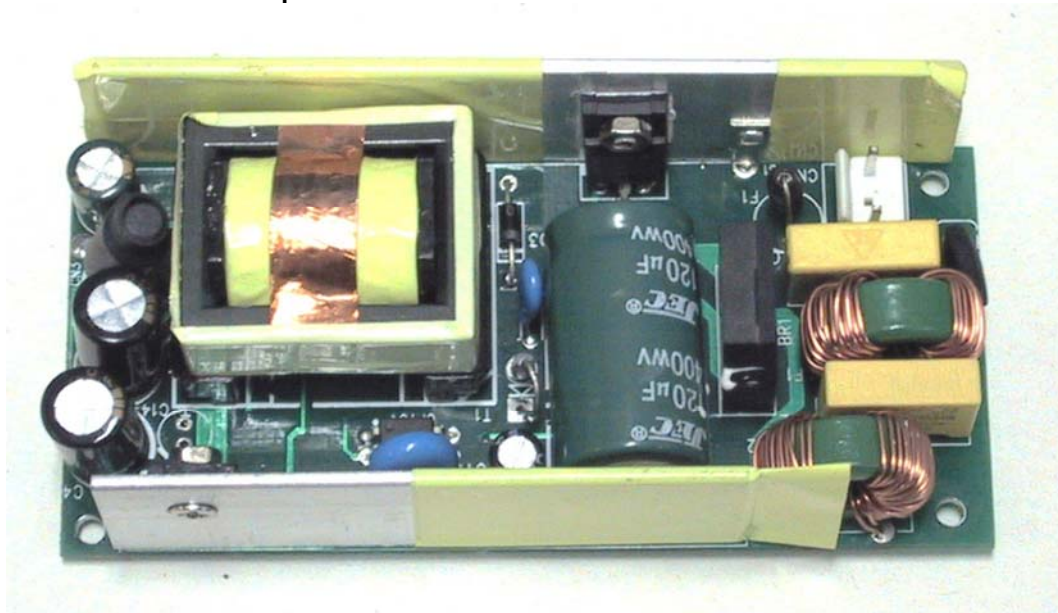

12V-65W WIDE-RANGE INPUT MAINS ADAPTER USING THE L6566B

Introduction

This note describes the characteristics and the features of a 65 W reference board, wide-range input mains, AC-DC adapter using the L6566B controller. The peculiarities of this design are the low standby input consumption ($<200\text{mW}@265\text{V}_{\text{inac}}$), low cost and small size.

Figure 1: EVL6566B-65W Adapter demo-board

Main characteristics and circuit description

- UNIVERSAL INPUT MAINS RANGE: 90÷264Vac - Frequency 45 ÷ 65Hz
- OUTPUT VOLTAGE: 12V@5.42A continuous operation
- MAINS HARMONICS: Acc. to EN61000-3-2 Class-D
- ST-BY MAINS CONSUMPTION: TYP. 0.2 W @265Vac
- OVERALL EFFICIENCY: TYP. 83 % @ 230Vac
- EMI: According to EN55022-Class-B
- SAFETY: According to EN60950
- DIMENSIONS: 51 x 109.5mm - 25mm maximum height
- PCB: Double layer mixed PTH/SMD technology

Circuit description

The topology of this converter is the classical Flyback working in continuous and discontinuous conduction mode at fixed frequency.

The controller, the new L6566B, is an extremely versatile current mode primary controller ICs. The nominal switching frequency, 80 KHz, has been chosen to get a compromise between the transformer size and the converter efficiency. The input EMI filter is a classical Pi-filter, 2-cells for differential and common mode noise filtering. A NTC limits the inrush current produced by the capacitor charging at plug-in. The MOSFET is a standard and inexpensive 600V-0.75Ω_{max}, TO-220FP, needing a heat sink. The transformer is a layer type, using a standard ferrite type EER28L. The reflected voltage is 90 V, providing enough room for the leakage inductance voltage spike with still margin for reliability of the MOSFET. The network D3, R11A, R11B, R11C and C11 clamps the peak of the leakage inductance voltage spike.

