APPLICATION NOTE

200W SMPS with TEA1504

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Abstract

This application note briefly describes a 200 Watt Switched Mode Power Supply (SMPS) for a typical TV or monitor application based upon the TEA1504 controller. The power supply is based on a flyback topology and operates in the discontinuous mode fixed frequency. The TEA1504 uses voltage mode (duty cycle) control. The concept allows a high efficient low power mode and standby mode.

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200W SMPS with TEA1504

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Keywords

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SMPS

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Summary

The TEA1504 controller is part of the GreenchipTM family. It is intended for off-line $90V_{AC}$-$276V_{AC}$ power supply applications. The controller is optimised for high efficiency operation by means of an integrated start-up current source, a special standby burst mode feature and low power consumption, especially in the off-mode.

This application note briefly describes a 200 Watt Switched Mode Power Supply (SMPS) for a typical TV or monitor application based upon the TEA1504 controller. The power supply is based on a flyback topology and operates in the discontinuous mode fixed frequency. The TEA1504 uses voltage mode (duty cycle) control.

After introducing the main TEA1504 features and the power supply specification, a detailed description of the circuit diagram and some measuring results (EMI included) are presented.

CONTENTS

1 FEATURES

- Full mains input range 90-276 V_{AC}
- Peak output power 200 Watt, continuous output power 150 Watt
- Output voltages: 140 V, 16.8 V, 10.8 V, 4.7 V, 5 V standby, floating 16.8 V for audio amplifiers
- Very low ‘OFF’ power without conventional expensive mains-switch
- Intelligent low power standby mode (< 2 Watt nominal from the mains input)
- Increased efficiency through automatically reduced switching frequency (low loads)
- EMI (mains conducted) friendly
- Minimum component count
- Main output short circuit proof

2 QUICK REFERENCE DATA

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
Supply						
V_{line}	mains voltage	nominal operation	85		276	V_{RMS}
f_{line}	mains frequency	nominal operation		50 / 60		Hz
Output voltages						
V_{OUT1}	main output voltage	all conditions		140		V_{DC}
$V_{OUT1,fl}$	100Hz ripple				150	mV_{ACpp}
$V_{OUT1,fs}$	high frequency ripple				15	mV_{ACpp}
$\Delta V_{OUT1,line}$	line regulation				100	mV_{DC}
$\Delta V_{OUT1,load}$	load regulation				100	mV_{DC}
I_{OUT1}	main output current				0.8	A_{DC}
V_{OUT2}	output voltage 2			16.8		V_{DC}
I_{OUT2}	output current 2				0.7	A_{DC}
V_{OUT3}	output voltage 3			10.5		V_{DC}
I_{OUT3}	output current 3				1.1	A_{DC}
V_{OUT4}	output voltage 4			4.7		V_{DC}
I_{OUT4}	output current 4				1.0	A_{DC}
V_{OUT5}	standby voltage			5.0		V_{DC}
I_{OUT5}	standby current				50	mA_{DC}
V_{OUT6}	Audio voltage			16.8		V_{DC}
I_{OUT6}	Typical audio current				1.45	A_{DC}
	Peak				2.9	A_{DC}

3 FUNCTIONAL BLOCK DIAGRAM

Figure 1 shows a functional block diagram of the application (this diagram corresponds to the PCB top view).

The functional switch switches the SMPS in the on- or off-state. When the SMPS is operational (on-state) the TEA1504 controller drives the MOSFET. When the MOSFET conducts, a saw tooth current is established in the transformer. The saw tooth current is converted in a voltage by means of the current sense resistors. This voltage is an indication of the transformer throughput power and is guarded by the TEA1504 controller. The transformer transfers the power to the output stage. The output stage (V_{OUT1}) is controlled by means of a secondary regulator circuit which communicates with the TEA1504 controller by means of an optocoupler. Both the dV/dt-limiter and the peak clamp are implemented in order to reduce MOSFET switch-off stress.

The SMPS is equipped with a special low power standby feature which can be controlled by a microprocessor. The microprocessor is simulated in the application by means of a Standby/Normal mode switch. When the controller operates in normal mode, the standby circuit is disabled. When the controller operates in standby the SMPS operates in the burst mode. During this high efficiency burst mode the SMPS alternately becomes activated and deactivated.

The standby circuit is optional. Low budget applications can be built without this circuit.

