiency is shown in table 4, with two configurations for the 1.8V output. As this output is delivered through a serial regulator from the 3.3V output, a first measurement is done with the sum of the two currents on the 3.3V output in order to get the real efficiency of the flyback converter, and then with the regular configuration where each output is loaded with its own current. This set of results is also given for the minimum and the maximum load.

Table 4: Efficiency

	Minimum load	**Maximum load**
3.3 V loaded	63%	64%
3.3 V and 1.8 V loaded	61%	57%

The output voltages have been measured in various conditions, in order to check the cross regulation between them. The 1.8V output has been ignored, as it is delivered through a serial regulator. Figures 5 to 7 present the voltages variation versus the other outputs and its own current for the 2.5V, 3.3V and 5V outputs respectively.

The 2.5V output presents a variation of 1.3% versus the other outputs, and a load regulation of 4.4%. The corresponding figures are 4.6% and 8.2% for the 3.3V output, and 5.3% and 0.3% for the 5 V output. This last load regulation is very good, because the load variation on the 5V output is much smaller than for the other outputs. All these results are not compliant with the specification given in table 1, but the used configuration represents a worst case which is not reached with the real load.

Note also the good cross regulation for the 2.5V output due to its particular configuration. The board offers the possibility to put back the rectifying diodes in a more conventional configuration by using the footprint D8, and replacing the diode D9 by a short circuit. The new connection is shown in

Figure 5: 2.5V Output Regulation

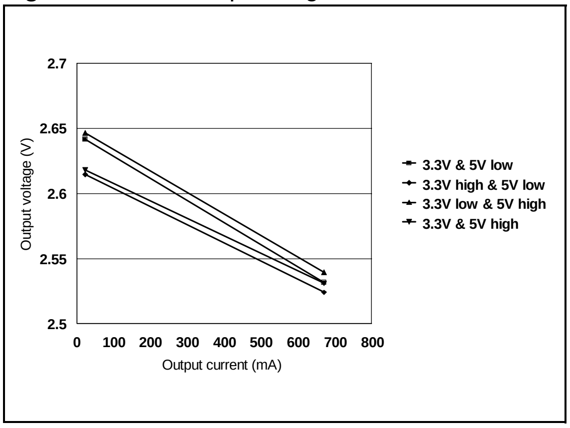


Figure 6: 3.3V Output Regulation

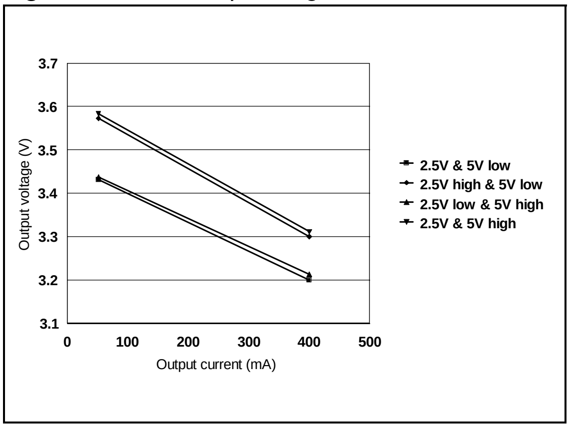


Figure 7: 5V Output Regulation

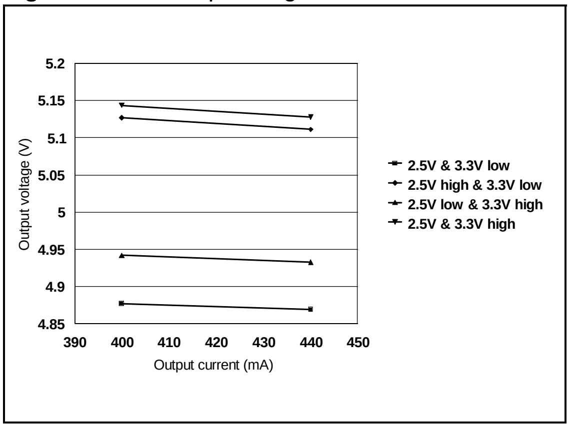


figure 8, and corresponding results in figure 9. The Y axis is directly given in percentage, because the output voltage values don't fit the specification any more. The fact that D9 is in series with all the outputs modifies the ratio between the output voltages, when compared to the situation where each output is rectified by its own diode.

