Application Note

AN- EVALQRS-ICE2QS02G-80W

80W Evaluation Board with Quasi-Resonant PWM Controller ICE2QS02G

Power Management & Supply

Never stop thinking.

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Title

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1 Content

The demo-board described here is an 80W power supply using quasi-resonant flyback converter topology. The PWM controller **ICE2QS02G** is a second generation quasi-resonant controller IC developed by Infineon Technologies. Its application is mainly focused on power supplies which has auxiliary converter working during standby mode, such as power supplies used in LCD TV, home audio or printer applications. The required VCC voltage for the IC is here drawn from the additional auxiliary power supply. In normal operation, the digital frequency reduction with decreasing load enables a quasi-resonant operation till very low load. As a result, the system efficiency, over the entire load range, is significantly improved compared to conventional free running quasi resonant converter implemented with only maximum switching frequency limitation. In addition, numerous asjustable protection functions have been implemented in **ICE2QS02G** to protect the system and customize the IC for the chosen application. In case of failure modes, like open control-loop/over load, output overvoltage, and transformer short winding, the device switches into **Auto Restart Mode** or **Latch-off Mode**. By means of the cycle-by-cycle peak current limitation plus foldback point correction, the dimension of the transformer and the secondary diode can be lower which leads to more cost effective design.