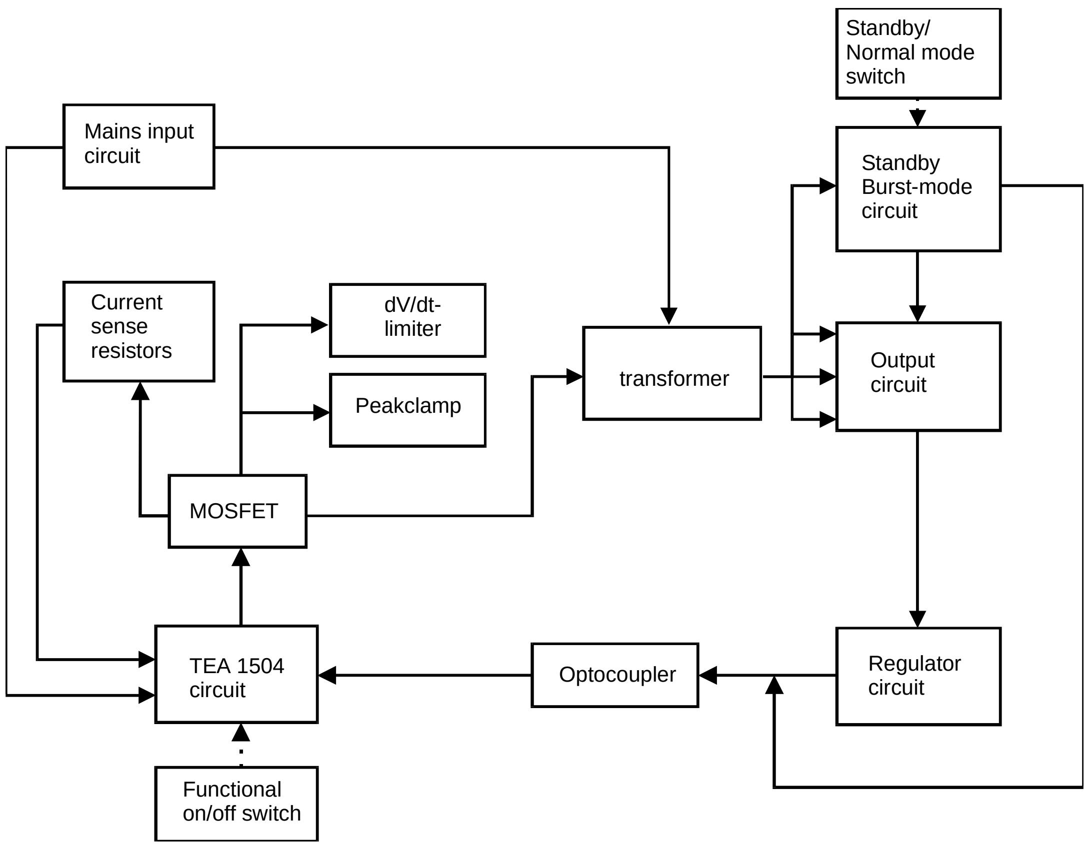


Figure 1 Functional block diagram

4 CIRCUIT DESCRIPTION

4.1 Mains input

The input circuit is a conventional full bridge rectifier. A common mode filter is included for mains conducted EMI suppression.

The conventional mains switch can be eliminated. Its function is taken over by functional switch S1, forcing the TEA1504 in an extremely low power consuming 'OFF' mode when opened. An NTC resistor is used to limit a first time inrush current when connecting the supply to the mains.

A degaussing circuit is not included. A standard PTC degaussing circuit can be added. To gain full advantage in terms of power consumption in 'OFF' and 'STANDBY' mode a circuit to switch off the degaussing PTC during these modes should be added.

4.2 Switching device

The TEA1504 is capable of directly driving the gate of a MOSFET. In this application any MOSFET can be used that has a breakdown voltage of at least 600 V and an R_{DSon} of 0.5 Ω up to 0.7 Ω.

The peak clamp (D7, R6 and C9) limits the peak voltage at the drain of the MOSFET during switch-off. The dV/dt limiter circuit (C14, D10 and R14) limits the switch-off power dissipation in the MOSFET and reduces EMI.

Gate resistor R10 determines the switch on and off speed of the MOSFET. Decreasing this value leads to a higher switching speed. The optimum switching speed is a compromise between switching losses in the MOSFET and EMI. A minimum resistor value of 5.6 Ω is required in order to prevent drive oscillations (caused by bond wire inductance and parasitic capacitance's) that might destroy the MOSFET.

4.3 The transformer

The transformer is designed to have an output voltage of 5.8 V per turn. The output voltages can be chosen in 5.8 V steps minus one diode forward drop.

4.4 Output voltage regulation*)

The TEA1504 can be used either with primary sensing as well as secondary sensing. Primary sensing is cheaper but output regulation is less accurate. It is used especially for the low end market (low power, low budget). Secondary sensing is more expensive but has a higher performance. It is used especially in the medium and high end market. Both kinds of regulation can be applied when using the TEA1504.

This 200 Watt application uses secondary sensing. IC3 is a voltage regulator that feeds an error signal through optocoupler OP1 back to the control input of the TEA1504. The TEA1504 uses this information to control an internal pulse width modulator (PWM). The PWM is connected to the gate drive pin and drives the external MOSFET. The total system is designed to operate in voltage mode fixed frequency. This means that the PWM controls the interval during which the MOSFET conducts (duty cycle). P1 can be used to adjust the output voltage.

Resistors R16, R17, R18 and R19 transform the current through the MOSFET, which equals the current through the transformer, into a sense voltage. This voltage is a reflection of the power flowing from input to output. Especially the peak current is a good indication for this throughput power. The sense voltage is guarded by the TEA1504 and is limited to a certain maximum level. When this level has been reached the TEA1504 PWM automatically switches off. This feature is called cycle by cycle current limitation. In this way the maximum throughput power is limited to a preset value (determined by resistors R16 through R19).

The TEA1504 is equipped with a leading edge blanking filter (LEB). Any distortion in the sensed voltage during MOSFET switch on is neglected by the TEA1504. This feature prevents the controller from false peak throughput power triggering.

*) See Advanced Design Note: '*TEA1504 Secondary Sensing Control Loop Design*' rep. No.:ETV98001

4.5 Low load start-up

Circuit C40, R34, R37 and D28 is added to the application in order to guarantee proper start-up behaviour. In general an SMPS can suffer from bad start-up behaviour, especially during low load situations. The added circuit eliminates this problem. The supply will always start-up in a proper way.

4.6 Input voltage sense

The TEA1504 is equipped with a minimum input voltage protection (Mains Under Voltage Lock Out). The input voltage is tapped by means of resistors R7, R8 and R11 and is connected to the OOB pin. If the input voltage drops below 50 V_{DC} (in this configuration) the TEA1504 will automatically switch off.

4.7 TEA 1504 supply voltage

An internal current source is connected from the DC mains input voltage V_{in} to the TEA1504 supply voltage V_{aux}. This high level current source charges capacitors C30 and C31 which are connected to this V_{aux} pin. As soon as the voltage level at this pin reaches a certain threshold level, the controller starts to operate and the internal current source is switched off. Transformer winding 8-9 takes over the TEA1504 supply current during steady state operation. This feature improves the total efficiency of the system.

