160W SMPS Evaluation Board for High End TV with New Quasi resonant Controller ICE1QS01

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The 160W Evaluation board described here was designed as a typical power supply in flyback converter topology with multi output voltage and secondary control. This type of switch mode power supply as an AC/DC power supply has been designed to enable safe, reliable and efficient SMPS at minimum cost for TV application. The ICE1QS01 is a quasi resonant controller where switched on the power transistor at minimum drain voltage. ICE1QS01 is the optimized controller which equipped with special enhancement to satisfy the needs for low power standby and protection features. Its unique digitally frequency reduction at reduced output power down to 20kHz frequency is used to avoid high frequency caused interference, lower the power consumption, avoid any jitter toward stabilization system and support stable output in this mode. In case of failure mode like overvoltage or under voltage, mains undervoltage and current limitation due to overload the device switches in Auto Restart mode which is controlled by internal protection unit. By mean of the Fold back point correction the dimension of the transformer and the secondary diode can be lower which leads to more cost efficiency.

Evaluation Board

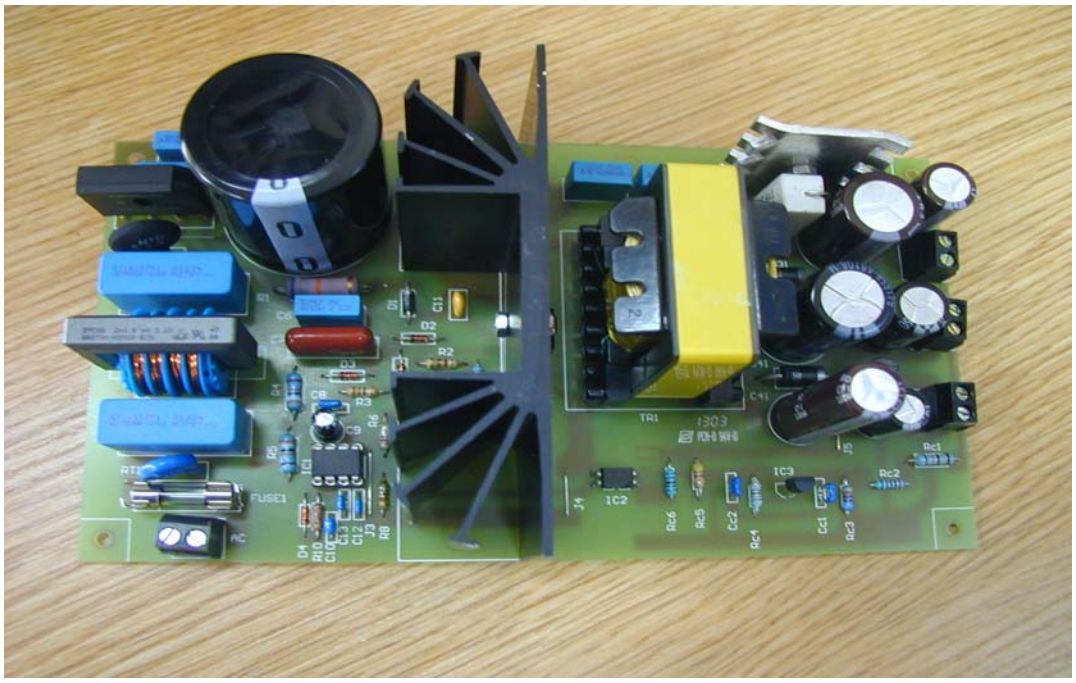


Figure 1.0 Shown 160W TV SMPS with ICE1QS01

Technical Specification:

Input Voltage	85VAC ~ 265VAC	
Input Frequency	50Hz, 60Hz	
Output Voltage and Current		
Deflection Output	120V	0.83A
Audio Output	33V	1.5A
Small Signal and Microcontroller output	12V	0.85A
Output Power	159.3W	
Efficiency	> 75%	
Switching Frequency	Free running	
Standby Load Condition	5V/0.03A only	
Standby Power	< 1W	

Circuit Description

Mains Input and Rectification

The AC line input side comprises the input fuse FUSE1 as overcurrent protection. The X2 Capacitor C1, C2 and Choke L1 and Y1 capacitor C3 and C4 forms a mains filter to minimize the feedback of RFI into the main supply. After the bridge rectifier BR1, together with a smoothing capacitor C5, provide a voltage of 80 to 380 VDC depending on input voltage is available. ICL1 is place in series with input to limit the initial peak inrush current whenever the power supply is switched on when C5 is fully discharged.