2 Evaluation Board

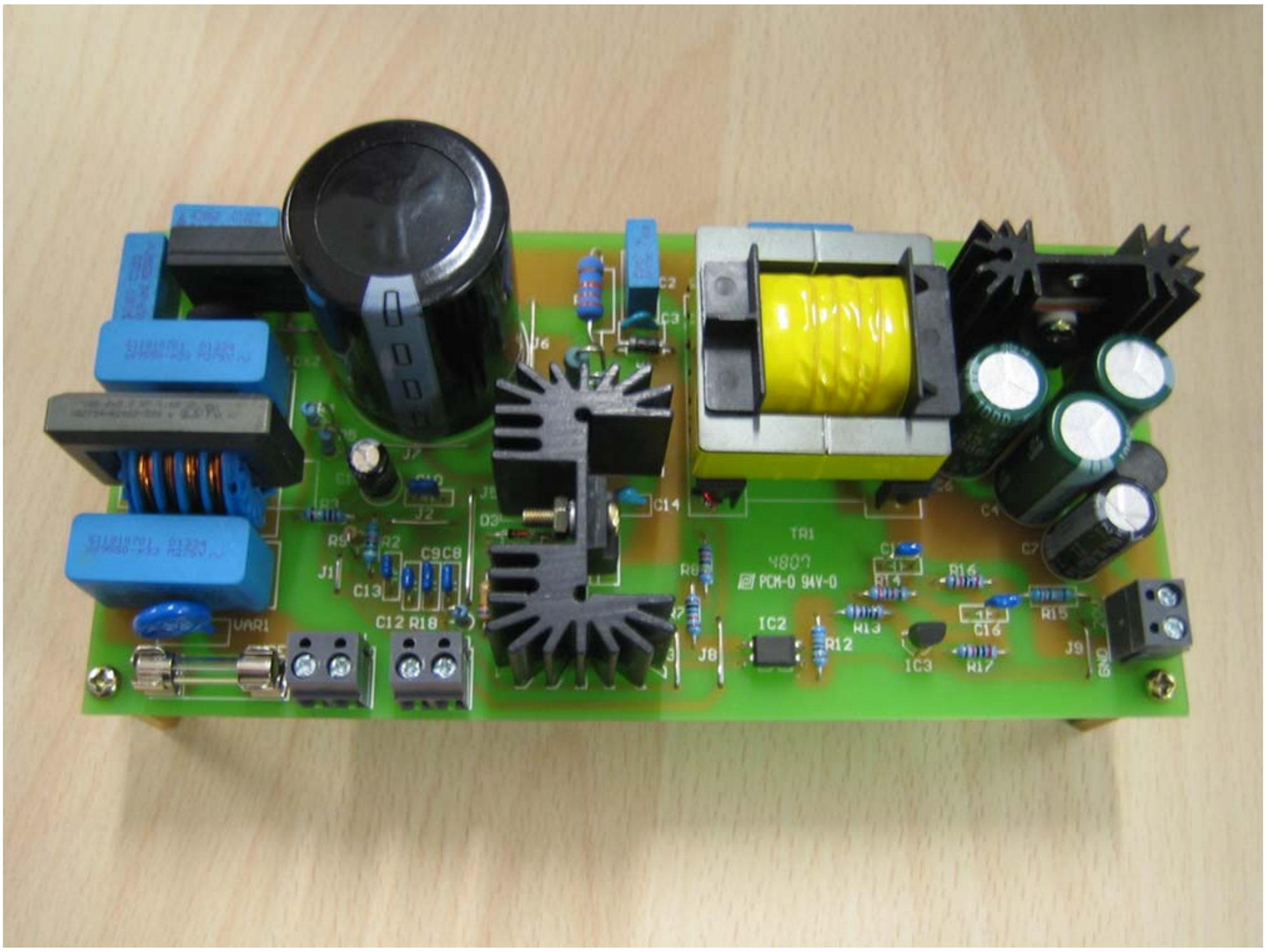

Figure 1-EVALSQ-80W-ICE2QS02G

3 List of Features

Quasi-resonant operation
Digital frequency reduction with decreasing load
Cycle-by-cycle peak current limitation with **foldback point correction**
Built-in **digital soft-start**
Direct current sensing with internal **Leading Edge Blanking Time**
VCC undervoltage protection: **IC stop operation, recover with softstart**
Main undervoltage protection: **Block gate and recover with soft start**
Openloop/Overload protection: **Auto Restart** with adjustable blanking time and adjustable restart time
Output overvoltage protection: **Latch-off with adjustable threshold**
Short-winding protection: **Latch-off**

4 Technical Specifications

Input voltage	**85VAC~265VAC**
Input frequency	**50Hz, 60Hz**
Output voltage and current	**20V 4A**
Output power	**80W**
Efficiency	**>86% at full load**
Minimum switching frequency at full load, minimum input voltage	**65kHz**

5 Circuit Description

5.1 Mains Input and Rectification

The AC line input side comprises the input fuse FUSE1 as overcurrent protection. The X2 Capacitors CX1, CX2 and Choke L1 and Y1 capacitors CY1 and CY2 forms a main filter to minimize the feedback of RFI into the main supply. After the bridge rectifier BR1, together with a smoothing capacitor C1, provide a voltage of 80VDC to 380 VDC depending on mains input voltage. RT1 is placed in series with input to limit the initial peak inrush current whenever the power supply is switched on when C1 is fully discharged.

5.2 PWM Control

The PWM pulse is generated by the 8-pin Quasi Resonant PWM curremt-mode Controller **ICE2QS02G**. It comprises the complete control for quasi-resonant flyback switch mode power supply especially in LCD TV, home audio and Printer applications. The PWM switch-on is determined by the zero-crossing input signal and the value of the up/down counter. The PWM switch-off is determined by the feedback signal V_{FB} and the current sensing signal V_{CS}. **ICE2QS02G** also performs all necessary protection functions in flyback converters. Details about the information mentioned above are illustrated in the product datasheet.

5.3 Snubber Network

A snubber network R1, C2 and D1 dissipate the energy of the leakage Inductance and to suppress ringing on the SMPS transformer.

5.4 Output Stage

On the secondary side, 20V output, the power is coupled out via a dual schottky diode D2. The capacitors C4, C5 and C6 provide energy buffering followed by the L-C filters to reduce the output ripple and prevent interference between SMPS switching frequency and line frequency considerably. Storage capacitors C4, C5 and C6 are designed to have an internal resistance as small as possible (ESR). This is to minimize the output voltage ripple caused by the triangular current.