4.7.1 Under Voltage Lock Out (UVLO)

When the voltage level V_{aux} becomes too low the controller stops its operation (Under Voltage Lock Out (UVLO)). This feature enables the hick-up mode operation during which the controller is alternately active and not active.

4.7.2 Over Voltage Protection (OVP)

When the voltage level V_{aux} becomes too high the controller also stops its operation (Over Voltage Protection (OVP)). Because V_{aux} is a reflection of the output voltage, this feature limits the maximum output voltage level.

4.8 Short circuit protection

When the main output (V_{OUT1}) gets short circuited, the controller supply voltage V_{aux} will drop because the transformer take-over winding 8-9 fails to charge capacitors C30 and C31. V_{aux} drops below UVLO. The internal current source charges V_{aux} up to the start-up threshold level. The TEA1504 becomes active but V_{aux} drops below UVLO again. The controller enters the safe restart mode. This situation persists until the short circuit is removed.

4.9 Modes of operation

For proper operation V_{OUT5} should always be loaded (e.g. 50 mA_{DC}).

4.9.1 on/off switch

The expensive mains switch can be replaced by an inexpensive functional switch when using the TEA1504 ON/OFF feature (according IEC95 regulations). If S1 is open, the voltage at the OOB (On Off Burst) pin drops below 2.5 V. At this OOB-level the controller switches into the OFF mode. In this mode the current consumption of the controller drops below 300 µA. If the voltage at the OOB pin rises above 2.5 V, the controller goes through the start-up sequence and commences normal operation.

4.9.2 normal mode: medium and high power

At normal operation and medium or high load the supply runs in discontinuous mode at a fixed frequency of 50 kHz. The oscillator frequency can be programmed by adjusting R22. This resistor determines the internal TEA1504 reference current. This current has a direct impact on the oscillator (switching) frequency. Several other functions are also related to this reference current. So changing the resistor value will not only influence the oscillator frequency but also other features like LEB. The practical oscillator range is 50 kHz up to 90 kHz.

The TEA1504 is equipped with a demag-protection circuit. This circuit ensures discontinuous mode operation under all conditions. The total design shows optimum performance through this feature.

4.9.3 normal mode: low power

When the output power drops to a level below approximately 10% of the peak power, the oscillator frequency is reduced a factor 2.5 in order to reduce switching losses (improved efficiency). In a TV set for example this occurs in sound-only mode or satellite standby operation.

4.9.4 standby operation

The ‘OOB’ pin is also used to switch the supply into the burst mode. During standby operation this mode increases the total system efficiency significantly. Figure 2 shows some characteristic burst mode waveforms.

When switch S2 is closed, thyristor Q2 will start to conduct. Transformer winding 17-18 is shunted in parallel with winding 11-12. Winding 17-18 dominates. The transformer has a current source characteristic. This means that the volts/turn ratio immediately drops to a much lower level. Together with thyristor Q2 also transistor TR1 will start to conduct (one-shot). The one shot current pulse generated by transistor TR1 is fed to the OOB pin by means of optocoupler OP1. This current pulse activates the TEA1504 standby mode: the controller stops driving the MOSFET. From that moment on the controller starts to operate in a regulated hick-up mode that is called the burst mode. Because the transformer take-over winding 8-9 stays at a low level (lower volts/turn ratio), V_{aux} will drop below the UVLO level. The internal current source charges capacitors C30 and C31 again up to the threshold level. The controller starts to operate again. Because thyristor Q2 is still closed all the transformer energy will flow to the standby output. Capacitor C23 gets charged. As soon as the zener Z1 voltage level (+ V_{beTR1}) is reached a current pulse is generated through transistor TR1 that again triggers the OOB pin. The controller stops its operation and again UVLO will be reached. This mode of operation is called ‘burst mode’ because the controller periodically generates an energy burst.

When switch S2 is opened thyristor Q2 stops conduction and all the transformer energy flows into the main output again. The zener Z1 level will not be reached, so the OOB pin will not be triggered. The controller detects this state and switches back to normal mode again.

During burst mode (standby) operation the transformer peak current is limited to a fraction of the maximum peak current that flows during normal mode. In this way transformer rattle is limited to a minimum.