The improvement is significant for two characteristics:

– The load regulation in the specified output current range is twice better.

– It is possible to control the output voltage down to 0mA, where as the standard configuration leads to a hiccup operation. This is due to the excessive increase of the 2.5V output voltage (almost +10%) and the split regulation which decreases the 5V output voltage and the auxiliary voltage at the same time. When VDDoff is reached, the converter stops switching and recharges the VDD capacitor C5.

Figure 8: Modified Rectifying Diodes Configuration

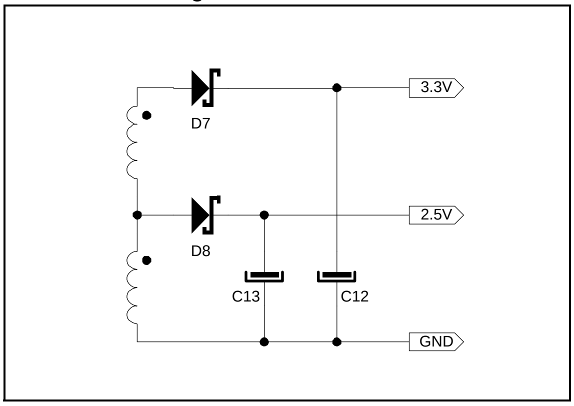
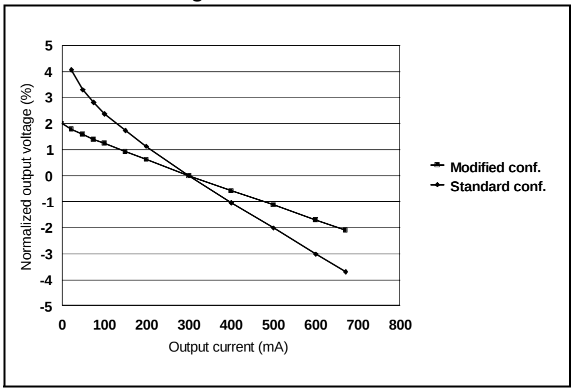


Figure 9: 2.5V Output Regulation with Modified Configuration



A full load switching cycle is shown in figure 10. The peak current reaches 320mA, which means that the VIPer22A could be swapped with a VIPer12A without any consequence on the electric behavior of the converter, inside its output specification. The temperature reached by this

Figure 10: Full Load Switching Cycle

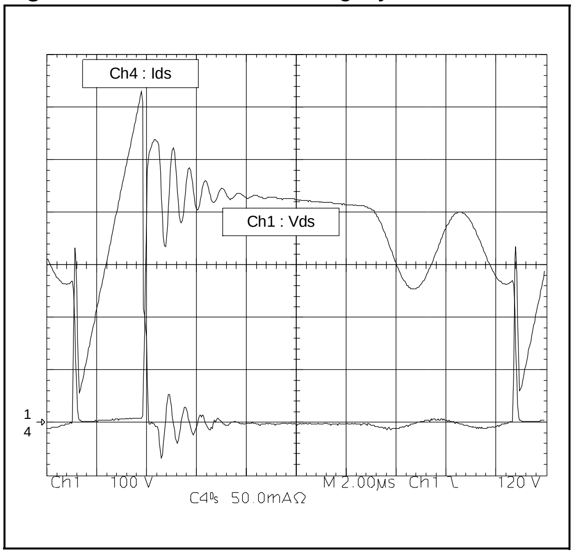
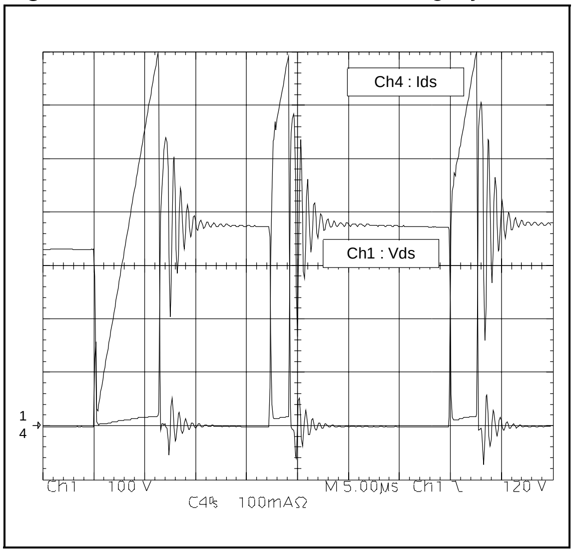


