Application Note

EVALQS-190W-ICE2QS02G

190W Evaluation Board Based on Quasi-resonant Flyback Converter for LCD TV SMPS

Power Management & Supply

Never stop thinking.

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ICE2QS02G

Revision History:	**2009-02-02**	V1.1
Previous Version:	1.0	
Page		
9	Update TR200 pin numbers	
11	Update TR300 pin numbers	
17	Update TR300 structure	
18	Update TR200 structure	

190W Evaluation Board for LCDTV SMPS based on Quasi-Resonant PWM Controller ICE2QS02G
License to Infineon Technologies Asia Pacific Pte Ltd AN-PS0034

He Yi
Yi.he@infineon.com

Wang Zan
Zan.wang@infineon.com

Mao Mingping
Mingping.mao@infineon.com

Jeoh Meng Kiat
Mengkiat.Jeoh@infineon.com

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1 Content

This application note describes the performance of a 190W evaluation board, with wide-range AC line voltage input and power-factor-correction pre-regulator (PFC). It has high efficiency at full load range, thanks to the quasi-resonant operation at main converter and very low power consumption during standby mode. This solution is particularly suitable for the power supply used in LCD TVs.

The circuit consists of three main blocks: the first is a front-end PFC pre-regulator based on the **ICE2PCS02** controller, which is designed for CCM boost converter. The MOSFET used in the PFC pre-regulator is **IPA60R199CP** from 500V CoolMOS® CP series; the second stage is the main converter using the quasi-resonant PWM controller **ICE2QS02G**. The MOSFET used in the main converter is **SPA11N80C3** from 800V CoolMOS® C3 series; the third stage is the auxiliary flyback converter based on CoolSET® F3R **ICE3BR4765J**. The picture of the evaluation board is shown in Figure 1.

2 Evaluation Board

Figure 1 Evaluation Board

3 Technical Specifications

Input voltage		**85Vac~265Vac**
Input frequency		**47 – 63 Hz**
Input harmonics		**Compliance with EN61000-3-2**
Normal operation	Main converter output	**24 V / 6 A**
		12 V / 3 A
	Auxiliary converter output	**5 V / 2 A**
Standby operation		**Pin < 1W @ output 5 V / 0.1 A** **Pin < 0.3W @ no load**
Size of the board		**231mm χ 170mm χ 30mm**

4 Circuit Description

The circuit consists of three power stages. A front-end PFC pre-regulator implemented by the controller ICE2PCS02, a quasi-resonant flyback converter based on the controller ICE2QS02G and an auxiliary flyback converter using the CoolSET® F3 ICE3BR4765J.

4.1 Mains Input and Rectification

The AC line input side comprises the input fuse F100 as overcurrent protection. The Chokes L100 and L102, X2-Capacitors CX100, CX101 and CX102 are used as radio interference suppressors. The high frequency current ripple generated by the CCM boost converter is filtered by CX102.

4.2 Power Factor Correction Converter: ICE2PCS02

After the bridge rectifier, there is a boost type PFC converter consisting of L103, Q100, D103 and C106. The CoolMOS® CP IPA60R199CP is used as the power switch Q100. Due to its low Rdson and small output capacitance, a small heat sink can fulfill the dissipation requirement. Output capacitor C106 provides energy buffering to reduce the output voltage ripple.

The input current is sensed by the external shunt resistor R104, R105 and R106. The sense voltage is fed into ICE2PCS02 Pin 3 and compared to the internal voltage level for PWM control.

The PWM control is realized by 8-Pin CCM PFC IC ICE2PCS02. It is a variant design of ICE2PCS01 with preserving most of the features. Unlike the conventional PFC controller, ICE2PCS02 does not need direct sine wave reference signal. The switching frequency is fixed at 65kHz by the IC internal oscillator. There are two control loops in the circuit, voltage loop and current loop. The output voltage is sensed by the voltage divider of R114, R115, R116 and R118 and sent to internal error amplifier. The output of error amplifier is used to control current in the inner current loop. The compensation network C103, C107, R109 constitutes the external circuitry of the error amplifier. This circuitry allows the feedback to be matched to various load conditions, thereby providing stable control. In order not to make the response for 100Hz ripple, the voltage loop compensation is implemented with low bandwidth. The inner loop, current control loop, is implemented with average current mode strategy. The instant current is adjusted to be proportional to both of MOSFET off duty D_{OFF} and the error amplifier output voltage of voltage loop. The current is sensed by shunt resistors R104, R105 and R106 and fed into IC through R111. The current

sense signal is averaged by an internal operating amplifier and then processed in the PWM generator which drives the gate drive. The averaging is realized by charging and discharging an external capacitor C104 at pin ICOMP. The IC supply is provided by external voltage source and filtered and buffered by C100 and C101. The IC output gate driver is a fast totem pole gate drive. It has a built-in cross conduction current protection and a Zener diode to protect the external transistor switch against undesirable over voltages. The gate drive resistor R108 is selected to limit and gate pulse current and drive MOSFET for fast switching. ICE2PCS02 provides the output over-voltage protections to the converter. This is especially needed as the regulation bandwidth of a PFC Boost converter is slow and the converter may exhibit dangerous output voltage overshoots because of abrupt load or input voltage variations.

4.3 Main Converter: Quasi-resonant flyback converter using ICE2QS02G

The Quasi-resonant flyback converter is widely used in switching mode power supplies due to its simple structure, low cost and easy design. Because the MOSFET is turned on at low voltage, the switching loss is greatly reduced. The efficiency of the converter is higher compared to traditional fixed frequency flyback converters. The EMI performance is also improved due to low voltage switching and slower turned-off process. The output power of a quasi-resonant flyback converter can go up to 200W because PFC pre-regulator is used. Therefore, it is a cost-effective solution for LCD TV with screen size less than 37”.

In the demoboard of this note, input voltage of the main converter comes from the output of the PFC converter, which is designed at 390V. The maximum output power of this converter is 180W which has two outputs with 24V/6A and 12V/3A respectively.

The main converter constitutes transformer TR300, switch Q300, resonant capacitor C307, output rectifiers D303, D304 and D305. Capacitors C311, C313 and C314 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.

The snubber network including R301, C304 and D300 dessipates the energy of the leakage inductance and suppresses ringing on the transformer.

The switch Q300 is realized with Infineon 800V CoolMOS® C3 SPA11N80C3. MOSFET current is sensed by the shunt resistors R312 and R313. The sensed voltage is fed into Pin 4 of the controller IC ICE2QS02G for peak current limitation and PWM control.

The power of ICE2QS02G is supplied by auxiliary flyback converter. ICE2QS02G starts operation when the voltage on Vcc pin exceeds 12V and the voltage on Vins pin 5 is higher than 1.25V. The pin 5 is connected to input DC bus through resistors R303, R304, R305, and R306 for mains undervoltage protection.