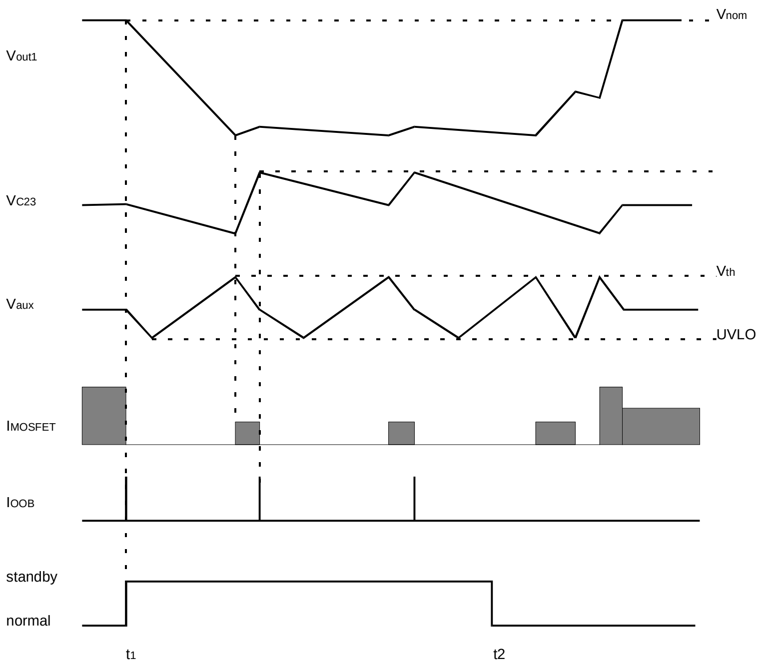


Figure 2 Burst mode waveforms

5 MEASURING RESULTS

5.1 General performance

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
Main output voltage line regulation						
$\Delta V_{OUT1,line}$	line regulation V_{OUT1}	$85V_{RMS}<V_{line}<276V_{RMS}$,; $I_{OUT1}=0.8A_{DC}$	139.9		140.0	V_{DC}
Output voltages load regulation ($V_{line}=230V_{RMS}$)						
$\Delta V_{OUT1,load}$	load regulation V_{OUT1}	$0.1A_{DC}<I_{OUT1}<0.8A_{DC}$	140.0		140.1	V_{DC}
$\Delta V_{OUT2,load}$	load regulation V_{OUT2}	$0.1A_{DC}<I_{OUT2}<0.7A_{DC}$; $I_{OUT1}=0.4A_{DC}$	16.6		17.2	V_{DC}
$\Delta V_{OUT3,load}$	load regulation V_{OUT3}	$0.1A_{DC}<I_{OUT3}<1.1A_{DC}$; $I_{OUT1}=0.4A_{DC}$	10.1		11.0	V_{DC}
$\Delta V_{OUT4,load}$	load regulation V_{OUT4}	$0.1A_{DC}<I_{OUT4}<1.0A_{DC}$; $I_{OUT1}=0.4A_{DC}$	4.2		5.0	V_{DC}
$\Delta V_{OUT6,load}$	load regulation V_{OUT6}	$0.1A_{DC}<I_{OUT6}<1.45A_{DC}$; $I_{OUT1}=0.4A_{DC}$	16.3		17.3	V_{DC}
Efficiency						
η	ratio P_{OUT}/P_{IN}	$V_{line}=230V_{RMS}$; $I_{OUT1}=1.1A_{DC}$		86		%
Standby power consumption from the mains						
P_{OFF}	OFF_{mode} input power	$V_{line}=230V_{RMS}$			0.1	W
$P_{STBY,in}$ 1)	standby input power	$V_{line}=230V_{RMS}$; $I_{out5}=50mA_{DC}$		1.88		W
Start-up time						
t_{START}	Start-up time 2)	$V_{line}=230V_{RMS}$; $I_{OUT1}=0.4A_{DC}$		75		msec

1) measured with WHrs meter

2) Figure 3 for reference

5.2 Typical oscillograms

5.2.1 Start-up behaviour

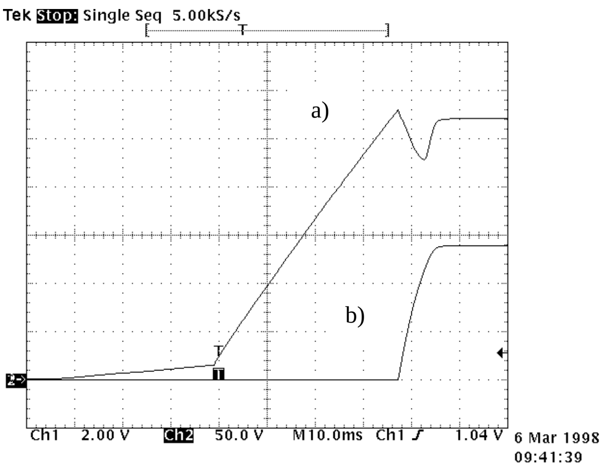


Figure 3 Start up behaviour at V_{line}=230V_{RMS}, I_{OUT1}=0.4A_{DC} a) V_{AUX} b) V_{OUT1}.

Figure 3 shows the main output voltage V_{OUT1} during start-up when functional switch S_1 is closed. Diagram a) shows the supply voltage of the TEA1504 (V_{AUX}). Diagram b) the main output voltage (V_{OUT1}).

5.2.2 Output load step (V_{out1})

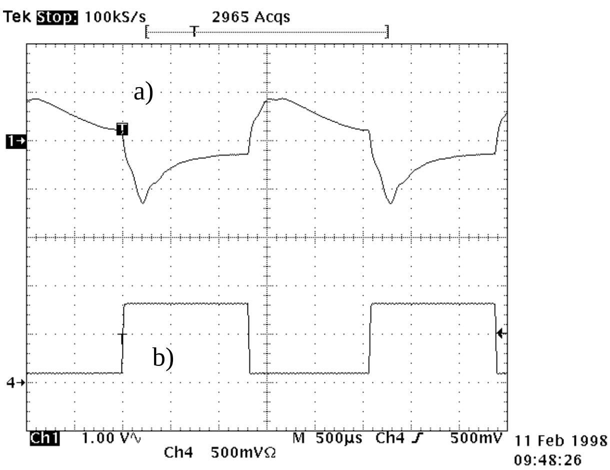


Figure 4 Output voltage (V_{OUT1}) during load steps (V_{line}=230V_{RMS}): a) V_{OUT1} (1V_{AC}/div), b) I_{OUT1} (500mA_{DC}/div)

Figure 4 shows the main output voltage (V_{OUT1}) when a load step is applied to this output. The load varies between 100 mA_{DC} and 800 mA_{DC}. Diagram a) shows the AC output voltage. Diagram b) shows the output current (I_{OUT1}).

From this figure it can be concluded that the output voltage stays within about 1 V of its nominal range during this severe load step.