PWM Control

The PWM pulse is generated by 8-pin Quasi Resonant Controller ICE1QS01. ICE1QS01 is a current mode controller. The ICE1QS01 comprises the complete control for free running flyback switch mode power supply especially in TV application. It also performs all necessary protection functions in flyback converters. The IC functions will be described in the next section.

Snubber Network

A snubber network R1, C6 and D1 dissipate the energy of the leakage Inductance and to suppress ringing on the SMPS transformer.

Minimum Power at Normal Mode

To shift the burst mode to a lower power, D4 and R10 can be connected parallel between PCS pin and capacitor C10. By adding the D4 and R10, the voltage of PCS pin should start from 2.2V instead of 1.5V. Then, the regulation voltage at SRC pin will always higher than 2V to prevent the IC go into the burst mode at nominal light power.

Output Stage

There are three secondary output, the 120V (scan voltage for deflection stage), 33V (audio supply), and 12V (small signal supply), The 5V standby supply for microcontroller can be derived from a regulator connected to the 12V output. On the secondary side, the power is coupled out via a group of fast-acting diodes D21, D31 and D41. The capacitors C22, C31 and C41 provide energy buffering following with the L-C filters to reduce the output ripple and prevent interference between SMPS switching frequency and line frequency considerably. Storage capacitors C22, C31 and C41 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 characteristic. R21 and C21 form a damping network to dissipate the energy in the high frequency ringing on 120V secondary winding.

Feedback Loop

For feedback, the output is sensed by the voltage divider of Rc1, Rc2 and Rc3 and compare to TL431 internal reference voltage. The output voltage of TL431 is converted to the current signal via optocoupler for regulation control.

Circuit Operation

Startup

From Mains rectified DC voltage, the IC receives its starting current supply provided through resistors R4 and R5 via PCS (pin2) and the internal diode to charge up the external capacitor C9 at V_{CC} pin. Additional Startup current can be provided by C7, to shorten the startup delay time at lower line input voltage. Because of the low current around 50uA, high-value resistor can be used. Series connection of the resistors is necessary for reason of insufficient dielectric strength of the individual resistors. The IC remains inactive during the V_{CC} charge up. When V_{CC} reaches the turn on voltage threshold 15V (typ.), the IC is switch on. The SMPS is going to start. The soft-Start function is realized with an internal soft start resistor, an internal current sink, a current source and the external capacitor C12. The pulse width is gradually increased during a soft start and finished 24ms after the IC is switched on.

Normal Mode Operation

The secondary output voltage is built up after startup. If the V_{SRC} (pin4) is higher than 2V, the SMPS is going to the normal mode. The secondary regulation control is adopted with TL431 and optocoupler. The compensation network Cc1, Cc2 and Rc4 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. During Normal mode, the IC voltage supply is provided through an Auxiliary transformer winding with associated rectifier D2. Resistor R2 is used to limit the IC supply current.

Standby Mode Operation

This IC has an integrated circuit for an advanced burst mode features during standby mode. If the regulation voltage V_{SRC} (pin4) falls below 2V, the IC goes into burst mode. The high burst frequency is achieved by shifting the V_{CC} undervoltage threshold from 9V to 14.5V. As the voltage V_{CC} range in between the switch on threshold 15V and the undervoltage threshold 14.5V will guarantees a high efficiency and desired for low ripple of the charged output voltage.

Protection Features

IC Supply Overvoltage

If V_{CC} exceeds the V_{CCD} threshold 20V (typ.), a comparator will shunt down the IC by set the latch and disable the gate. Reset of latch is activated when the V_{CC} falling below the 14.5V (typ.)

IC Supply Undervoltage

A comparator checks the voltage at pin V_{CC}. If V_{CC} is lower than 9V (typ.), IC will stop and restart again.

Mains undervoltage protection

The circuit sensed the flowing current at pin PCS during the off-time of the Mosfet switch. If the flowing current is smaller than 100uA, this means that the main voltage is too low and IC stop and restart again.