5.5 Feedback Loop

For feedback, the output is sensed by the voltage divider of R15, R16 and R17 and compared to TL431 internal reference voltage. C15, C16 and R14 comprise the compensation network. The output voltage of TL431 is converted to the current signal via Optocoupler and two resistors R12 and R13 for regulation control.

6 Circuit Operation

6.1 Startup Operation

When VCC reaches the turn on voltage threshold 12V, the IC begins with a soft start which is realized internally with a built-in digital block. The maximum soft start time is 20ms. During this period, feedback voltage will be generated internally, which is 1.8V at the first step and increases step by step with preset voltage at a time interval of 4ms. In such a way, the primary peak current and the gate drive pulse width are both gradually increased during the soft start.

6.2 Normal Mode Operation

The secondary output voltage is built up after startup. The secondary regulation control is adopted with TL431 and optocoupler. The compensation network C15, C16 and R14 constitutes the external circuitry of the error amplifier of TL431. This circuitry allows the feedback to be precisely controlled to dynamically varying load conditions, therefore providing stable control.

6.3 Digital Frequency Reduction

During normal operation, the switching frequency for **ICE2QS02G** is digitally reduced with decreasing load. At light load, the MOSFET will be turned on not at the first minimum drain-source voltage time, but on the n_{th}. The counter is in range of 1 to 7, which depends on feedback voltage in a time-base. The feedback voltage decreases when the output power requirement decreases, and vice versa. Therefore, the counter is set by monitoring voltage V_{FB}. The counter will be increased with low V_{FB} and decreased with high V_{FB}. The thresholds are preset inside the IC.

7 Protection Features

7.1 Vcc under voltage protection

During normal operation, the VCC voltage is continuously monitored. When the Vcc voltage falls below the under voltage lock out level (VCCoff), the IC is off and gate signal is disabled.

7.2 Foldback point protection

For a quasi-resonant flyback converter, the maximum possible output power is increased when a constant current limit value is used for all the mains input voltage range. This is usually not desired as this will increase additional cost on transformer and output diode incase of output over power conditions.

The internal fold back protection is implemented to adjust the V_{CS} voltage limit according to the bus voltage. Here, the input line voltage is sensed using the current flowing out of **ZC** pin, during the MOSFET on-time. As the result, the maximum current limit will be lower at high input voltage and the maximum output power can be well limited versus the input voltage.

7.3 Open loop/over load protection

In case of open control loop, feedback voltage is pulled up with internally block. After an adjustable blanking time, the IC enters **Auto restart mode**. In case of secondary short-circuit or overload, regulation voltage V_{FB} will also be pulled up, same protection will be applied and IC will enters **Auto restart mode.**

The charging time and the discharging time of the capacitor C8, determines respectively the openloop/overload protection blanking time and the restart time of the IC. This allows the system to face a sudden power surge for a short period of time fixed by the charging time of C8 without triggering the overload protection. Once the protection triggered, the IC will restart using the internal soft-start circuit, after a period of time fixed by the discharging time of C8.

7.4 Adjustable output overvoltage protection

During off-time of the power switch, the voltage at the zero-crossing pin ZC is monitored for output overvoltage detection. If the voltage is higher than the preset threshold for a preset period, the IC is latched off.

7.5 Short winding protection

The source current of the MOSFET is sensed via two shunt resistors R11 and R19 in parallel. If the voltage at the current sensing pin is higher than the preset threshold V_{CSSW} of 1.68V during the on-time of the power switch, the IC is latched off. This constitutes a short winding protection. To avoid an accidental latch off, a spike blanking time of 190ns is integrated in the output of internal comparator.

7.6 Mains undervoltage protection

Finally, this IC has an adjustable main undervoltage detection system. Once the Voltage at pin VINS drops below 1.25V, the protection is triggered. For a stable operation, a hysteresis operation is ensured using an internal current source. When the VINS exceeds the hysteresis point, the system resumes its operation with a soft-start.