At power on, the L6566B has an internal high-voltage current source sourcing a current from the DC bus and charging the capacitors C2 and C3 connected to the V_{cc} pin. Once the turn-on threshold is reached, the HV current source is turned-off. This allows saving power dissipation during normal operation and provides very good circuit efficiency during standby. The divider R4, R10, R45 and R46 senses the input voltage and it is dedicated to the Brownout and Voltage feed-forward pins. The AC_OK pin (#16) is dedicated to the brownout protection. When the voltage on this pin is below the internal threshold (0.45V typ.) the IC is disabled. The VFF pin (pin#15), is dedicated to limit the maximum power deliverable according to the input voltage of the converter.

As previously mentioned, the control system is Current Mode, so the current flowing in the transformer primary winding is sensed by R7B, R7C and R7D then it is fed into the CS (pin #7). For over voltage protection (OVP), the transformer auxiliary winding is connected to ZCD (pin #11) via the R3 and R9 divider. In case of feedback network failures or open loop operation, if the voltage on ZCD pin rises over its threshold the L6566B is latched. After OVP detection and the following latch, the controller operation can be resumed by disconnecting the mains plug.

The switching frequency is programmed by OSC (pin #13) connected to the resistor R18.

Furthermore the L6566B has the Soft Start (pin #14), Disable (pin #8) and 5 Volt Reference voltage VREF (pin #10) available.

The output rectifier is a dual common-cathode Schottky diode, Q201. A snubber, made up of R19A, R19B and C12, damps the oscillation produced by the diode Q201. A small LC filter has been added on the output in order to reduce the high frequency ripple.

The output regulation makes use of a dedicated control IC, the TSM1014, embedding a reference and an error amplifier. The output signal of the error amplifier drives the optocoupler OPTO4 transferring the information to primary side with the required insulation of the secondary side.

Test Results

Efficiency measurements at full load

In table 1 the converter overall efficiency measurement at nominal load (5.42 A) and different input voltage are reported. In table 2 the efficiency measurements according to the Energy Star regulation are taken. The average values at both the nominal input mains voltages are reported too, in bold. In all conditions the efficiency measurements are compliant with the current energy saving rules.

Table 1: Efficiency measurements at full load

V_{in ac}	EFFICIENCY
90 [V]	80.47 %
115 [V]	82.52 % (*)
230 [V]	83.91 % (*)
265 [V]	83.64 %