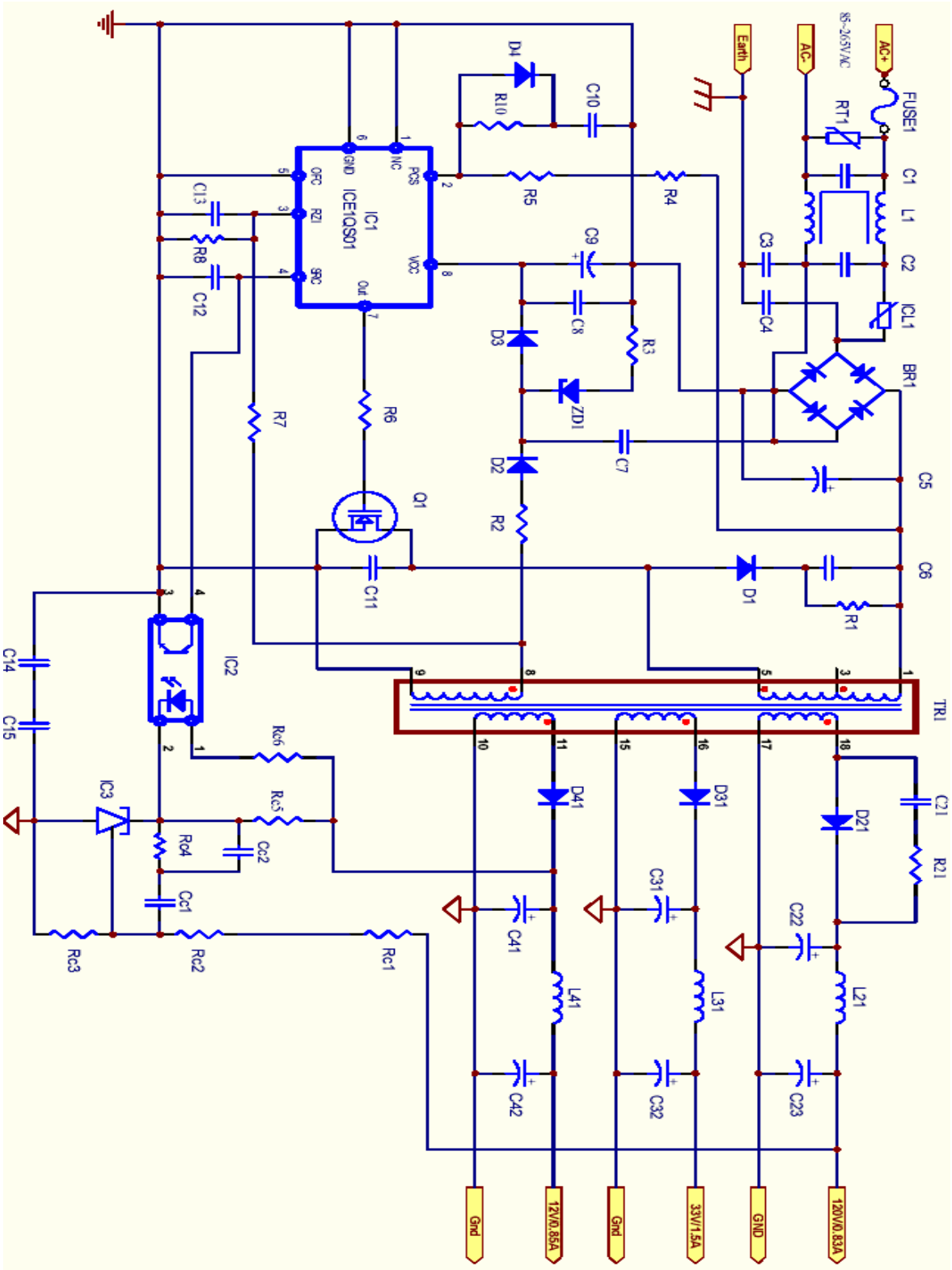
Primary Current Simulation and Pulse by Pulse current limit

The CoolMOS source current is simulated by Pin PCS. The simulated voltage is fed into ICE1QS01 and compare with the Feedback voltage V_{SRC} for PWM control. Primary peak current is limited by maximum voltage of V_{SRC}, 5V. When overload occurs, the output power is limited. IC will go to auto-restart when Vcc is down to UVLO, typical 9V.