8 Circuit diagram

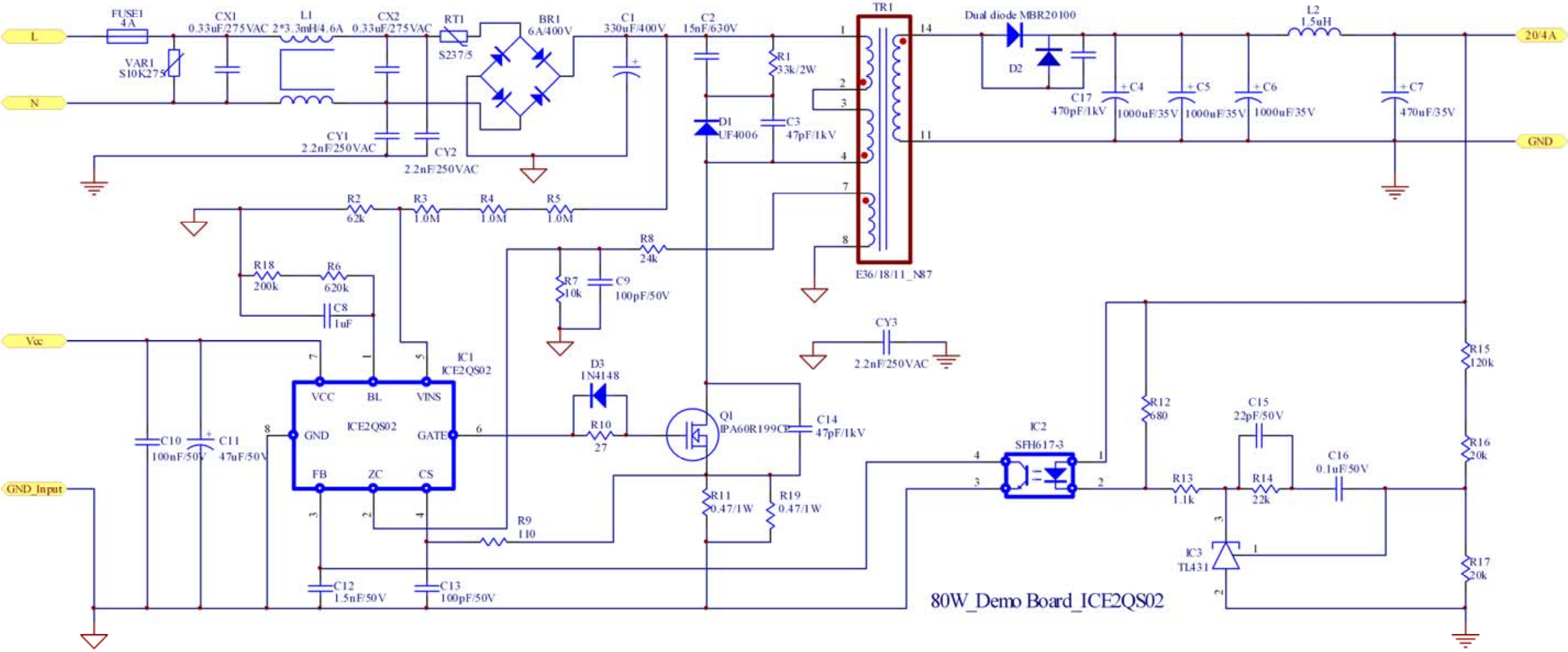

Figure 2 – Schematics

8.1 PCB Topover layer

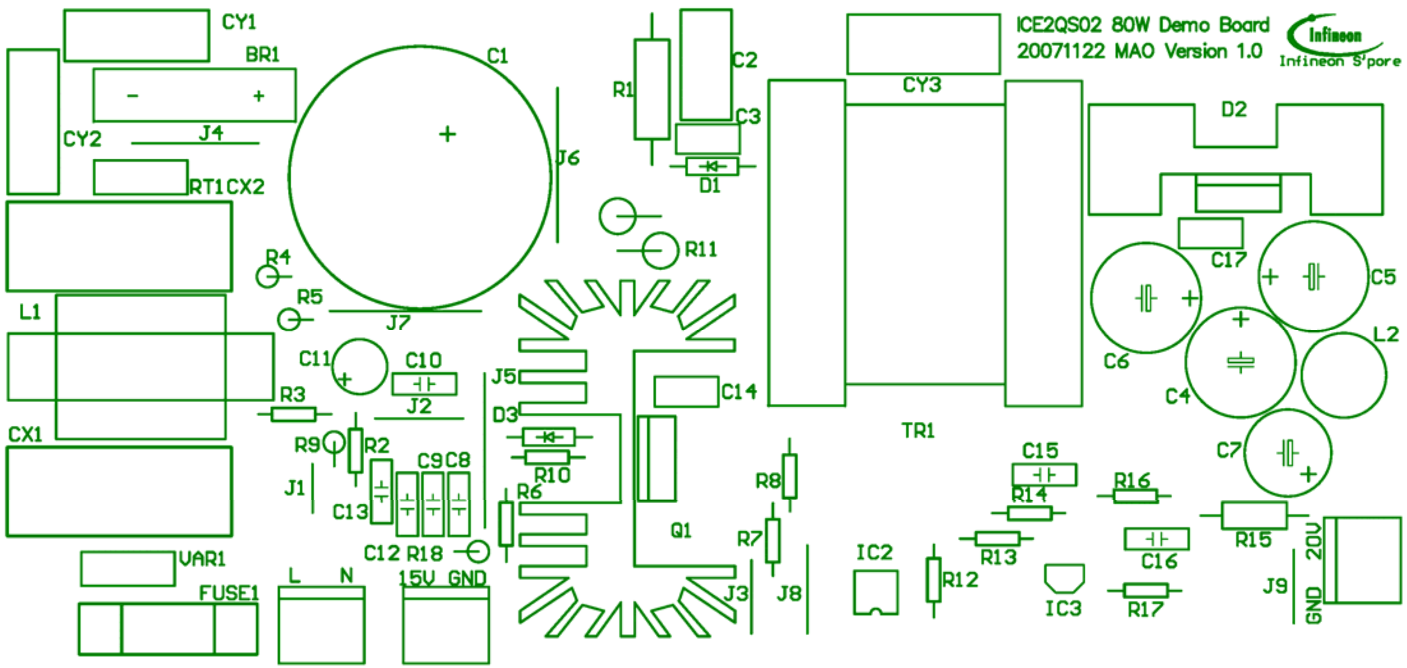

Figure 3 – Component side Component Legend – View from Component Side

8.2 PCB Bottom Layer

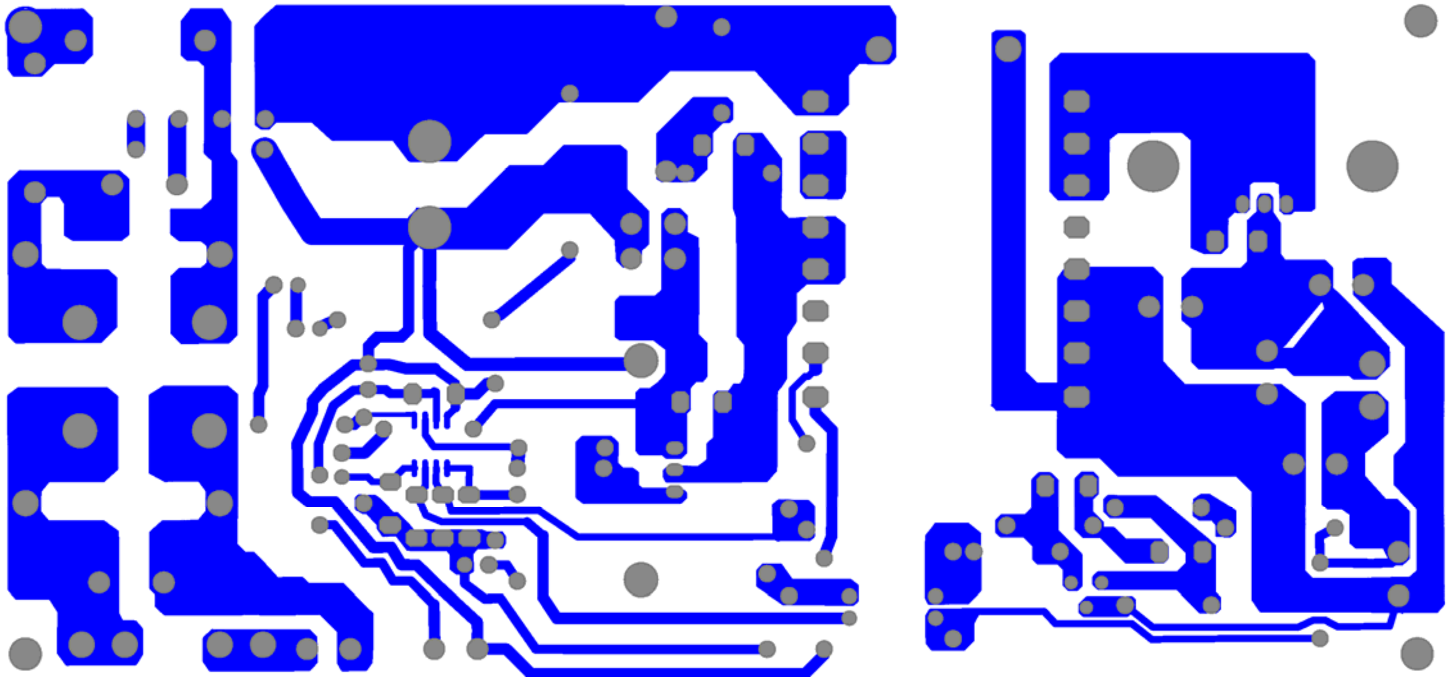

Figure 1 Solder side copper – View from component side

9 Component List

Table 1– Component List

Items	Part	Type	Quantity
1	BR1	KBU6G,4A/400V	1
2	C1	330uF/400V	1