(*) Compliant to CEC, EU-COC, regulation

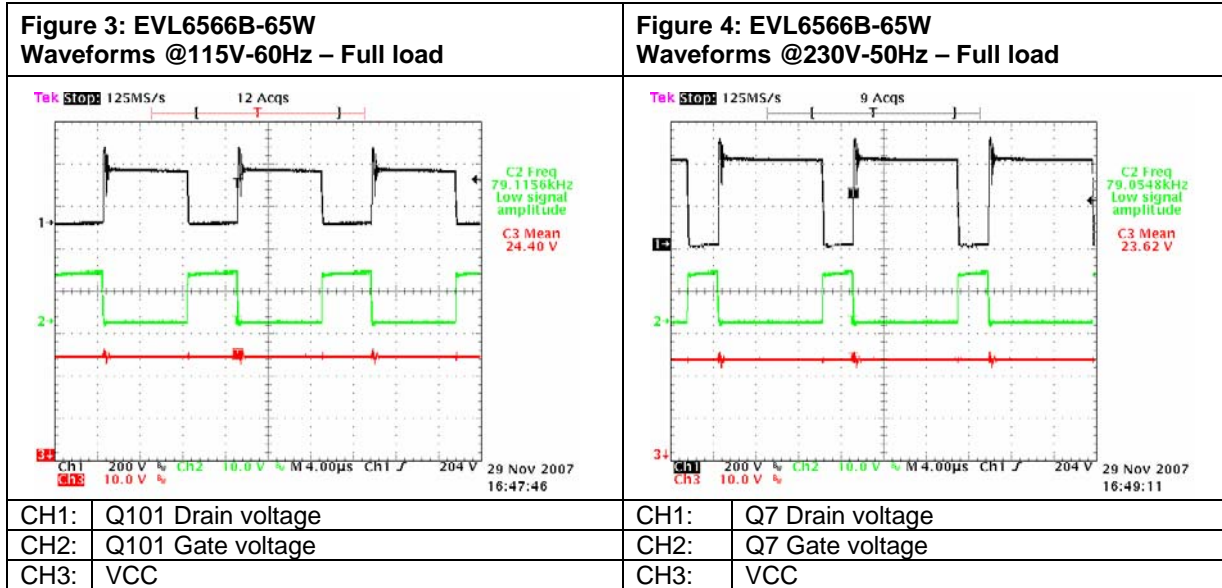
Table 2: Energy star

V_{in ac}	ENERGY STAR EFFICIENCY				Average
	1.35 A (25%)	2.7 A (50%)	4.1 A (75%)	5.42 A (100%)	
115 [V]	84.24%	84.46%	83.53%	82.52%	83.69%
230 [V]	82.77%	83.92%	84.34%	83.91%	83.74%

Functional Check

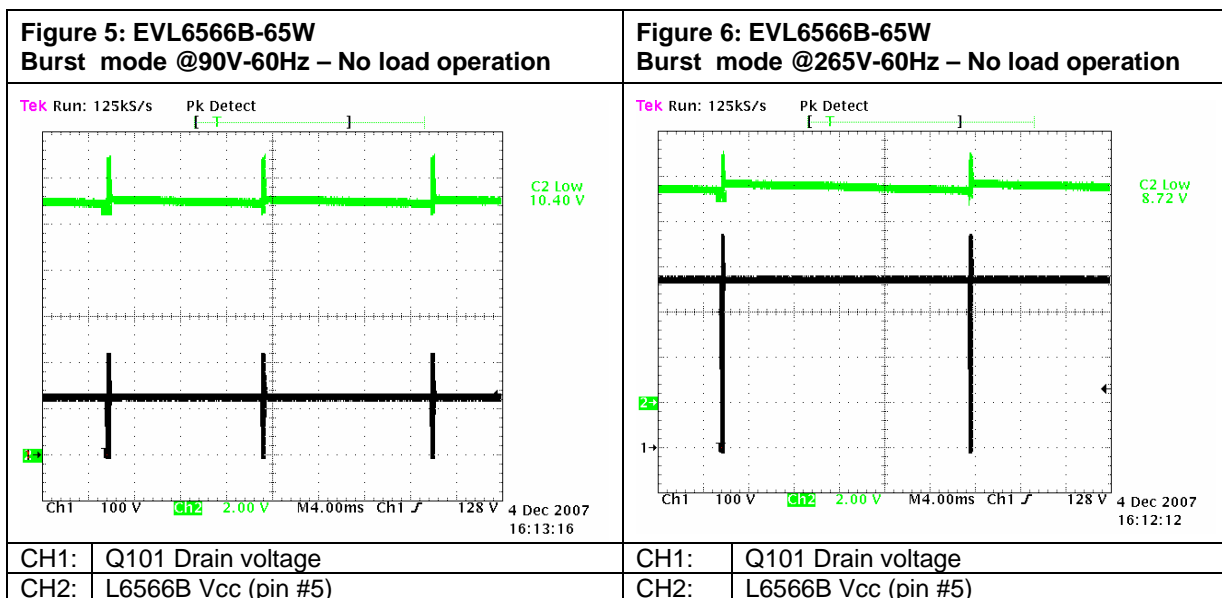
Full load operation

In figure 3 and 4 some waveforms during steady state operation are reported. It is possible also to note which the working switching frequency is 79 kHz.



Stand by and No-load operation

In figures 5 and 6, some waveforms during no-load condition are captured. As visible, the L6566B works in burst mode achieving the best efficiency. In the pictures even the Vcc value is captured. It is shown that even in worst condition, at maximum input voltage (265Vac), the L6566B is powered correctly with good margin with respect to its maximum turn-off threshold (8 V). This prevents from spurious turn off that could affect the output voltage stability.