ICE2QS02G is a current mode controller. With the direct current information input from Pin 4, IC will compare this sensed voltage with a feedback voltage determined by the secondary feedback voltage on Pin 3. A cycle-by-cycle current limitation is therefore achieved on the control of the converter. The maximum current sense voltage on Pin 4 is set to 1V internally. In case the transformer primary winding is short or saturated, the current in MOSFET will rise very fast. Corresondingly, the voltage on Pin 4 will also rise very fast. ICE2QS02G provides short-winding protection which is activated when voltage on Pin 4 is higher than 1.68V for 200ns. IC will pull the gate drive to low immediately. Only recycling of the VCC voltage can release such a protection mode.

The quasi-resonant switching is realized with the help of auxiliary winding and the divider and filter network with R310, R314 and C302. The sensed voltage is fed into Pin 2 of the IC. After the MOSFET is turned off, the voltage on Pin 2 will go to a value proportional to the output voltage. This voltage is also used to compare with an internal threshold, which forms the output overvoltage protection. In case of an output over voltage protection, only recycling of the VCC voltage can let the converter go out from the protection mode.

To achieve good cross regulation, a weighted voltage control is adopted. R321, R322, R325, R320, R323 and R324 form a voltage divider network that senses both the output voltages. Output voltage regulation is controlled through shunt regulator TL431 (IC302) and the optocoupler (IC301) provides electrical isolation between primary and secondary side. Resistor R318 provides bias current required by IC302 and is placed in parallel to IC301 to ensure that the bias current to the IC does not become a part of feed

back current. Resistor R317 sets the overall DC loop gain and limits the current through IC301 during transient conditions. R317, R319, C315 and C318 set the frequency response for the feed back circuit.

In cases of output short circuit, output overload and control open loop, the regulation voltage will go to high (5V). ICE2QS02G provides an over-load protection. If the regulation voltage is higher than 4.5V for longer than over-load blanking time, IC will stop the switch immediately. The Blanking time is set by external resistor R300 and capacitor C303 on pin 1. The IC enters into autorestart mode.

4.4 Auxiliary flyback converter: ICE3BR4765J

The auxiliary flyback converter is implemented with integrated power IC CoolSET® F3 ICE3BR4765J, a fixed frequency current mode PWM controller with integrated MOSFET. The maximum output power of ICE3BR4765J is 18W in case of a wide range AC input (85VAC~265VAC) and open frame working environment.

The auxiliary flyback converter consistutes of transformer TR200, IC ICE3BR4765J and an output stage including D202 as the output rectifier, C208 as the output buffering and L200 and C207 as a filter network. The output of the converter is 5V/2A. The feedback loop includes the TL431 (IC203) and optocoupler SFH617A-3 (IC202).

This auxiliary flyback converter is designed to operate in the whole mains voltage range, even when the PFC stage is not working. The auxiliary winding of transformer TR200 supplies the power to ICE3BR4765J during operation. It is also intended to supply the other controllers including ICE2QS02G and ICE2PCS02.

The PFC converter and the quasi-resonant converter can be switched on and off through the circuit based mainly on components Q201, R211, R212, IC201, R204, R205, R210 and Q200, which, depends on the level of the Power On/Off signal. Every time the AC power supply is applied to the power supply, the auxiliary flyback converter switches on first; then when the PowerOn/Off signal is high, the PFC converter becomes on, and last the quasi-resonant converter can deliver the output power to the load.

If PowerOn/Off signal is pulled to the ground, the PFC and quasi-resonant converter will not be turned on and only 5V supply is available on the output. This is used during standby mode. Thanks to the built-in Active Burst Mode function of ICE3BR4765J, the system's power consumption can be reduced to extremely low level, less than 1W @ 0.5W load and 265VAC input.