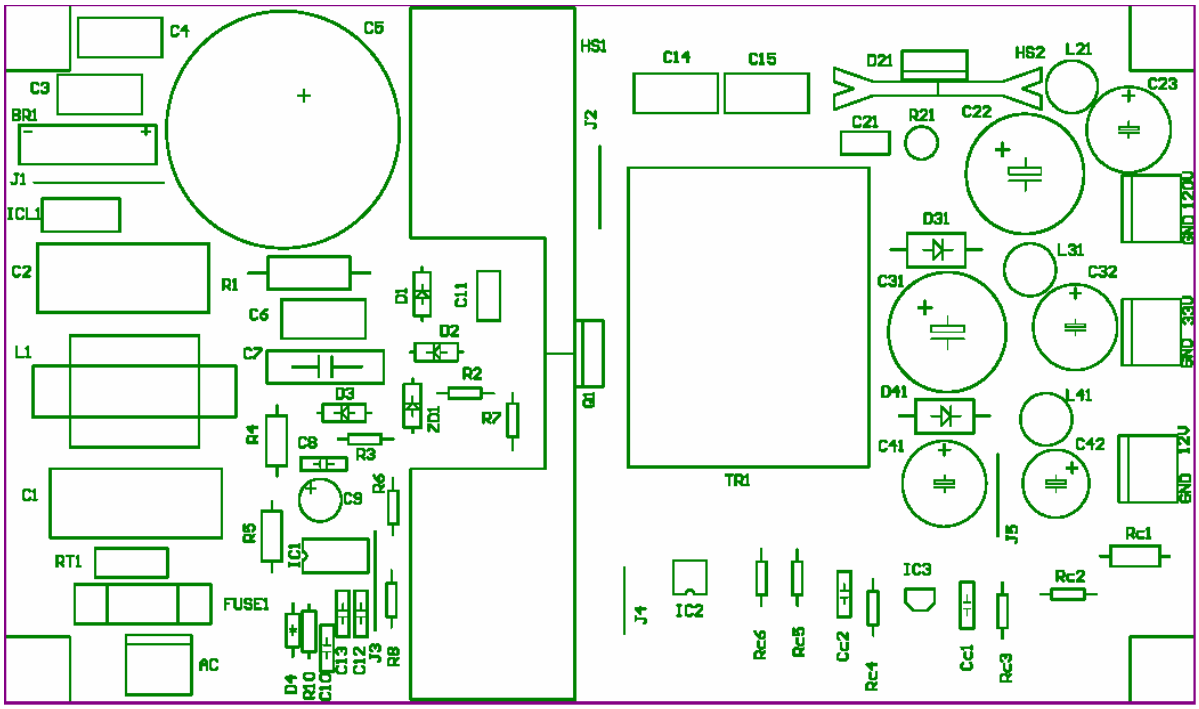
Fold Back Correction

This function is necessary in free running SMPS to make the maximum output power independent on AC input voltage. By mean of this the dimension of the transformer can be smaller and the rating of secondary diode can be lower, which leads to more cost efficiency. This feature is obtained by passing some part of RZI current to PCS to reduce on time of power transistor and thus lower power at high main input voltage.

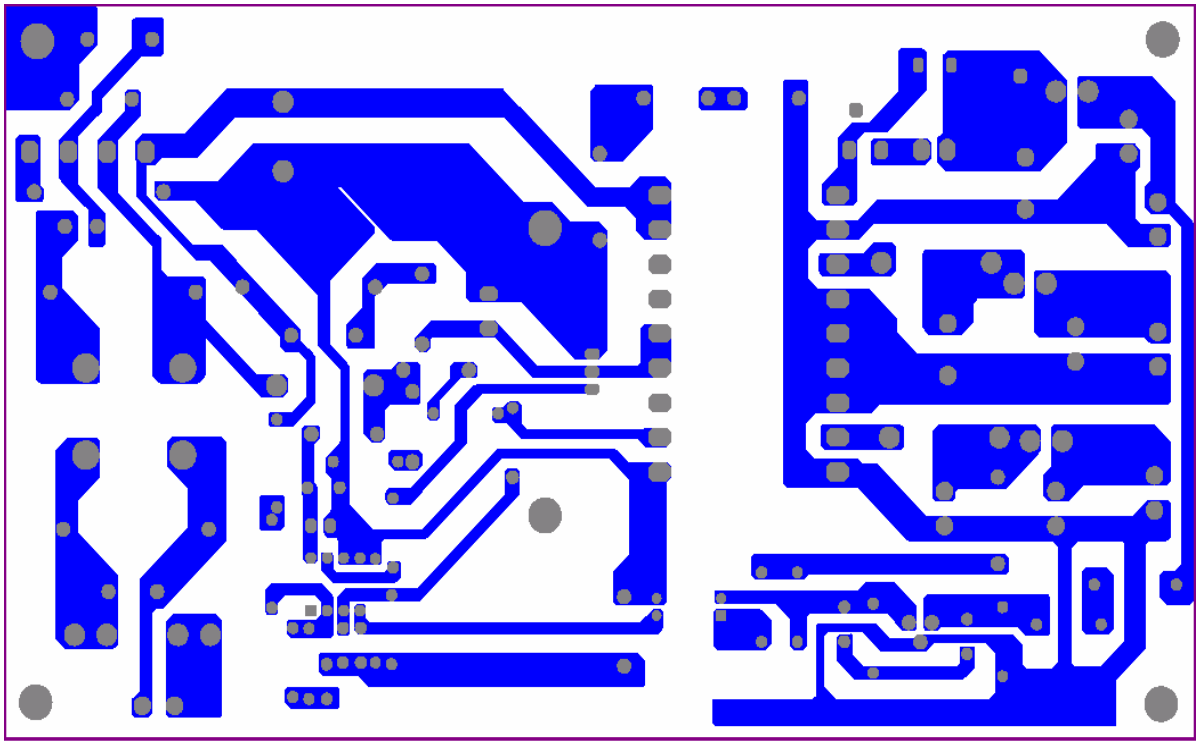
Circuit Diagram:



PCB Layout Top Layer



PCB Layout Bottom Layer



Component List:

Items	Part	Type	Number
1	BR1	KBU6G	1
2	C1	0.33uF/275V, X2 Capacitor	1
3	C2	0.33uF/275V, X2 Capacitor	1
4	C3	2.2nF/250V , Y2 Capacitor	1
5	C4	2.2nF/250V , Y2 Capacitor	1
6	C5	470uF/400V	1
7	C6	15nF/630V	1
8	C7	100nF/400V	1
9	C8	100nF/50V	1
10	C9	47uF/25V	1
11	C10	820pF/50V	1
12	C11	470pF/1KV	1
13	C12	10nF/50V	1
14	C13	33pF/50V	1
15	C14	4.7nF/250V	1
16	C15	4.7nF/250V	1
17	C21	220pF/1KV	1
18	C22	100uF/160V	1
19	C23	47uF/160V	1
20	C31	1000uF/50V	1
21	C32	470uF/50V	1
22	C41	2200uF/25V	1
23	C42	470uF/25V,	1
24	Cc1	0.33uF/50V	1
25	Cc2	2.7nF/50V	1
26	D1	UF4006	1
27	D2	1N4148	1
28	D3	1N4148	1
29	D4	1N4148	1
30	D21	STTA506D	1
31	D31	UF5402	1
32	D41	UF5401	1
33	Fuse1	4.0A/250V	1
34	IC1	ICE1QS01	1
35	IC2	SFH617A-3X016	1
36	IC3	TL431CLP	1
37	ICL1	237/2.5	1
38	HS1	Heatsink 1	1
39	HS2	Heatsink 2	1
40	J1	Jumper, 20mm	1
41	J2	Jumper, 12.5mm	1
42	J3	Jumper, 15mm	1
43	J4	Jumper, 10mm	1
44	J5	Jumper, 12.5mm	1
45	L1	2 x 3.3mH, 4.6A	1
46	L21	20uF	1
47	L31	20uF	1
48	L41	20uF	1

49	Q1	SPP11N60C3	1
50	R1	68K , 2W , 5%	1
51	R2	11 , 0.25W, 5%	1
52	R3	11 , 0.25W , 5%	1
53	R4	390k, 0.5W, 1%	1
54	R5	390k, 0.5W, 1%	1
55	R6	27 , 0.25W , 5%	1
56	R7	22K , 0.25W , 5%	1
57	R8	5.6K , 0.25W , 5%	1
58	R10	1.8K, 0.25W	1
59	R21	100 , 5W	1
60	Rc1	180K , 0.5W , 1%	1
61	Rc2	22k , 0.25W , 5%	1
62	Rc3	4.3K, 0.25W , 1%	1
63	Rc4	13K , 0.25W , 5%	1
64	Rc5	470, 0.25W, 5%	1
65	Rc6	1K, 0.25W , 5%	1
66	RT1	S10K275	1
67	TR1	E42/15/21 N67	1
68		Bobbin E42/15/21	1
69	X1	Connector 2pol.	4
70	ZD1	18V , zener diode	1
71		Isolating Pad	1
72		Fuse Holder	1
73		3mm screw for Q1	1
74		Plastic Isolating bushes	1
75		Nuts Φ 3mm	2
76		IC sockets DIP8	1
77		M3 screw	3

Transformer Construction:

Layer No.	Start	Stop	No. of Turns	Wire Size	
7	3	1	11	4x Φ0.32mm	Primary
6	11	10	3	4 x Φ0.32mm	Secondary
5	16	15	8	4 x Φ0.32mm	
4		17	13	3 x Φ0.32mm	
3	18		14	3 x Φ0.32mm	
2	8	9	4	4 x Φ0.32mm	Primary
1	5	3	11	4 x Φ0.32mm	
Core Inside					

Core: E42/15/N67
Primary Inductance, Lp=132μH, measured between pin 5 and pin 1
(Gapped to Inductance)

Test Report:

Normal Mode operation

V_{in} (V)	I_{in} (A)	P_{in} (W)	P_{out} (W)	η (%)	120V (0.83A)		33V (1.5A)		12V (0.85A)	
					V_{o1}	I_{o1}	V_{o2}	I_{o2}	V_{o3}	I_{o3}
85	1.17	57.2	50.3	87.94	119.98	0.3	35.16	0.3	12.52	0.3
	2.17	114.2	100.4	87.92	119.95	0.6	35.11	0.6	12.31	0.6
	3.61	189.6	162.0	85.44	119.92	0.83	34.75	1.5	12.22	0.85
110	0.96	56.3	50.3	89.34	119.98	0.3	35.14	0.3	12.51	0.3
	1.79	111.9	100.4	89.72	119.93	0.6	35.08	0.6	12.27	0.6
	2.94	183.5	162.0	88.28	119.93	0.83	34.75	1.5	12.20	0.85
140	0.81	55.9	50.3	89.98	119.98	0.3	35.11	0.3	12.50	0.3
	1.51	110.9	100.4	90.53	119.95	0.6	35.06	0.6	12.29	0.6
	2.47	180.4	162.0	89.80	119.93	0.83	34.73	1.5	12.18	0.85
180	0.68	55.9	50.3	89.98	119.98	0.3	35.09	0.3	12.49	0.3
	1.26	110.8	100.3	90.52	119.95	0.6	35.03	0.6	12.17	0.6
	2.07	179.0	162.0	90.50	119.92	0.83	34.75	1.5	12.15	0.85
220	0.59	56.1	50.3	89.66	119.98	0.3	35.07	0.3	12.47	0.3
	1.10	111.4	100.3	90.03	119.95	0.6	35.01	0.6	12.17	0.6
	1.79	179.3	162.0	90.35	119.92	0.83	34.67	1.5	12.14	0.85
265	0.52	56.6	50.3	88.87	119.98	0.3	35.06	0.3	12.46	0.3
	0.96	112.2	100.2	89.30	119.95	0.6	35.00	0.6	12.13	0.6
	1.57	180.4	162.0	89.80	119.92	0.83	34.66	1.5	12.12	0.85

Minimum Power in Normal Mode Operation

V_{in}(V)	P_{in} (W)	120V		33V		12V	
		V_{o1}	I_{o1}	V_{o2}	I_{o2}	V_{03}	I_{03}
85	10.1	119.96	0.018	35.07	0.09	12.42	0.24
110	9.2	119.98	0.0106	35.06	0.09	12.38	0.24
140	10.8	119.96	0.0203	35.03	0.09	12.40	0.24
220	21.7	119.98	0.0646	35.07	0.09	12.39	0.24
265	29.2	119.96	0.1	35.02	0.09	12.46	0.24

Standby Power (Burst Mode Operation)

V_{in}(V)	P_{in}(mW)	120V (0.83A)		33V (1.5A)		12V (0.85A)	
		V_{o1}	I_{o1}	V_{o2}	I_{o2}	V_{03min}	I_{03}
85	520	120.09	0.0	34.49	0.0	8.6	0.03
110	559	120.03	0.0	34.93	0.0	8.8	0.03
140	616	120.06	0.0	34.98	0.0	8.8	0.03
180	672	120.09	0.0	34.96	0.0	8.8	0.03
220	788	120.07	0.0	34.26	0.0	8.8	0.03
265	909	120.06	0.0	34.43	0.0	9.0	0.03

References:

[1] Infineon Technologies, “ICE1QS01 controller for Quasirensonant Switch Mode Power Supplies Supporting Low Power Standby and Power Factor Correction”, Infineon Technologies Datasheet, version 1.3, January 2003.

[2] Peter Preller, “A New Quasiresonant Controller for Switch Mode Power Supplies Supporting Low Power Standby and Power Factor Correction (PFC)” , Infineon Technologies Application Note, AN-ICE1QS01, version 1.0, February 2003.