5.2.3 Output AC-ripple (V_{out1})

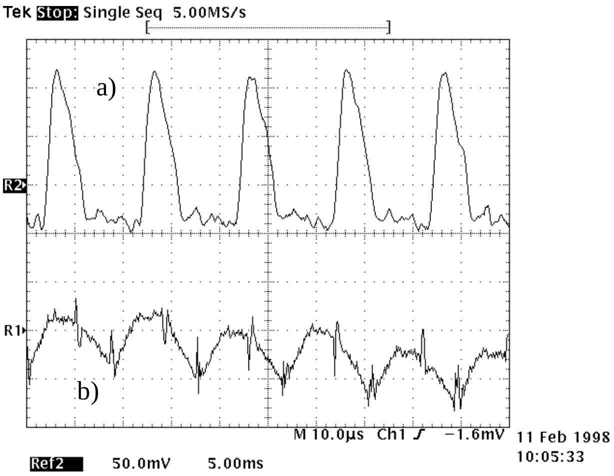


Figure 5 Output AC-ripple (V_{OUT1}) at V_{line}=90V_{RMS}:
a) 100Hz ripple (50mV/div, 5msec/div), b) switching ripple (10mV/div, 10µsec/div)

Figure 5 shows the main output voltage (V_{OUT1}) AC ripple during high load conditions at minimum input voltage (worst case). The output is loaded with 800mA_{DC} (I_{OUT1}). Diagram a) shows the 100 Hz low frequency ripple. This ripple is about 150 mV_{PP}. Diagram b) shows the switching ripple. This ripple is about 10 mV_{PP}.

The 100 Hz low frequency ripple and the high frequency switching ripple both are well within specification.

5.2.4 Standby-normal mode transitions

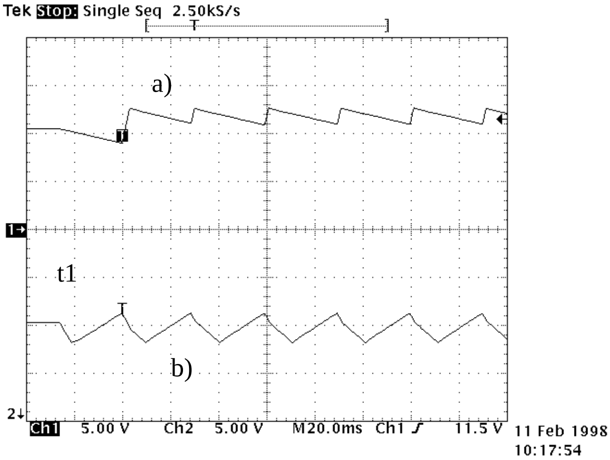


Figure 6 Normal mode to standby (burst mode) transition: a) C23 voltage (5V/div), b) TEA1504 V_{aux} voltage (5V/div)

Figure 6 shows the transition from normal mode to standby mode. Diagram a) shows the unregulated standby output voltage (capacitor C23). Diagram b) shows the TEA1504 supply voltage V_{aux}. V_{OUT5} is loaded with 50 mA. The supply switches from normal to standby mode at t_1.

Diagram a) shows that during the transition the capacitor C23 voltage never drops below 7.5 V (stabiliser input voltage). This means that the stabiliser output voltage V_{OUT5} will remain 5 V during the transition from normal to standby mode.

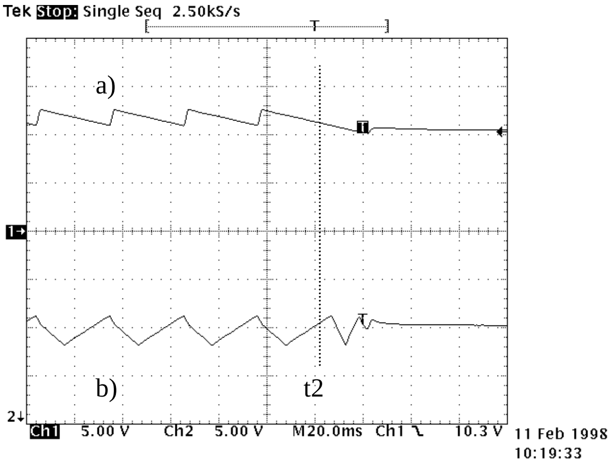


Figure 7 Standby (burst mode) to normal mode transition: a) C23 voltage (5V/div), b) TEA1504 V_{aux} voltage (5V/div)

Figure 7 shows the transition from standby mode to normal mode. Diagram a) shows the unregulated standby output voltage (capacitor C23). Diagram b) shows the TEA1504 supply voltage V_{aux}. The supply switches from standby to normal mode at t_2.

Diagram a) shows that during the transition the capacitor C23 voltage never drops below 7.5 V (stabiliser input voltage). This means that the stabiliser output voltage V_{OUT5} will remain 5 V during the transition from standby to normal mode.

5.3 EMI measurement (CISPR13/22)

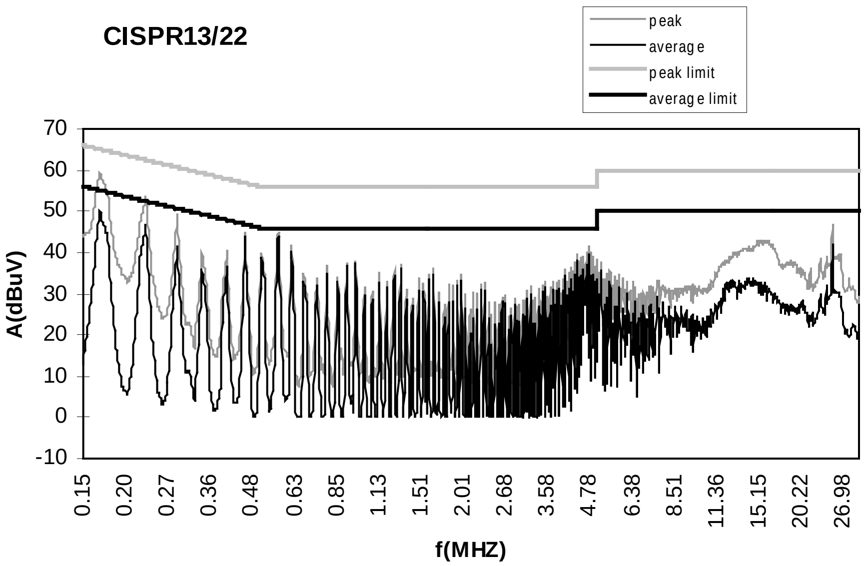


Figure 8 CISPR13/22 measurement (150kHz-30MHz) (V_{line}=230V_{RMS}, R_{OUT1}=220Ω)