5 Circuit Diagram

5.1 Schematics

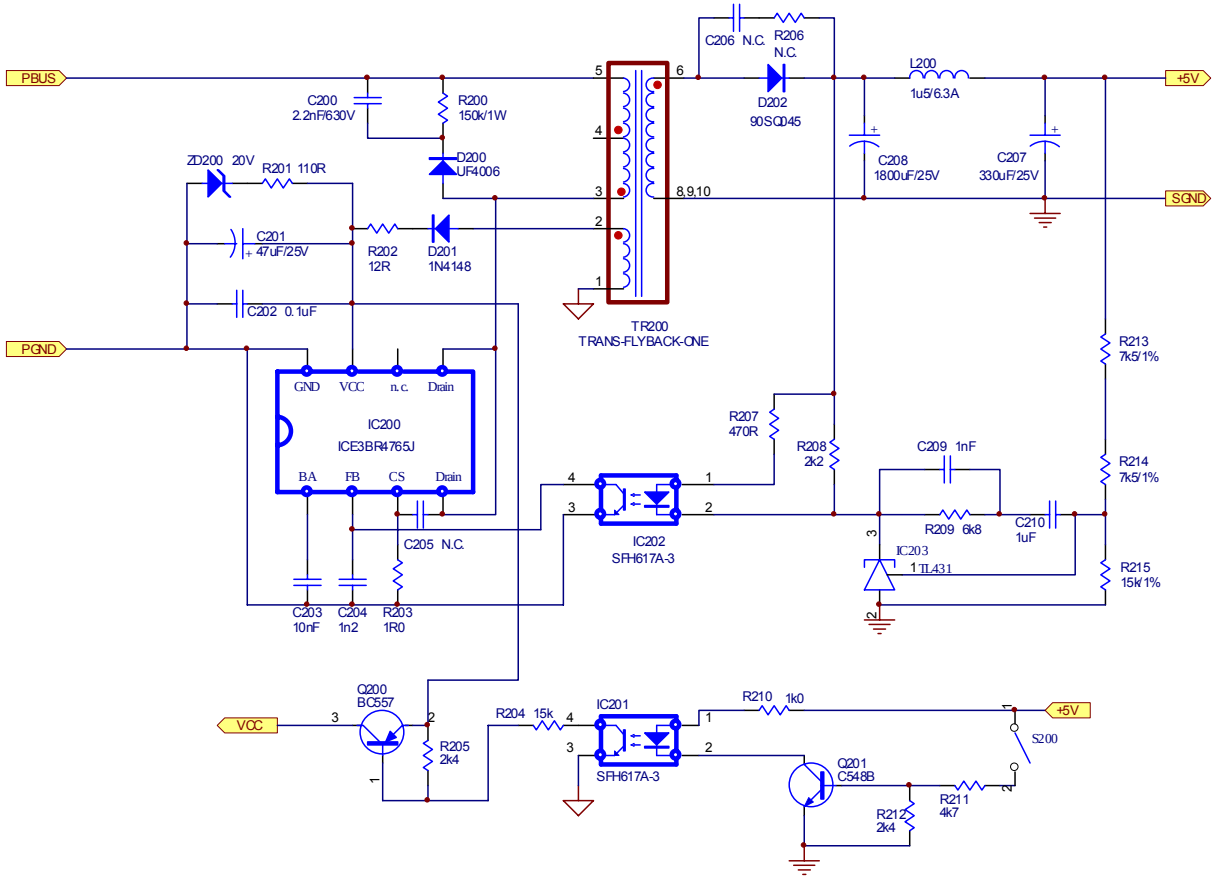


Figure 2 schematic of standby power supply

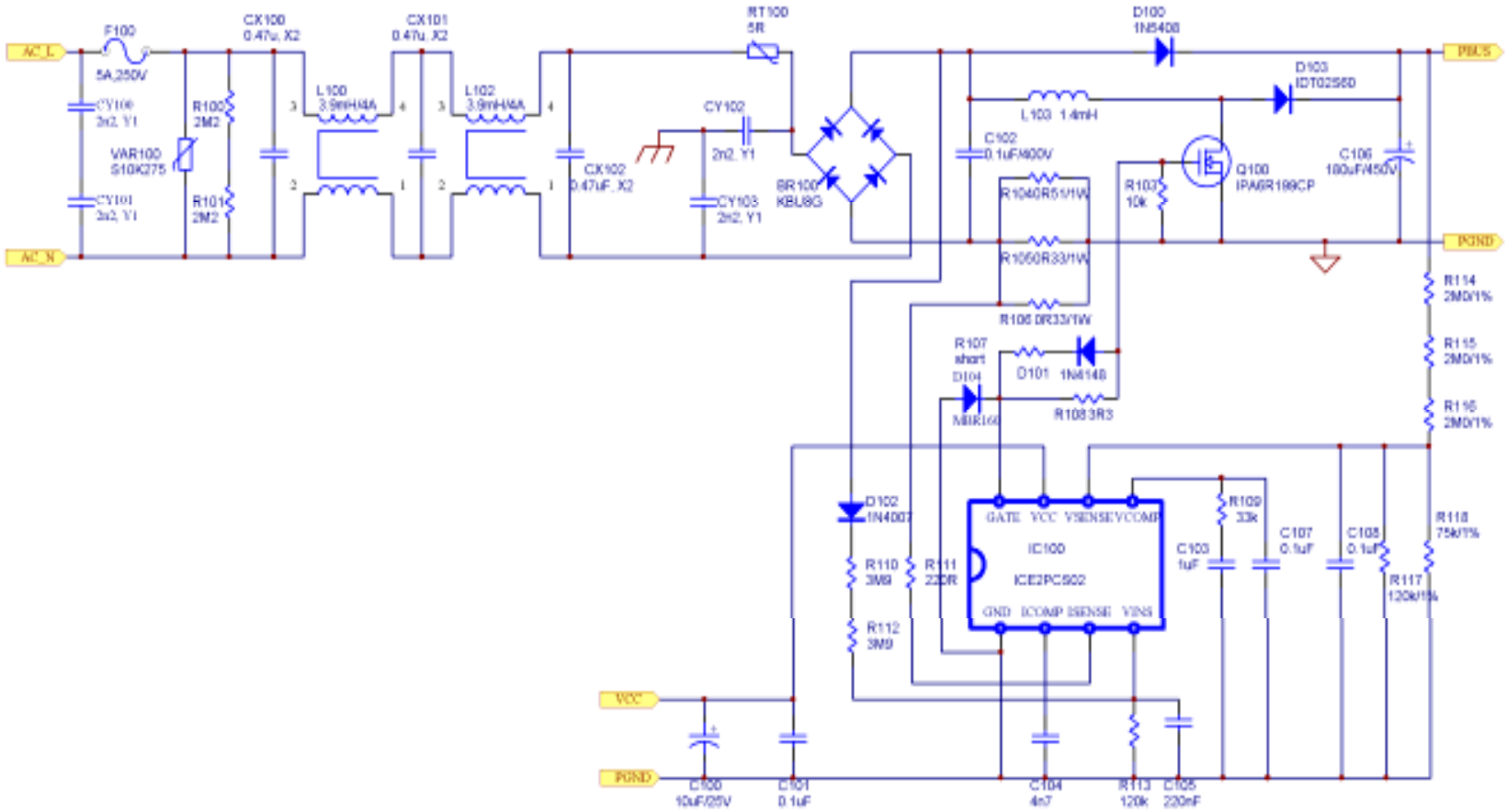


Figure 3 Schematic of AC input and PFC circuit

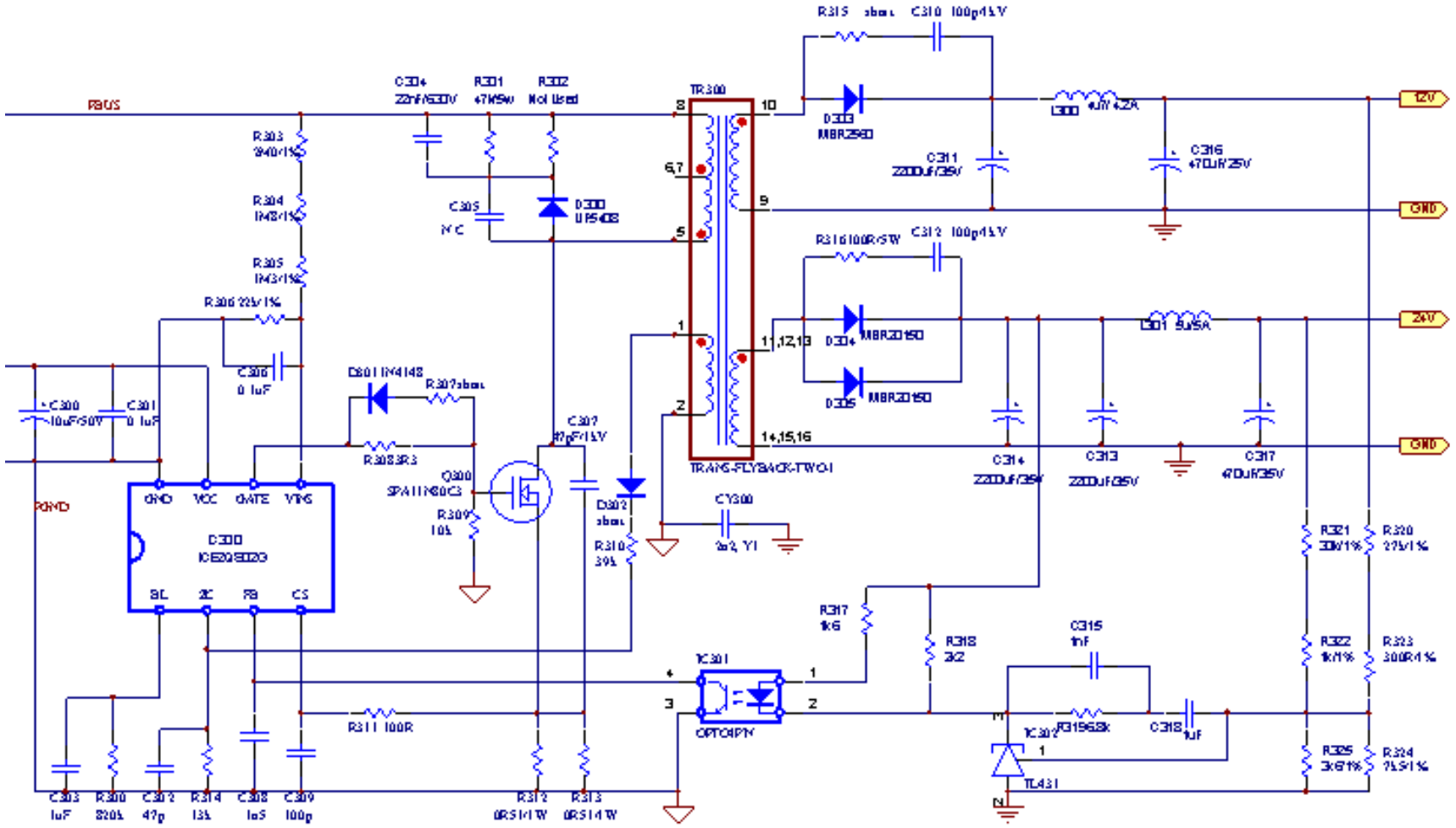


Figure 4 Schematic of mains output

5.2 PCB Topover Layer

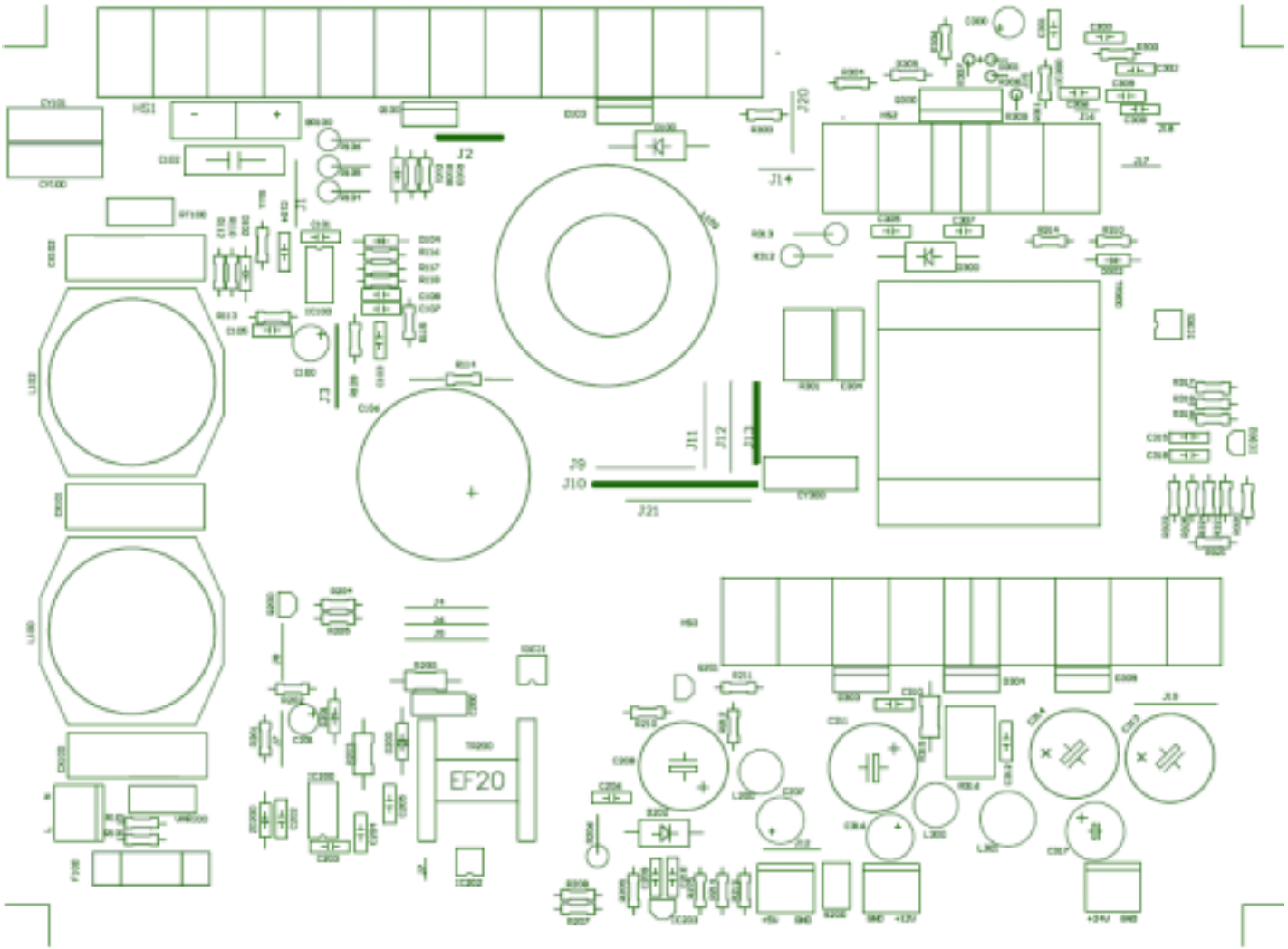


Figure 5 Component side Component Legend – View from Component Side

5.3 PCB Bottom Layer

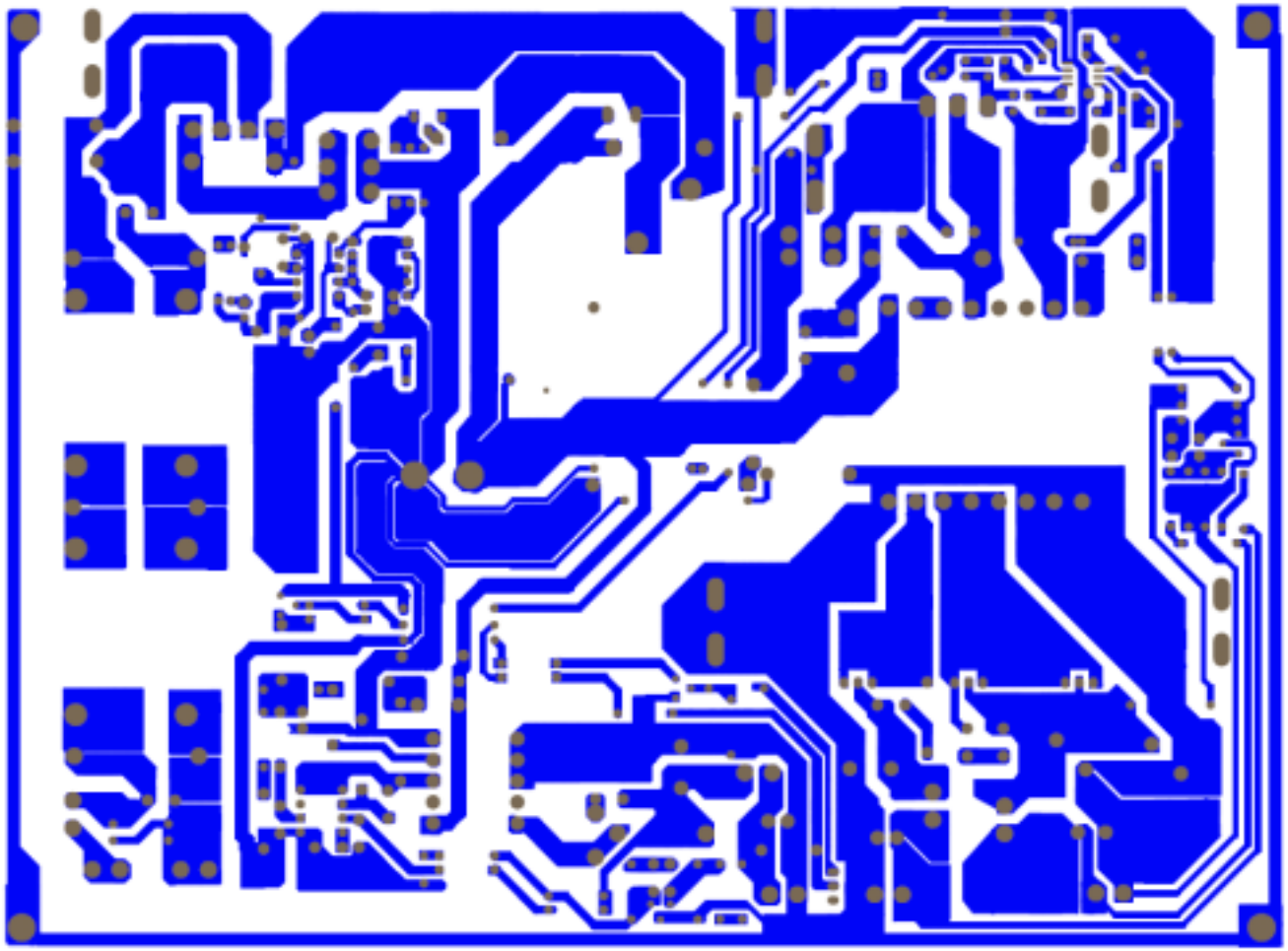


Figure 6 Solder side copper – View from component side

6 Component List

Table 1 Bill of Materials

Items	Part/Value	Description	Supplier
C108	0.1uF	CERAMIC CAP	
C101	0.1uF	CERAMIC CAP	
C107	0.1uF	CERAMIC CAP	
C102	0.1uF/400V	CERAMIC CAP	
CX100	0.47u, X2	CERAMIC CAP	EPCOS
CX101	0.47u, X2	CERAMIC CAP	EPCOS
CX102	0.47uF, X2	CERAMIC CAP	EPCOS
R105	0R33/1W	RESISTOR	
R106	0R33/1W	RESISTOR	
R104	0R51/1W	RESISTOR	
L103	1.4mH	CHOKE	
D102	1N4007	DIODE	
D101	1N4148	DIODE	
D100	1N5408	DIODE	