3	C2	15nF/630V	1
4	C3	47pF/1kV	1
5	C4	1000uF/35V	1
6	C5	1000uF/35V	1
7	C6	1000uF/35V	1
8	C7	470uF/35V	1
9	C8	1uF/50V	1
10	C9	100pF/50V	1
11	C10	100nF/50V	1
12	C11	47uF/50V	1
13	C12	1.5nF/50V	1
14	C13	100pF/50V	1
15	C14	47pF/1kV	1
16	C15	22pF/50V	1
17	C16	0.1uF/50V	1
18	C17	470pF/1kV	1
19	CX1	0.33uF/275VAC	1
20	CX2	0.33uF/275VAC	1
21	CY1	2.2nF/250VAC	1
22	CY2	2.2nF/250VAC	1
23	CY3	2.2nF/250VAC	1
24	D1	UF4006	1
25	D2	MBR20100	1
26	D3	IN4148	1
27	FUSE1	4A	1
28	IC1	ICE2QS02	1
29	IC2	SFH617-3	1
30	IC2	TL431	1
31	L1	2*3.3mH/4.6A	1
32	L2	1.5uH	1
33	Q1	IPA60R199CP	1
34	R1	33k/2W	1

35	R2	62k	1
36	R3	1.0M	1
37	R4	1.0M	1
38	R5	1.0M	1
39	R6	620k	1
40	R7	10k	1
41	R8	24k	1
42	R9	110	1
43	R10	27	1
44	R11	0.47/1W	1
45	R12	680	1
46	R13	1.1k	1
47	R14	22k	1
48	R15	120k,1%	1
49	R16	20k, 1%	1
50	R17	20k, 1%	1
51	R18	200k	1
52	R19	0.47/1W	1
53	RT1	S237/5	1
54	VR1	S10K275	1
55	TR1	E36/18/11_N87	1