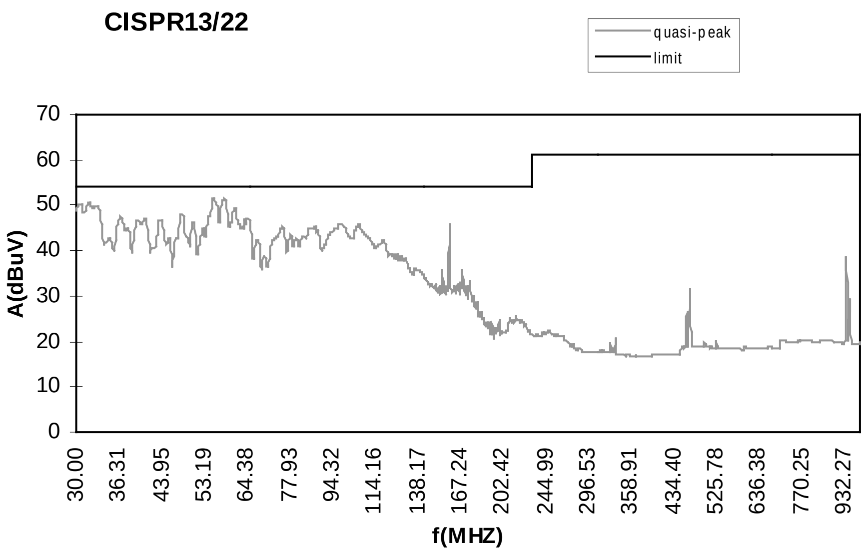
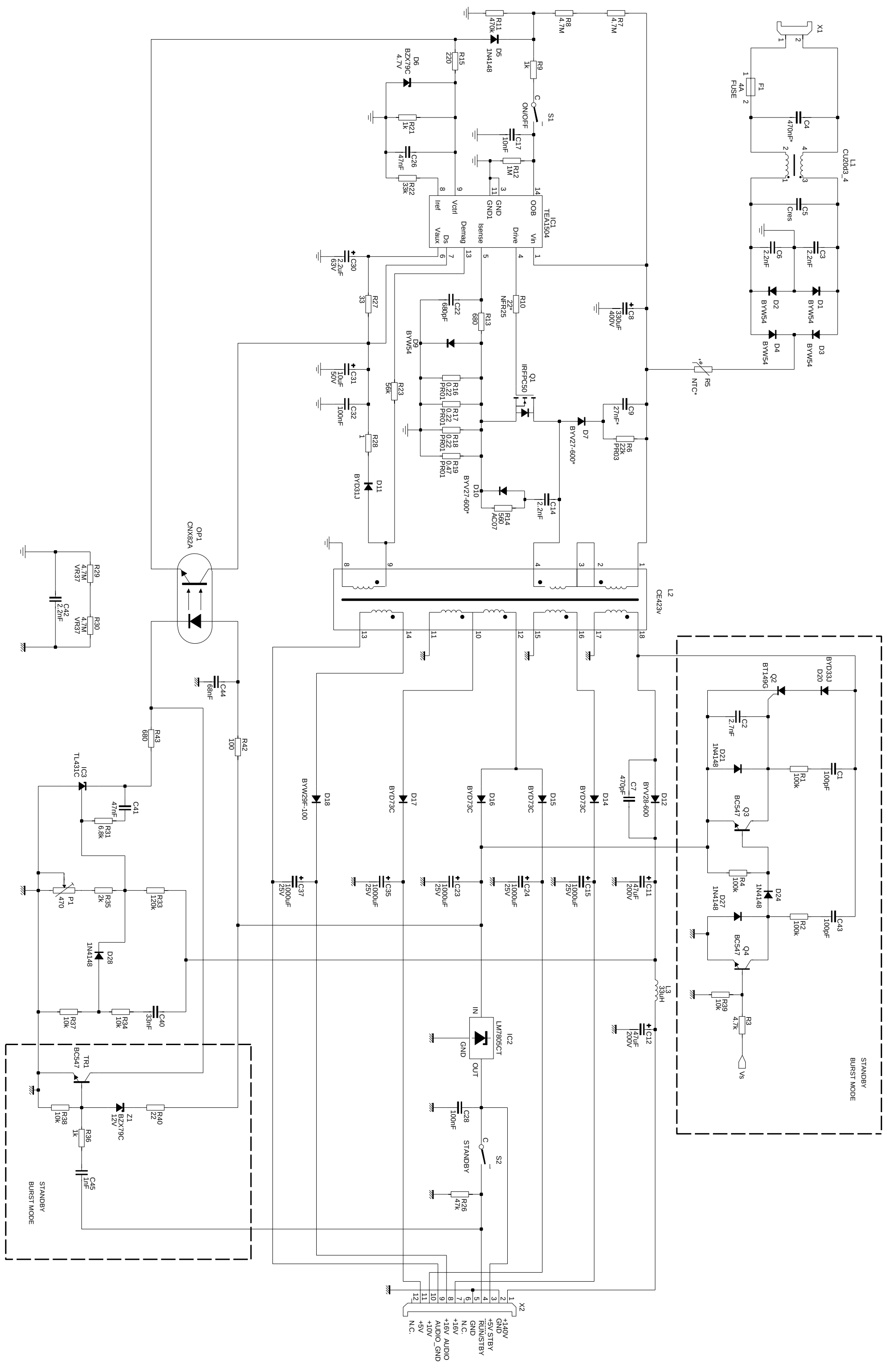