C103	1uF	CERAMIC	
R116	2M0/1%	RESISTOR	
R115	2M0/1%	RESISTOR	
R114	2M0/1%	RESISTOR	
R101	2M2	RESISTOR	
R100	2M2	RESISTOR	
CY101	2n2, Y1	MKG 250Vac	EPCOS
CY100	2n2, Y1	MKG 250Vac	EPCOS
L100	3.9mH/4A	COMMON MODE CHOKE	EPCOS
L102	3.9mH/4A	COMMON MODE CHOKE	EPCOS
R110	3M9	RESISTOR	
R112	3M9	RESISTOR	
R108	3R3	RESISTOR	
C104	4n7	CERAMIC	
F100	5A,250V	FUSE	
RT100	5R	NTC THERMISTOR	
R103	10k	RESISTOR	
C100	10uF/25V	Aluminum Electrolyte	
R109	33k	RESISTOR	
R118	75k/1%	RESISTOR	
R113	120k	RESISTOR	
R117	120k/1%	RESISTOR	
C106	180uF/450V	Aluminum Electrolyte	
R111	220R	RESISTOR	
C105	220nF	CERAMIC	
IC100	ICE2PCS02	Quasi-Resonant PWM Controller	INFINEON
D103	IDT02S60	DIODE	INFINEON
Q100	IPA60R199CP	MOSFET	INFINEON
BR100	KBU8G	BRIDGE RECTIFIER	
D104	MBR160	DIODE	

VAR100	S10K275		
R107	short	RESISTOR	
C202	0.1uF	CERAMIC	
D201	1N4148	DIODE	
R203	1R0	RESISTOR	
R210	1k0	RESISTOR	
C204	1n2	CERAMIC CAP	
C209	1nF	CERAMIC CAP	
L200	1u5/6.3A	CHOKE	
C210	1uF	CERAMIC CAP	