APPLICATION NOTE

In Table 3, the input power consumption at no load is reported: as visible, thanks to the L6566B stand-by functions, the input power remains always below 200mW.

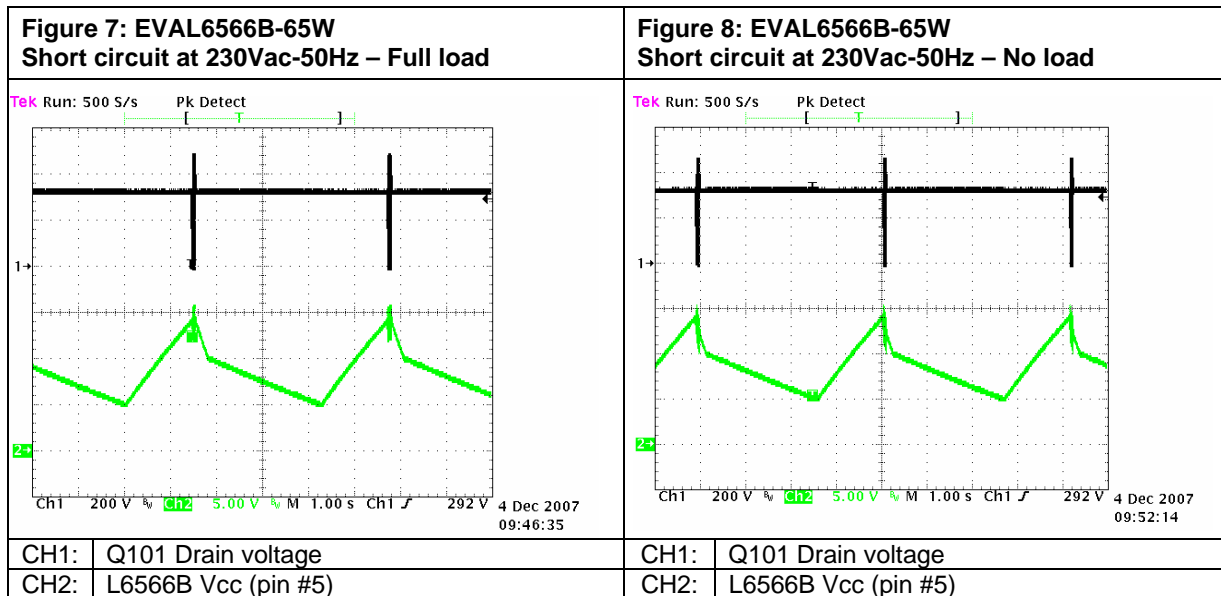
Table 3: Input power at no load vs. mains voltage

<i>Vin</i> [Vrms]	<i>Input power</i> [W]
90	0.066
115	0.077 (*)
230	0.162 (*)
265	0.200

(*) Compliant to CEC, EU-COC, Energy Star

Over Current and Short Circuit Protection (OCP)

In figure 7 and 8 it is shown the circuit behaviour in case of an output short circuit: as visible the L6566B stops switching and the Vcc voltage drops till the UVLO threshold. The controller reduces its consumption so increasing the duration of the Off-time and avoiding high dissipation on the secondary side in short conditions. The restart tentative is repeated indefinitely, until the short is removed.