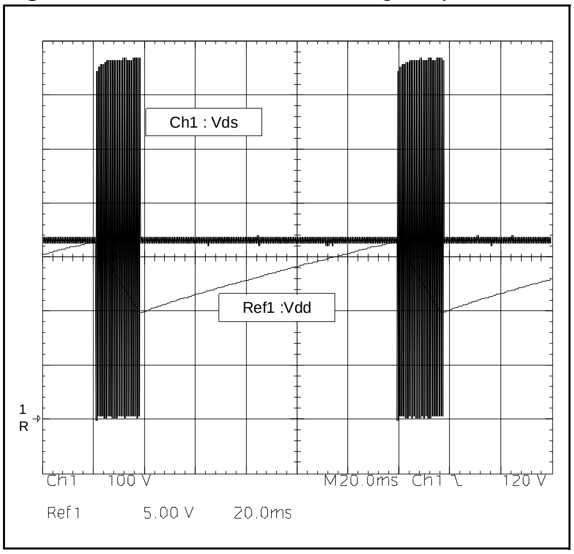
Figure 11: Short Circuit First Switching Cycles



device is of course higher than the original one because the RDSon is 30Ω instead of 16Ω. This situation may be acceptable, depending on the thermal environment.

In case of short circuits on any output (except the regulated ones, i.e. the 1.8V and the 30V which have their own protections), the converter enters an endless restarting cycles sequence. The first switching cycles of each sequence is presented in figure 11. The first cycle has a long on time, because the transformer is fully charged up to the current limitation of the device. Then, the converter works in continuous mode as the transformer does not demagnetize completely between cycles. All the switching cycles following the third one are very similar, and the converter stops switching when the VDD voltage reaches V_{DDoff}. The VIPer22A recharges the capacitor C5 on the VDD pin, and tries to restart when it reaches V_{DDon}. This sequence is shown in figure 12 together with the peak drain voltage. As the recharging time is much longer than the discharging one, the active phase where the device tries to restart and provides its full current capability is much shorter than the inactive phase. This leads to a small restart duty cycle and ensures a controlled temperature of the output rectifying diodes and transformer.

Figure 12: Short Circuit Restarting Sequence



The startup waveforms of the outputs in minimum load conditions have been measured and are presented together in figure 13. Some reasonable overshoot can be observed. There is no particular sequencing and all voltages appear simultaneously, with a small delay for the 1.8V regulator.

2.3. Transformer specification

The transformer has been studied and manufactured by PULSE under the reference PF0163.

Table 6 gives its electrical specification with further information in figure 14. Table 5 provides some information on the physical arrangement. Note that all secondary winding are stacked one on top of the previous one, and wound with triple insulation wire. The primary winding is entirely wound first and the auxiliary is placed over the secondary windings, as the last one.