C200	2.2nF/630V	Capacitor	
R208	2k2	RESISTOR	
R212	2k4	RESISTOR	
R205	2k4	RESISTOR	
R211	4k7	RESISTOR	
R209	6k8	RESISTOR	
R213	7k5/1%	RESISTOR	
R214	7k5/1%	RESISTOR	
C203	10nF	CERAMIC	
R202	12R	RESISTOR	
R204	15k	RESISTOR	
R215	15k/1%	RESISTOR	
ZD200	20V	Zener Diode	
C201	47uF/25V	Aluminum Electrolyte	
D202	90SQ045	DIODE	
R201	110R	RESISTOR	
R200	150k/1W	RESISTOR	
C207	330uF/25V	ELECTROLYTIC CAP	
R207	470R	RESISTOR	
C208	1800uF/25V	ELECTROLYTIC CAP	
Q200	BC557	PNP TRANSISTOR	
Q201	C548B	NPN TRANSISTOR	
IC200	ICE3BR4765J	Quasi-Resonant PWM Controller	INFINEON
R206	N.C.	RESISTOR	
C206	N.C.	CERAMIC	
C205	N.C.	CERAMIC	
IC201	SFH617A-3	OPTO COUPLER	
IC202	SFH617A-3	OPTO COUPLER	
IC203	TL431		
TR200	TRANS-FLYBACK-ONE	Fix frequency flyback transformer	TDK
D200	UF4006	DIODE	
C301	0.1uF	CERAMIC	
C306	0.1uF	CERAMIC	
R313	0R51/1W	RESISTOR	
R312	0R51/1W	RESISTOR	
R305	1M3/1%	RESISTOR	
R304	1M8/1%	RESISTOR	
D301	1N4148	DIODE	
R317	1k6	RESISTOR	
R322	1k/1%	RESISTOR	