10 Transformer Construction

Core and material: E 36/18/11, N87
Bobbin: Horizontal Version
Primary Inductance, Lp=220uH, measured between pin 1 and pin 4 (Gapped to Inductance)

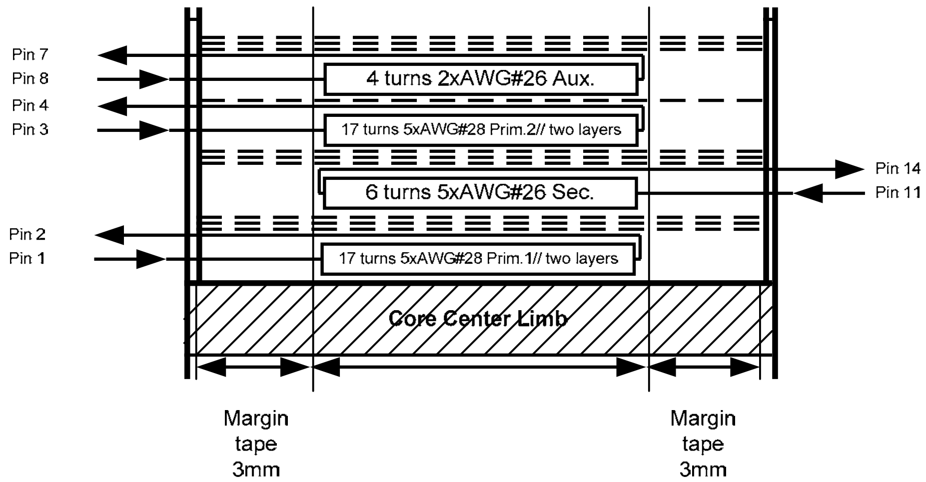

Figure 5 – Transformer structure

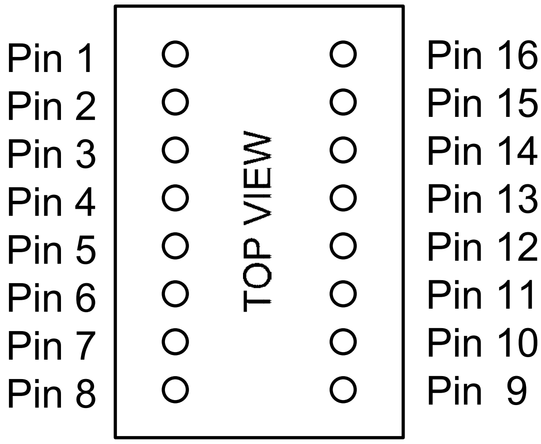

Figure 6 – Transformer complete – top view

11 Test Results

11.1 Efficiency

Table 2 – Load condition

Full load	20V/4A
Med load	20V/2A
Light load	20V/0.4A

Table 3 – Efficiency vs. AC line voltage

Vin(AC)		Pin(W)	Vout(V)	Iout(A)	Pout(W)	Efficiency
85	Full load	92.20	20.01	3.985	79.73	86.48%
	Med load	46.10	20.01	1.993	39.880	86.50%
	Light load	9.40	20.01	0.388	7.764	82.59%
110	Full load	90.32	20.01	3.985	79.740	88.28%
	Med load	44.96	20.01	1.993	39.880	88.70%
	Light load	9.18	20.01	0.390	7.804	85.00%
220	Full load	89.50	19.99	3.985	79.660	89.00%
	Med load	44.88	19.99	1.993	39.840	88.77%
	Light load	9.74	20.01	0.390	7.804	80.12%
265	Full load	90.10	20.00	3.986	79.720	88.47%
	Med load	45.15	20.01	1.993	39.880	88.32%
	Light load	10.13	20.01	0.390	7.804	77.03%