Figure 13: Output Voltages Startup

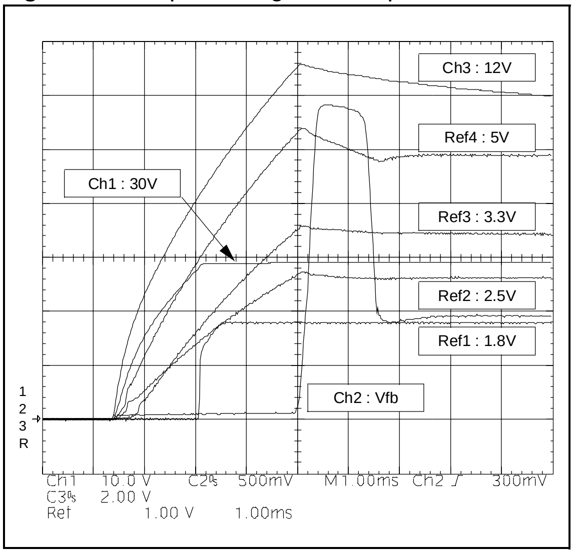


Table 5: Transformer Internal Definition

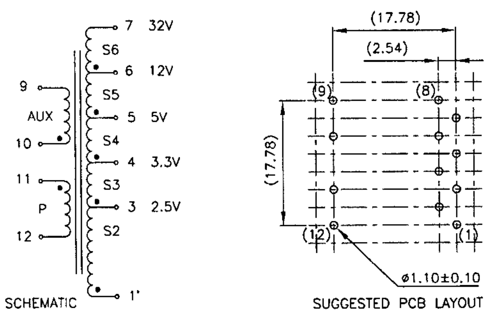
Parameter	Value
Core Size	E20
Primary number of turns	219
Auxiliary number of turns	29
2.5 V number of turns	7
3.3 V number of turns	3
5 V number of turns	3
12 V number of turns	14
32 V number of turns	57

Figure 14: PULSE Transformer Specification

FINAL OUTLINE NOTES:
DIMENSIONS IN ( ) ARE GIVEN ONLY FOR INFORMATION

ELECTRICAL CHARACTERISTICS:
(FOR REFERENCE ONLY. USED FOR CUSTOMER INFORMATION.)

ITEM	SPECIFICATIONS	TEST CONDITIONS	VALUE		UNIT
2	RATIO (11'–12):(1'–3)		NOM.	31.28	/
3	RATIO (11'–12):(1'–4)		NOM.	21.9	/
4	RATIO (11'–12):(1'–5)		NOM.	16.85	/
5	RATIO (11'–12):(1'–6)		NOM.	7.55	/
6	RATIO (11'–12):(1'–7)		NOM.	2.61	/
7	RATIO (11'–12):(10'–9)		NOM.	7.55	/
8	INDUCTANCE (11'–12)	10KHz–100mV	NOM.	2.83	mH
9	HIPOT (11',12)+(9',10) TO (1',7)	3000Vac	/	1 min.	/
10	HIPOT (11',12) TO (9',10)	1000Vac	/	1 min.	/



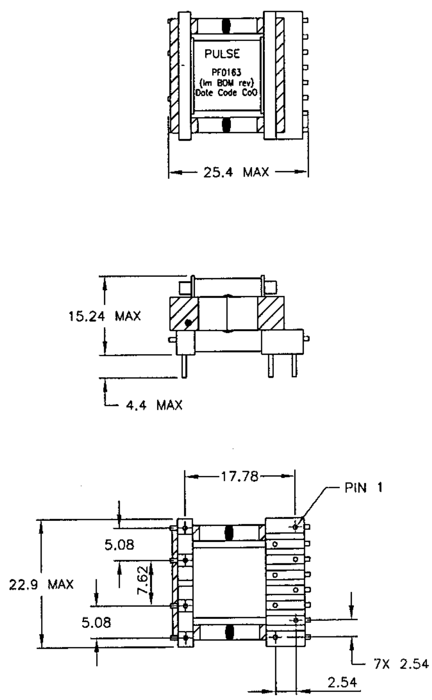


Table 6: Transformer Electrical Specification

Parameter	Value
Primary inductance	2.8 mH typical
Leakage inductance	120 µH maximum
Saturation current	700 mA minimum