C308	1n5	CERAMIC	
C315	1nF	CERAMIC CAP	
C303	1uF	CERAMIC	
C318	1uF	CERAMIC CAP	
R303	2M0/1%	RESISTOR	
R318	2k2	RESISTOR	
CY300	2n2, Y1	CERAMIC	
R308	3R3	RESISTOR	
R325	3k6/1%	RESISTOR	
L300	4u7/4.2A	OUTPUT CHOKE	
L301	5u/5A	OUTPUT CHOKE	
R319	6.8k	RESISTOR	
R324	7k5/1%	RESISTOR	
R309	10k	RESISTOR	
C300	10uF/50V	Aluminum Electrolyte	
R314	13k	RESISTOR	
R306	22k/1%	RESISTOR	
C304	22nF/630V	Capacitor	
R320	27k/1%	RESISTOR	
R321	30k/1%	RESISTOR	
R310	39k	RESISTOR	
R301	47k/5w	RESISTOR	
C302	47p	CERAMIC	
C307	47pF/1kV	CERAMIC	
R311	100R	RESISTOR	
R316	100R/5W	RESISTOR	
C309	100p	CERAMIC	
C310	100p/1kV	CERAMIC	
C312	100p/1kV	CERAMIC	
R323	300R/1%	RESISTOR	
C316	470uF/25V	ELECTROLYTIC CAP	
C317	470uF/35V	ELECTROLYTIC CAP	
R300	820k	RESISTOR	
C314	2200uF/35V	ELECTROLYTIC CAP	
C313	2200uF/35V	ELECTROLYTIC CAP	
C311	2200uF/35V	ELECTROLYTIC CAP	
IC300	ICE2QS02G	Quasi-Resonant PWM Controller	INFINEON
D303	MBR2560	DIODE	
D305	MBR20150	DIODE	
D304	MBR20150	DIODE	
TR300	Main	Quasi-resonant flyback transformer	EPCOS
C305	N.C.	CERAMIC	
R302	Not Used	RESISTOR	
IC301	OPTO4PIN	OPTO COUPLER	
Q300	SPA11N80C3	POWER MOSFET	INFINEON
IC302	TL431		
D300	UF5408	DIODE	
R307	short	RESISTOR	
R315	short	RESISTOR	
D302	short	DIODE	

7 PFC Choke (L103) Construction

Core: CS400090 toroid

Turns: 100

Wire: 1 χ Φ1mm, AWG18

Inductance: L=1.2 mH

8 Quasi-resonant flyback Transformer (TR300) Construction

Core and Material: N87

Bobbin: BEER35-1116CPHFR

Primary Inductance: 334uH, measured between Pin 5 and 8, (Pin 6 and Pin 7 shorted)

Manufacturer: EPCOS

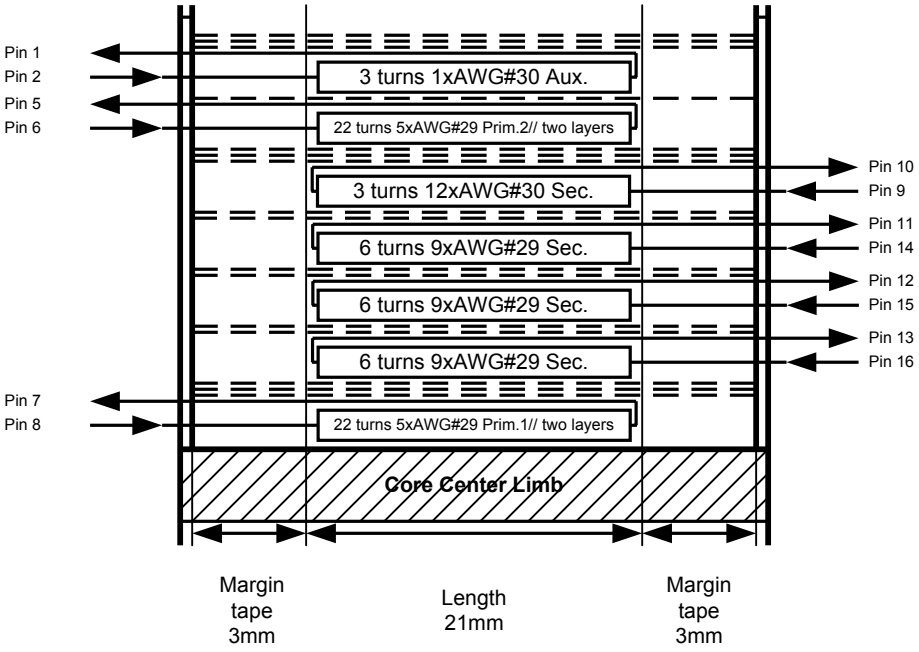


Figure 7 Quasi-resonant flyback transformer structure

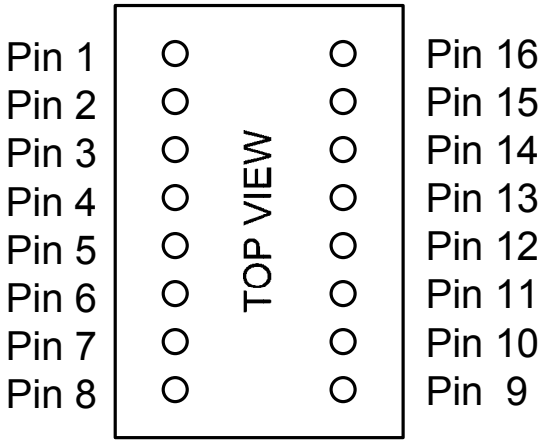


Figure 8 Quasi-resonant flyback transformer complete – top view

9 Auxiliary flyback transformer (TR200) construction

Core and material : EF20/10/6, PC40

Bobbin: Horizontal Version

Primary Inductance, Lp = 900µH, measured between pin 3 and pin 5 (Gapped to Inductance)