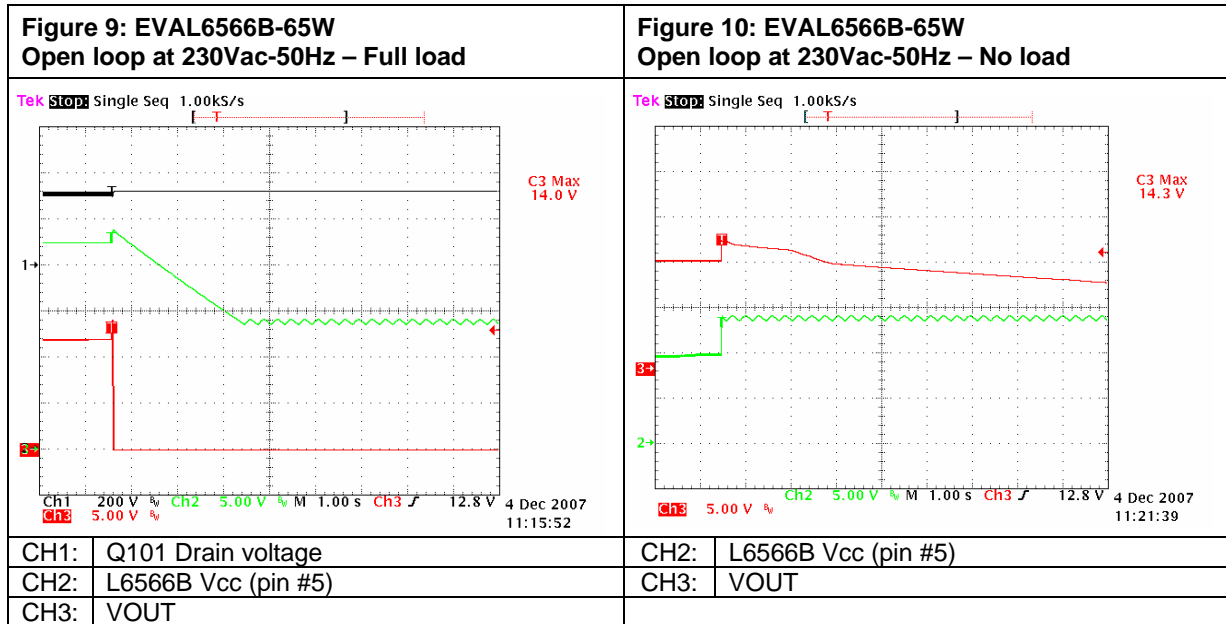


APPLICATION NOTE

Open Loop Protection (OVP)

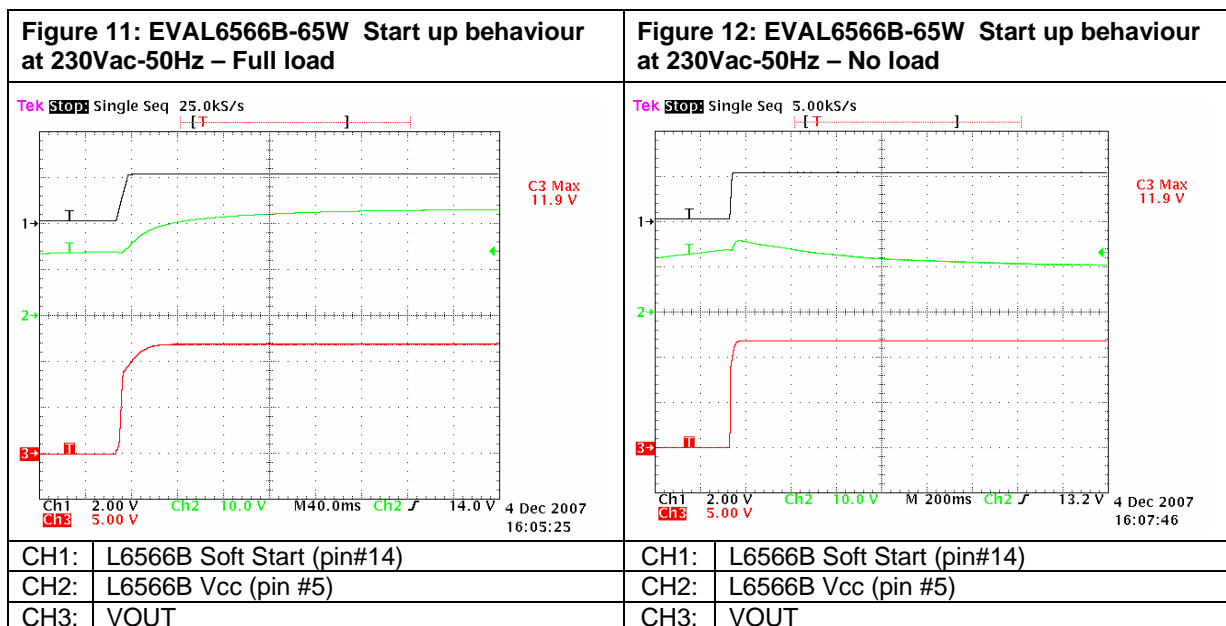
In figure 9 and 10 it is shown the circuit behaviour simulating an open loop condition by opening R17. Once the voltage on ZCD pin connected to the transformer auxiliary winding by a divider rises over its threshold, the L6566B stops switching. To prevent from unlatching the circuit by the Vcc drop, the internal HV current source of the L6566B is periodically reactivated to keep the Vcc voltage above the turn-off threshold. The IC consumption is reduced too. To resume the normal operation the input mains has to be re-cycled.