2.4. Board description

FIgures 15 and 16 present respectively the top and bottom sides of the PCB. Both of them are top view. This board is double layer copper, and most of the top part is used for shielding, in order to avoid interferences with the rest of the receiver. For this purpose, two ground planes are placed over primary and secondary circuits where high dV/dt exist.

Figure 15: PCB Top Side

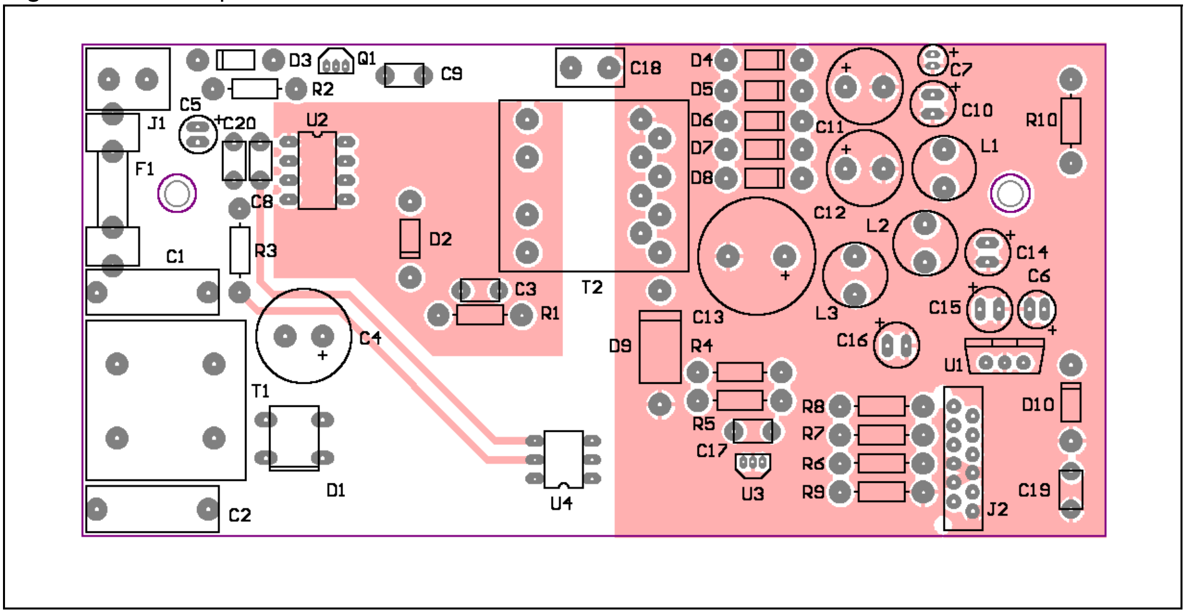


Figure 16: PCB Bottom Side

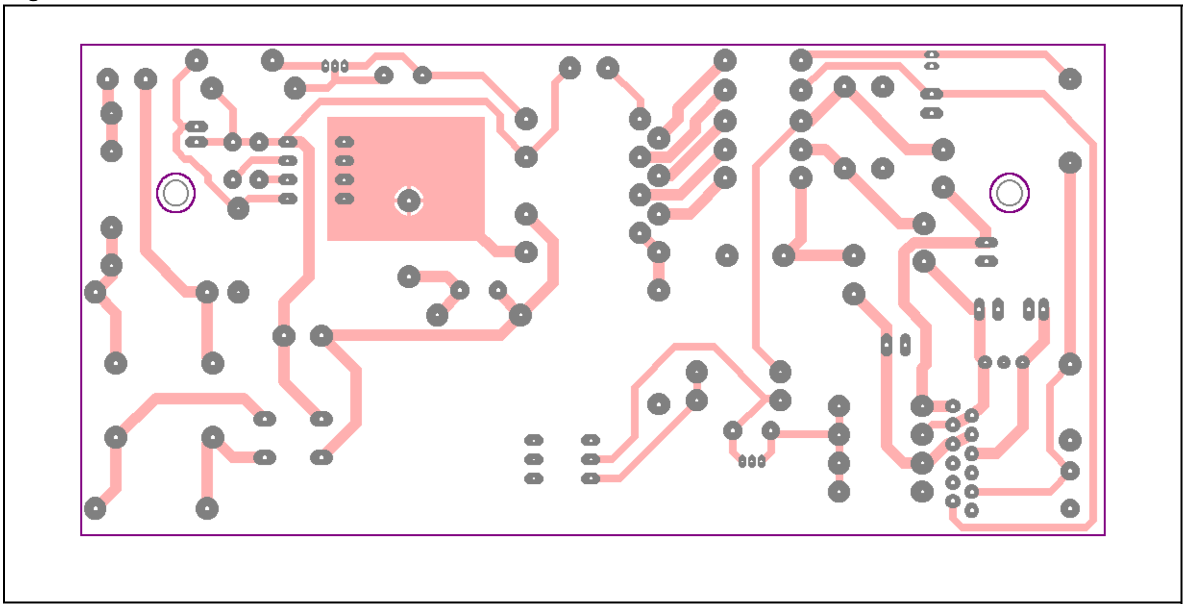


Table 7: Component list

Reference	Value	Description
C1	100nF / 250 Vac	Plastic
C2	100nF / 250 Vac	Plastic
C3	1nF / 1kV	Ceramic HT
C4	10µF / 450V	Electrolytic
C5	10µF / 35V	Electrolytic
C6	10µF / 35V	Electrolytic
C7	10µF / 50V	Electrolytic / Low ESR
C8	10nF	Ceramic
C9	2.2nF	Ceramic
C10	120µF / 25V	Electrolytic / Low ESR
C11	1000µF / 10V	Electrolytic / Low ESR