Figure 9 CISPR13/22 measurement (30MHz-1GHz) (V_{line}=230V_{RMS}, R_{OUT1}=220Ω)

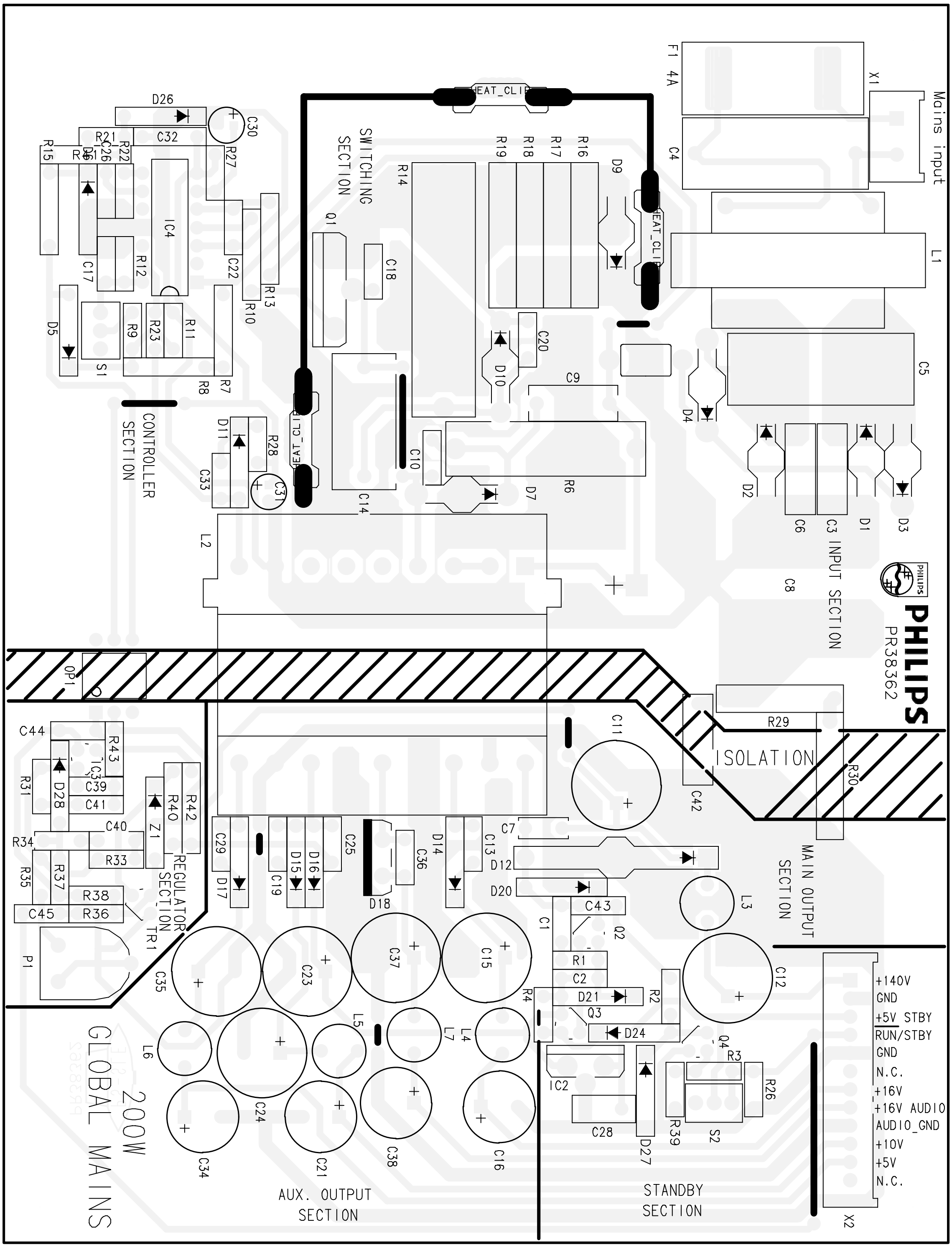
The power supply complies both with CISPR13 and CISPR22. Figure 9 shows a peak at 460MHz due to analogue telephony and at 943MHz due to GSM. Both disturbances are due to the open area test site.

(*C5: 470nF was added, C14: was changed to a 1KV ceramic capacitor (smaller pitch))

6 CIRCUIT DIAGRAM AND PCB LAYOUT



**) V_s is connected to RUN(not)/STBY


Mains input
F1 4A
X1
SWITCHING SECTION
CONTROLLER SECTION
INPUT SECTION
ISOLATION
MAIN OUTPUT SECTION
REGULATOR SECTION
AUX. OUTPUT SECTION
STANDBY SECTION
PHILIPS
PR38362
GLOBAL MAINS
200W
+140V
GND
+5V STBY
RUN/STBY
GND
N.C.
+16V
+16V AUDIO
AUDIO_GND
+10V
+5V
N.C.
X2

7 PARTS LIST

REFERENCE	VALUE	TYPE	PACKAGE	12NC
Resistors				
R1	100K	SFR16		2322 187 …..
R2	100K	SFR16		2322 187 …..
R3	4K7	SFR16		2322 187 …..
R4	100K	SFR16		2322 187 …..
R5	NTC	NTC		
R6	22K	PR03		2322 195 …..
R7	4M7	VR25		2322 241 …..
R8	4M7	VR25		2322 241 …..
R9	1K	SFR16		2322 187 …..
R10	22	NFR25		2322 205 …..
R11	470K	SFR16		2322 187 …..
R12	1M	SFR16		2322 187 …..
R13	680E	SFR16		2322 187 …..
R14	560E	AC07		2322 329 07…
R15	220E	SFR16		2322 187 …..
R16	0E22	PR01 (low mounted)		available on request
R17	0E22	PR01 (low mounted)		available on request
R18	0E22	PR01 (low mounted)		available on request
R19	0E47	PR01 (low mounted)		available on request
R21	1K	SFR16		2322 187 …..
R22	33K	SFR16		2322 187 …..
R23	56K	SFR16		2322 187 …..
R26	47K	SFR16		2322 187 …..
R27	33E	SFR16		2322 187 …..
R28	1E	SFR16		2322 187 …..
R29	4M7	VR25		2322 241 …..
R30	4M7	VR25		2322 241 …..
R31	6K8	SFR16		2322 187 …..
R33	120K	SFR16		2322 187 …..
R34	10K	SFR16		2322 187 …..