In pictures 9 and 10 the output voltage during Open loop operation has been captured. As visible comparing the two pictures, thanks to the L6566B internal circuitry, the output voltage value in this condition is almost independent by the load.



Start up behaviour

In the pictures below, the start up behaviour is shown in two different load conditions. The output voltage rising is monotonic and doesn't show any overshoot



APPLICATION NOTE

Bill of material

Table 4: EVAL6566B-65W: Bill of Material

Reference	Part name	Description	
BR1	DB 4A 600V	SINGLE PHASE BRIDGE RECTIFIER	
C2	100uF - 25V	25V - ALUMINIUM ELCAP - 105°C	
C3	100nF	50V CERCAP - GENERAL PURPOSE	0805
C4	470u - 25V	25V - ALUMINIUM ELCAP - 105°C	
C5	470u - 25V	25V - ALUMINIUM ELCAP - 105°C	
C7	470u - 16V	16V - ALUMINIUM ELCAP - 105°C	
C8	2.2nF	50V CERCAP - GENERAL PURPOSE	0805
C9	100nF	50V CERCAP - GENERAL PURPOSE	0805
C10	100nF	50V CERCAP - GENERAL PURPOSE	0805
C11	3nF - 1kV		
C12	470pF	100V CERCAP - GENERAL PURPOSE	1206
C13	0R0	SMD FILM RES - 1/8W - 5% - 250ppm/°C	0805
C16	1nF	50V CERCAP - GENERAL PURPOSE	0805
C18	100nF	50V CERCAP - GENERAL PURPOSE	0805
C19	120u - 400V	400V - ALUMINIUM ELCAP - 85°C	
C214	330nF	50V CERCAP - GENERAL PURPOSE	0805
CN1	CON2-IN	TWO WIRES CONNECTOR	
CX1	100nF	X2 - FLM CAP - 250V	
CX2	100nF	X2 - FLM CAP - 250V	
CY3	3.3nF	Y1 - SAFETY CAP. - 250V	
D1	LL4148	FAST SWITCHING DIODE	SOD-80
D2	STTH108	HIGH VOLTAGE ULTRAFAST RECTIFIER	DO41
D3	STTH108	HIGH VOLTAGE ULTRAFAST RECTIFIER	DO41
D105	LL4148	FAST SWITCHING DIODE	SOD-80
F1	FUSE 2A	FUSE T2A	
HS1	HEAT-SINK	HEAT-SINK	
HS2	HEAT-SINK	HEAT-SINK	
L1	2.2uH	2u2 - RADIAL INDUCTOR - 6A	
LF1	CHOKE-D15x10	INPUT EMI FILTER	
LF2	CHOKE-D15x10	INPUT EMI FILTER	
OPTO4	SFH617A-4_0	OPTOCOUPLER	
Q101	STP10NK60ZFP	N-CHANNEL POWER MOSFET	TO-220FP
Q201	STPS20H100FP	COMMON CATHODE SCHOTKY DIODE	TO-220FP
R1	33R	SMD FILM RES - 1/8W - 5% - 250ppm/°C	0805
R1A	510K	SMD FILM RES - 1/4W - 5% - 250ppm/°C	1206
R1B	510K	SMD FILM RES - 1/4W - 5% - 250ppm/°C	1206
R2	200K	SMD FILM RES - 1/8W - 5% - 250ppm/°C	0805
R3	10K	SMD FILM RES - 1/8W - 5% - 250ppm/°C	0805
R4	12K	SMD FILM RES - 1/8W - 5% - 250ppm/°C	0805
R6	100K	SMD FILM RES - 1/8W - 5% - 250ppm/°C	0805
R7	15K	SMD FILM RES - 1/8W - 5% - 250ppm/°C	0805
R7B	1R2	SMD FILM RES - 1/4W - 1% - 100ppm/°C	1206
R7C	1R2	SMD FILM RES - 1/4W - 1% - 100ppm/°C	1206
R7D	1R2	SMD FILM RES - 1/4W - 1% - 100ppm/°C	1206
R8	470R	SMD FILM RES - 1/8W - 5% - 250ppm/°C	0805
R9	36K	SMD FILM RES - 1/8W - 5% - 250ppm/°C	0805
R10	62K	SMD FILM RES - 1/8W - 5% - 250ppm/°C	0805