C12	1000µF / 10V	Electrolytic / Low ESR
C13	2700µF / 6.3V	Electrolytic / Low ESR
C14	220µF / 10V	Electrolytic / Low ESR
C15	220µF / 10V	Electrolytic / Low ESR
C16	220µF / 10V	Electrolytic / Low ESR
C17	100nF	Ceramic
C18	2.2nF / 2kV	UL approved
C19	100nF	Ceramic
C20	Strap	Reserved for future option
R1	100kΩ	1/2W 5%
R2	4.7kΩ	1/2W 5%
R3	4.7kΩ	1/2W 5%
R4	100Ω	1/2W 5%
R5	1kΩ	1/2W 5%
R6	2.2kΩ	1/2W 1%
R7	Not fitted	1/2W 1%
R8	5.1kΩ	1/2W 1%

Reference	Value	Description
R9	4.7kΩ	1/2W 1%
R10	1.5kΩ	1/2W 5%
L1	10µH	Isat>1A, R<0.1Ω
L2	10µH	Isat>1A, R<0.1Ω
L3	10µH	Isat>1A, R<0.1Ω
T1	EH20-0.5-0.2-18M	18mH, 0.5A
T2	PF0163	PULSE
D1	DF08M	800V/1A bridge
D2	BYT11-600	
D3	UF4003	
D4	BYV26C	
D5	BYW100-200	
D6	1N5819	
D7	1N5819	
D8	Strap	
D9	1N5822	
D10	BZX85C30V	
U1	LF18ABV	
U2		**STMicroelectronics VIPer22ADIP**
U3	TL431CZ	
U4	4N25	
F1	1A	Fuse
	12 points output connector	Molex Picoflex
	2 points input connector	Weidmuller