REFERENCE	VALUE	TYPE	PACKAGE	12NC
R35	2K	SFR16		2322 187 …..
R36	1K	SFR16		2322 187 …..
R37	10K	SFR16		2322 187 …..
R38	10K	SFR16		2322 187 …..
R39	10K	SFR16		2322 187 …..
R40	22E	SFR16		2322 187 …..
R42	100E	SFR16		2322 187 …..
R43	680E	SFR16		2322 187 …..
P1	470E	OMP10H		2322 482 …..
Capacitors				
C1	100P	CLASS 1, 500V		2222 65. …..
C2	2N2	CLASS 2, 50V		2222 225 20222
C3	2N2	MKP 336 1 (X1)		2222 336 1....
C4	470N	MKP 336 2 (X2)		2222 336 2….
C5	res			
C6	2N2	MKP 336 1 (X1)		2222 336 1....
C7	470P	CLASS 2E2 (X5U)		2222 695 09222
C8	330µ (400V)	PSM-SI 057		2222 057 46331
C9	27N (250V)	MKP 379/380		2222 380 45273
C11	47µ (200V)	RLH 151		2222 151 …..
C12	47µ (200V)	RLH 151		2222 151 …..
C14	2N2	CLASS 2E2 (X5U)		2222 695 09222
C15	1000µ (25V)	RSM 037		2222 037 …..
C17	10N	CLASS 2, 50V		2222 225 20103
C22	680P	CLASS 2, 50V		2222 225 20681
C23	1000µ (25V)	RSM 037		2222 037 …..
C24	1000µ (25V)	RSM 037		2222 037 …..
C26	47N	CLASS 2, 50V		2222 225 20473
C28	100N	MKT 370, 63V		2222 370 …..
C30	2µ2 (25V)	RSM 037		2222 037 …..

REFERENCE	VALUE	TYPE	PACKAGE	12NC
C31	10µ (25V)	RSM 037		2222 037 …..
C32	100N	MKT 370, 63V		2222 370 …..
C35	1000µ (25V)	RSM 037		2222 037 …..
C37	1000µ (25V)	RSM 037		2222 037 …..
C40	33N	MKT 370, 250V		2222 370 …..
C41	47N	CLASS 2, 50V		2222 225 20473
C42	2N2	MKP 336 6 (Y2)		2222 336 6....
C43	100P	CLASS 1, 500V		2222 65. …..
C44	68N	CLASS 2, 50V		2222 225 40683
C45	1N	CLASS 2, 50V		2222 225 20102
Diodes				
D1	BYW54	control. avalanche	SOD57	9333 636 10153
D2	BYW54	control. avalanche	SOD57	9333 636 10153
D3	BYW54	control. avalanche	SOD57	9333 636 10153
D4	BYW54	control. avalanche	SOD57	9333 636 10153
D5	1N4148	general purpose	DO35	9330 839 90153
D6	BZX79C4V7	zener diode	DO35	9331 177 10153
D7	BYV27-600	ultra fast	SOD57	9340 418 70113
D9	BYW54	control. avalanche	SOD57	9333 636 10153
D10	BYV27-600	ultra fast	SOD57	9340 418 70113
D11	BYD31D	fast soft recovery	SOD91	9337 234 …..
D12	BYV28-600	ultra fast	SOD57	9340 418 60113
D14	BYD73D	ultra fast	SOD81	9337 537 60153
D15	BYD73C	ultra fast	SOD81	9337 537 60153
D16	BYD73C	ultra fast	SOD81	9337 537 60153
D17	BYD73C	ultra fast	SOD81	9337 537 60153
D18	BYW29F-100	ultra fast	SOD100	
D20	BYD33J	fast soft recovery	SOD81	9337 234 20153
D21	1N4148	general purpose	DO35	9330 839 90153
D24	1N4148	general purpose	DO35	9330 839 90153
D27	1N4148	general purpose	DO35	9330 839 90153
D28	1N4148	general purpose	DO35	9330 839 90153
Z1	BZX79C12V	zener diode	DO35	9331 177 …..

REFERENCE	VALUE	TYPE	PACKAGE	12NC
Transistors				
Q1	MOSFET (600V/0.5Ω)	MOSFET	SOT93	
Q2	BT149G	thyristor	TO92	9339 984 40112
Q3	BC547	transistor	TO92	9331 976 10112
Q4	BC547	transistor	TO92	9331 976 10112
TR1	BC547	transistor	TO92	9331 976 10112
IC's				
IC1	TEA1504	controller	DIL14	
IC2	µA7805	voltage stabilizer	TO220	
IC3	TL431	voltage regulator	TO92	
OP1	CNX82A	optocoupler	DIL6 wide	
Inductors				
L1	CU20d3/4	common mode filter	U20	3112 338 32441
L3	33µ	TSL0709		
Transformer				
L2	N2-1=12 N3-4=12 N8-9=2 N10-11=1 N10-12=1 N13-14=3 N15-16=3 N17-18=24	All wires: 12*0.2 (Litze) Lp=165µH	CE423v	8222 289 54491
Miscellaneous				
X1	2p	connector (mains)		
X2	12p	connector		
F1	4A slow	fuse		
S1	TL36G3	switch		
S2	TL36G3	switch		
PCB	PR38362	PCB		
Heatsink				