APPLICATION NOTE

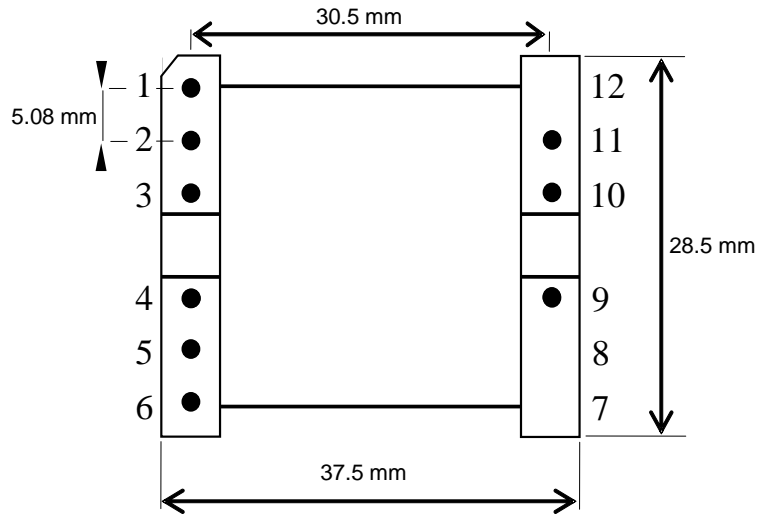
R11A	300K	SMD FILM RES - 1/4W - 5% - 250ppm/°C	1206
R11B	300K	SMD FILM RES - 1/4W - 5% - 250ppm/°C	1206
R11C	300K	SMD FILM RES - 1/4W - 5% - 250ppm/°C	1206
R14	10R	SMD FILM RES - 1/8W - 5% - 250ppm/°C	0805
R15	12K	SMD FILM RES - 1/8W - 5% - 250ppm/°C	0805
R17	23K4	SMD FILM RES - 1/8W - 1% - 100ppm/°C	0805
R18	27K	SMD FILM RES - 1/8W - 1% - 100ppm/°C	0805
R19	6K2	SMD FILM RES - 1/8W - 5% - 250ppm/°C	0805
R19A	100R	SMD FILM RES - 1/4W - 5% - 250ppm/°C	1206
R19B	100R	SMD FILM RES - 1/4W - 5% - 250ppm/°C	1206
R22	2K7	SMD FILM RES - 1/8W - 1% - 100ppm/°C	0805
R23	22K	SMD FILM RES - 1/8W - 5% - 250ppm/°C	0805
R45	3M	SMD FILM RES - 1/4W - 5% - 250ppm/°C	1206
R46	3M	SMD FILM RES - 1/4W - 5% - 250ppm/°C	1206
T1	ERL28-12PIN	POWER TRANSFORMER	
TH1	NTC 10R	NTC RESISTOR	
U1	TSM1014AIDT	LOW CONSUMPTION CC/CV CONTROLLER	MINI SO-8
U5	L6566B	ADVANCED PWM CONTROLLER	SO-16
U4	TS2431ILT	VOLTAGE REFERENCE	SOT-23

APPLICATION NOTE

TRANSFORMER specification

PIN DISTANCE: 5.08 mm
PIN ROW DISTANCE: 30.5 mm
PINS #7, 8, 12 are removed – Pin 3, 9 are for insertion polarity key.