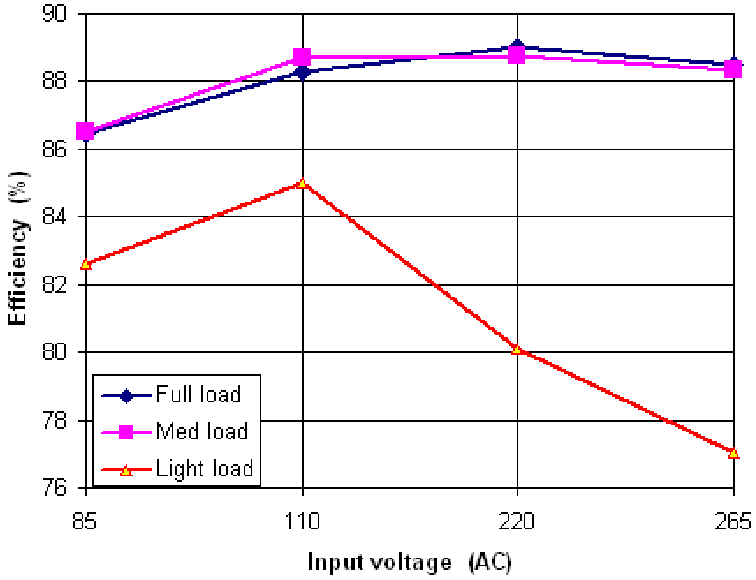

Figure 7 – Efficiency vs. AC line voltage

Table 4 – Efficiency vs. output power at 220Vac line voltage

Pin(W)	Vout(V)	Iout(A)	Pout(W)	Efficiency
9.74	20.01	0.390	7.804	80.12%
18.51	20.00	0.795	15.900	85.89%
27.35	20.01	1.198	23.972	87.64%
35.91	19.99	1.589	31.764	88.45%
44.88	19.99	1.993	39.840	88.77%
53.81	19.99	2.398	47.936	89.08%
62.45	19.99	2.787	55.712	89.21%
71.40	19.98	3.193	63.796	89.35%
80.90	19.99	3.596	71.884	88.85%
89.50	19.99	3.985	79.660	89.00%

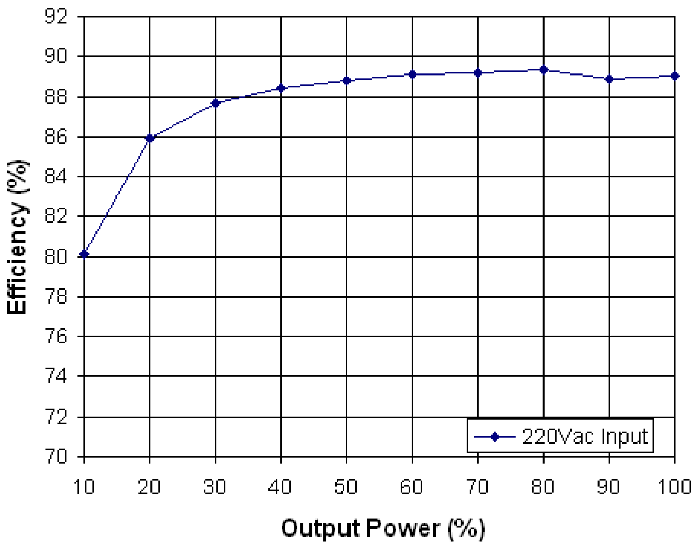

Figure 8 – Efficiency vs. output power at 220Vac line voltage

12 References

[1] ICE2QS01 datasheet, Infineon Technologies AG, 2006

[2] ICE2QS02G datasheet, Infineon Technologies AG, 2008

[3] AN-ICE2QS01, 25W Evaluation Board with Quasi –Resonant PWM Controller ICE2QS01, Infineon Technologies AG, 2006

[4] CoolMOS® IPA60R199CP datasheet Rev 1.3, Infineon Technologies AG, 2007

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