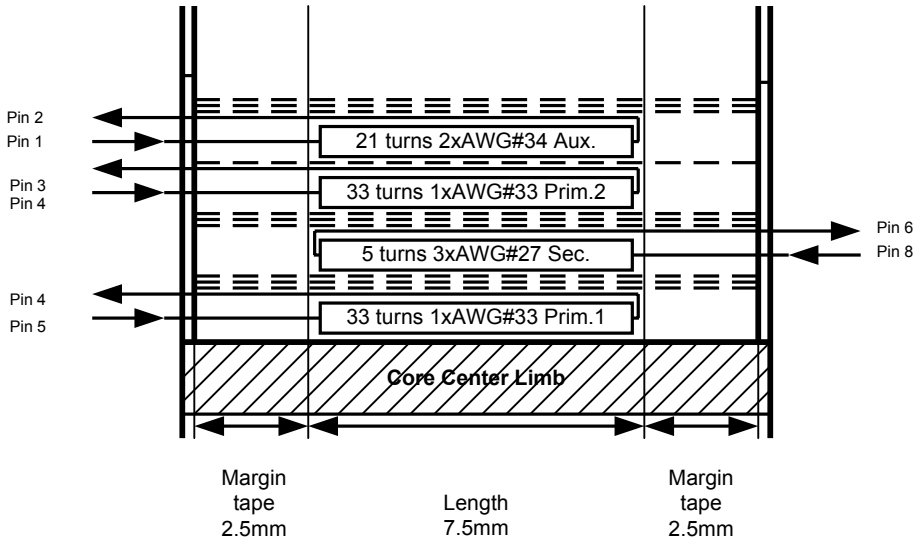


Figure 9 Auxiliary flyback transformer structure

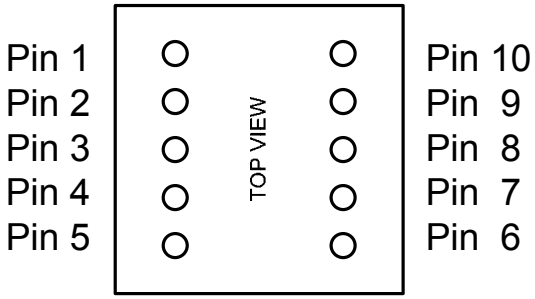


Figure 10 Auxiliary flyback transformer complete – top view

10 Test Results

10.1 Efficiency

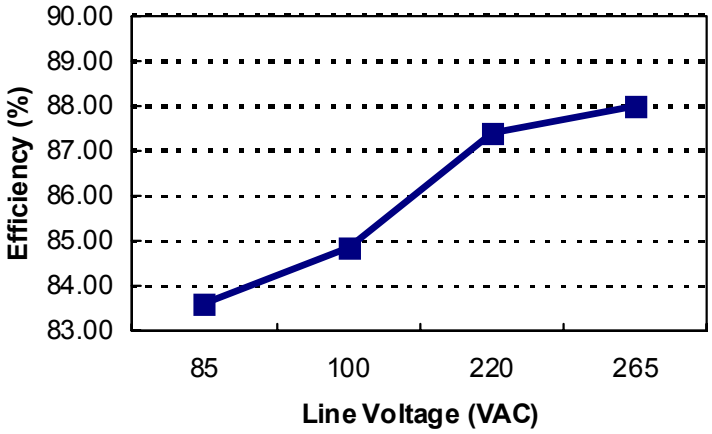


Figure 11 – Efficiency @ full load vs. AC line voltage

Table 2 Efficiency vs. load @ 100VAC

Vin (VAC)	Pin (W)	Input PF	Pout (W)	Output 1		Output 2		Output 3		Efficiency (%)
				Vout1 (V)	Iout1 (A)	Vout2 (V)	Iout2 (A)	Vout3 (V)	Iout3 (A)	
100	46.43	0.9700	37.29	23.62	1.20	11.66	0.60	4.99	0.39	80.31
100	67.91	0.9849	56.00	23.63	1.80	11.64	0.90	4.99	0.60	82.47
100	89.32	0.9906	74.67	23.63	2.40	11.64	1.20	4.99	0.80	83.60
100	110.71	0.9933	93.29	23.63	3.00	11.64	1.50	4.99	0.99	84.27
100	132.32	0.9949	112.01	23.63	3.60	11.64	1.80	4.99	1.20	84.65
100	154.15	0.9950	130.58	23.64	4.20	11.63	2.09	4.99	1.40	84.71
100	175.95	0.9964	149.08	23.64	4.79	11.63	2.40	4.99	1.59	84.73
100	198.08	0.9969	167.80	23.64	5.39	11.63	2.70	4.99	1.80	84.71
100	220.00	0.9972	186.59	23.64	6.00	11.63	2.99	4.99	2.00	84.82

Table 3 Efficiency vs. load @ 220VAC

Vin (VAC)	Pin (W)	Input PF	Pout (W)	Output 1		Output 2		Output 3		Efficiency (%)
				Vout1 (V)	Iout1 (A)	Vout2 (V)	Iout2 (A)	Vout3 (V)	Iout3 (A)	
220	45.48	0.7694	37.34	23.62	1.20	11.66	0.60	4.99	0.40	82.09
220	66.00	0.8570	56.00	23.63	1.80	11.64	0.90	4.99	0.60	84.85
220	87.20	0.9056	74.67	23.63	2.40	11.64	1.20	4.99	0.80	85.63
220	108.30	0.9330	93.34	23.63	3.00	11.64	1.50	4.99	1.00	86.19
220	129.53	0.9530	112.01	23.63	3.60	11.64	1.80	4.99	1.20	86.47
220	150.20	0.9641	130.34	23.64	4.19	11.63	2.09	4.99	1.40	86.78
220	171.20	0.9705	149.13	23.64	4.79	11.63	2.40	4.99	1.60	87.11
220	192.30	0.9758	167.85	23.64	5.39	11.63	2.70	4.99	1.81	87.29
220	213.50	0.9791	186.59	23.64	6.00	11.63	2.99	4.99	2.00	87.40