MECHANICAL ASPECT AND PIN NUMBERING



TOP VIEW

Transformer specification

General description and characteristics

- APPLICATION TYPE: **Consumer, Home Appliance**
- TRANSFORMER TYPE: **Open**
- WINDING TYPE: **Layer**
- COIL FORMER: **Horizontal type, 6+6 pins**

- MAX. TEMP. RISE: **45 °C**
- MAX. OPERATING AMBIENT TEMP.: **60 °C**

Electrical characteristics

- CONVERTER TOPOLOGY: **Flyback, CCM/DCM Mode**
- CORE TYPE: **EER28L – PC40**

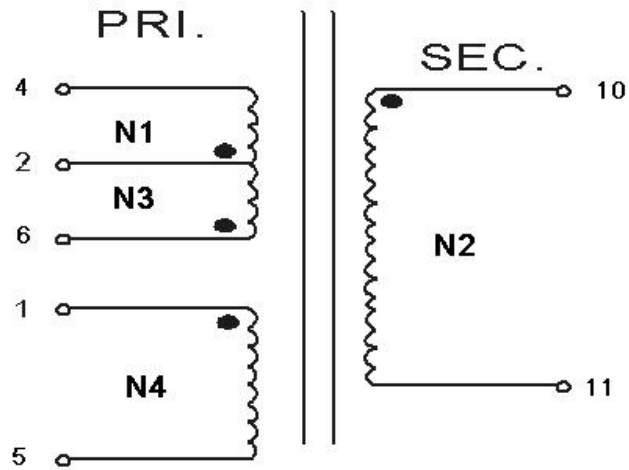
- MIN. OPERATING FREQUENCY: **-**
- TYPICAL OPERATING FREQ: **80 KHz**
- PRIMARY INDUCTANCE: **480 μ H \pm 5% @1KHz – 0.25V** [1]
- LEAKAGE INDUCTANCE: **5.12 μ H @ 100KHz – 0.25V** [1]-[2]

[1]: Measured between pins 4-6

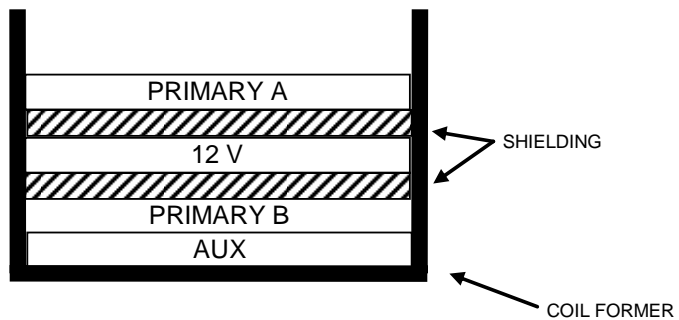
[2]: Measured between pins 4-6 with all secondary windings shorted

APPLICATION NOTE

Electrical diagram and winding characteristics



PINS:	WINDING	NUMBER OF TURNS	WIRE TYPE
6-2	PRIMARY - B	28	G2- 2 x ϕ 0.45 mm
21mm x 0.1mm Copper Shielding connected to pin 5			
10-11	12V	8	G2 - 4 x ϕ 0.4 mm
21mm x 0.1mm Copper Shielding connected to pin 5			
2-4	PRIMARY - A	28	G2 - 2 x ϕ 0.45 mm
1-5	AUX	12	G2 - ϕ 0.3 mm



NOTE: PRIMARIES A & B ARE IN SERIES