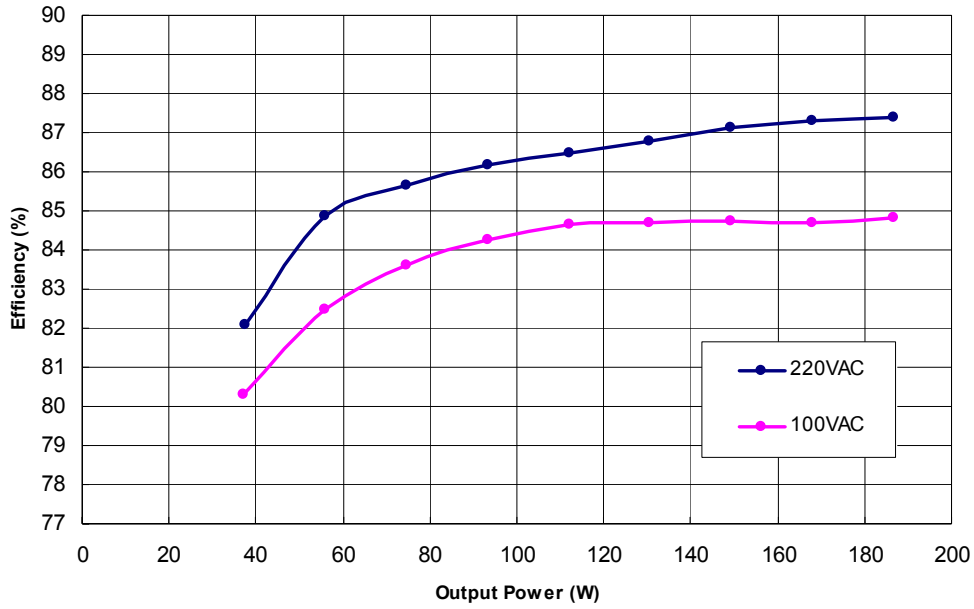


Figure 12 Overall efficiency versus output power at nominal input voltages

10.2 Standby Power

Table 4 shows the input standby power at different input AC line voltage. The test condition is only 5V standby output working while the ICE2PCS02 and 2QS02G power is off.

Table 2 – Input standby power(mW) @ 0W, 0.1W and 0.5W load vs. AC line input

VAC (V)	85	110	150	180	220	240	265
Po=0W	13	22	73	98	140	162	194
Po=0.1W	175	182	194	206	263	289	330
Po=0.5W	760	760	791	822	860	882	917

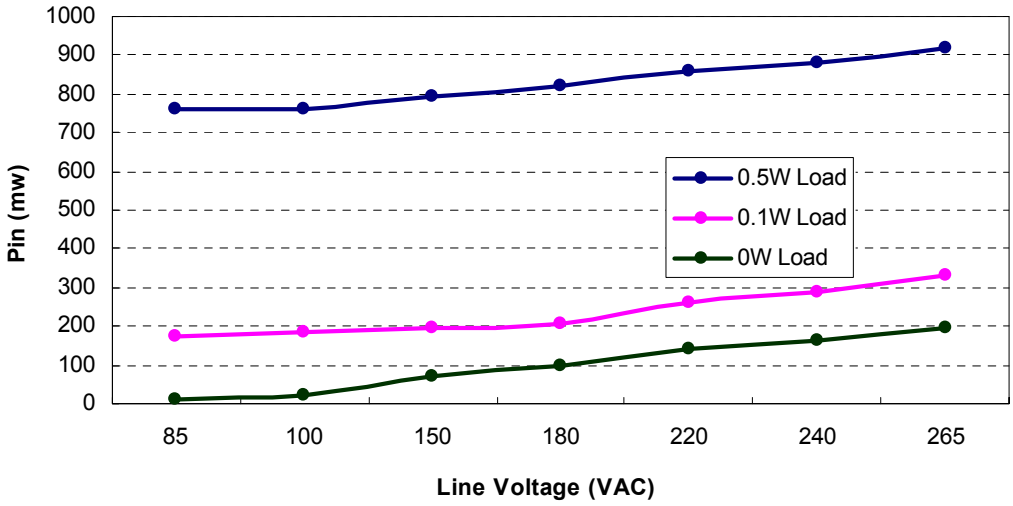
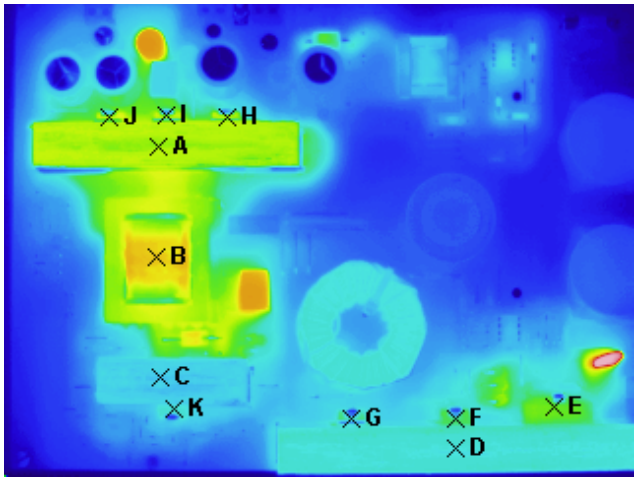


Figure 13 Input Standby Power @0W, 0.1W and 0.5W load vs. AC Line Input Voltage

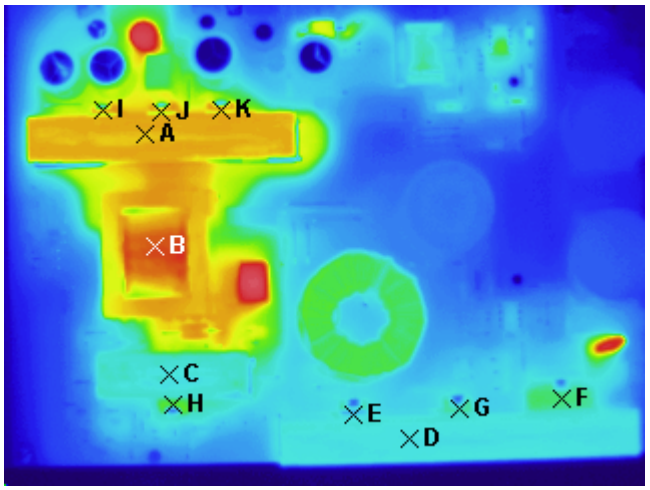
10.3 Thermal performance

The thermal images are taken by TVS500 thermal camera at room temperature.



Point	T °C	Emis.	Ta °C
A	70.5°C	1.00	34.3
B	83.4°C	1.00	34.3
C	49.8°C	1.00	34.3
D	56.5°C	1.00	34.3
E	66.9°C	1.00	34.3
F	61.3°C	1.00	34.3
G	58.6°C	1.00	34.3
H	71.9°C	1.00	34.3
I	65.6°C	1.00	34.3
J	73.1°C	1.00	34.3
K	57.2°C	1.00	34.3

Figure 14 thermal image at 110Vac/60Hz



Point	T °C	Emis.	Ta °C
A	70.5°C	1.00	34.3
B	83.4°C	1.00	34.3
C	49.8°C	1.00	34.3
D	56.5°C	1.00	34.3
E	66.9°C	1.00	34.3
F	61.3°C	1.00	34.3
G	58.6°C	1.00	34.3
H	71.9°C	1.00	34.3
I	65.6°C	1.00	34.3
J	73.1°C	1.00	34.3
K	57.2°C	1.00	34.3

Figure 15 Thermal image at 220Vac/60Hz

11 References

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