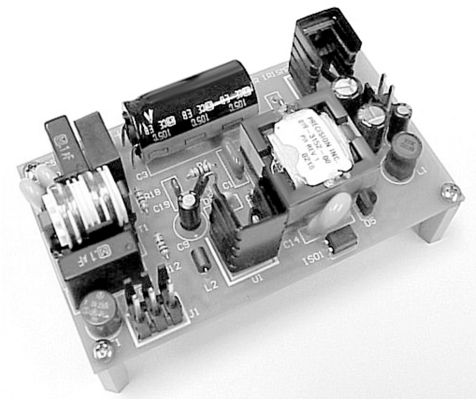
International Rectifier

REFERENCE DESIGN

International Rectifier · 233 Kansas Street El Segundo CA 90245 USA

Technical Specifications



1. AC Input: V=90~265V, f=57~63Hz, I= 0.3Arms max

2. Inrush Current: 8A max

3. Efficiency: 84% at full load high line (82% at low line)

4. Turn On Delay: <1secs @ 90V full load

5. Short Circuit Protection: Yes

6. Over Voltage Protection: Yes

7. Hold-Up Time: 160msec (230Vin Full load) / 20ms (90Vin Full load)

8. Output Rise Time: 2ms max (10-90%)

9. Output Characteristics

Nominal Ouput Voltage	Load Range		Regulation (V)
	Min	Max	
12V	0A	1A	11.4V ~ 12.6V

10: Switching Frequency: 20 -220kHz

Relevant Technical Documents

AN1018a - Using the IR40xx Series SMPS ICs
AN1024a - Flyback transformer design for the IR40xx series
AN1025a - Designing a Power Supply Using The IRIS40xx Series
IRIStran.xls - IRIS Series Flyback Transformer Design Spreadsheet
IRIS4009(K) - Datasheet

Circuit Description

The IRISMPS4 reference design is a complete tested power supply circuit. It is designed for a universal AC line input and will provide a 15V, 4A full load DC output.

The design uses a flyback converter topology, with an IRIS4009 as the main switch and control device. The initial start-up current for the IRIS4009 is provided by a dropper resistor from the DC bus. Once the circuit is started the Vcc power for the IRIS4009 comes from the bias winding of the main transformer. The primary current control circuit consists of a current sensing resistor which feeds a voltage proportional to the transformer primary current into the feedback (FB) pin of the IRIS4009. The secondary voltage control loop uses an LM431 precision shunt regulator as the reference and an optocoupler to feedback the information across the transformer galvanic isolation boundary back to the control circuit of the IRIS4009.

Test Circuit Set-up

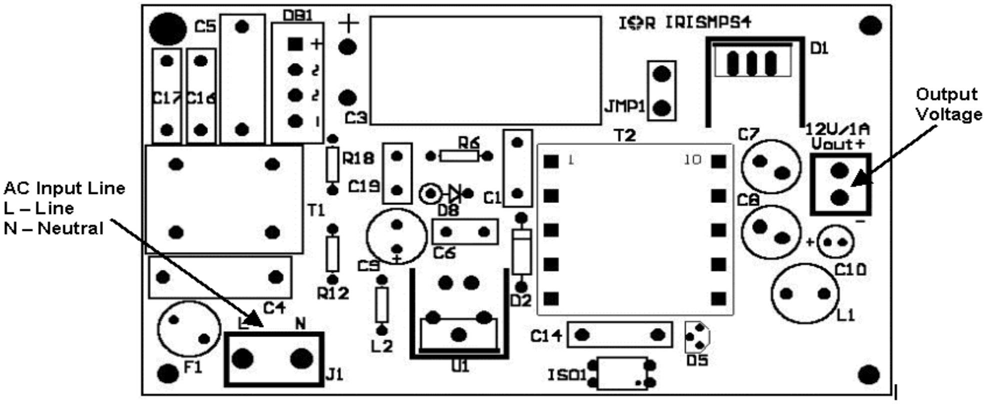


Fig 1) Connections to the board viewed from the top board layout

The circuit is designed for a universal AC line input. To safely test and evaluate this circuit it is recommended that an isolation transformer or a synthesized and isolated AC source (such as a Pacific Power Source 115-ASX) is used to power the board, with a voltage in the range of 90-265VAC, with a frequency of 50/60Hz. The AC input signal is applied to the pins at P1 and P3 marked on the board.

For the output the best load to use is an electronic load which will allow easy changes in the output load, e.g. something like a Chroma 63102. Another simple alternative is to use a High power resistor for the load. The output connection are as follows: P2 is the Positive output voltage connection, P4 is the negative(or return) output connection.

Circuit Operation

The front end of the circuit consists of an EMI Filter, a diode bridge rectifier, and a DC bus filter capacitor. These are all fairly common circuit components used to create a DC voltage at the top end of the transformer.

At power up the DC voltage is applied to the top of the transformer, and the top of resistor R2. R2 and R4 allow about 100uA of quiescent current to flow which charges the Vcc capacitor C9. When the voltage at the Vcc pin of the IRIS4009 reaches the positive undervoltage lockout threshold (V_{CCUV+}) , the IRIS4009 starts to operate and will turn on the internal FET. Now the DC bus voltage is applied across the transformer primary winding, the FET and the current sense resistors R15/R16. The current through the transformer primary, the FET and the current sense resistors will start to ramp up. The rate of the ramp is dependent on the DC bus voltage and hence the input line voltage (for example, the rate at 90VAC in is much lower than the rate at 230VAC in). The current ramps until the voltage across R15/R16 reaches the Vth1 of the IRIS4009 (0.73V typ). During this time there is no current flowing in either the bias winding or the output winding, because this is blocked by the diodes D3 and D1 respectively.

At the point when the voltage across R15/R16 reaches Vth1 this activates a comparator in the IRIS4009 and the internal FET is switched off. Now the energy stored in the transformer causes the voltage at the Drain connected end of the transformer to rise, and as a result the voltage at the bias winding and the output winding changes from negative to positive. The output rectifiers now conducts and the energy is transferred to the output and the bias winding. If there is a fixed full current load on the output it will take a number of cycles for the output voltage to rise to the required level, and also it will take a few cycles for the bias winding to begin supplying power to the Vcc pin of the IRIS4009K. Until this happens, C9 holds the voltage above the undervoltage lockout level (Vccuv-) to make sure the circuit does not drop out. During this time the circuit cannot create enough voltage signal through the delay circuit to activate the quasi-resonant operation, so the circuit operates with a fixed off time of 50us (this is the pulse ratio control mode or PRC mode).

Once the output capacitors C7 & C8 and the Vcc capacitor C9 are fully charged, the complete quasi-resonant signal can be passed through the mode switching circuit & delay circuit D4/Q1/R11/D6 to the feedback (FB) pin This will happen only if the Bias winding voltage is above the switching threshold of the mode switching circuit (the operation of the mode switching circuit will be discussed in the next section). This will give a voltage above the Vth2 threshold of the IRIS4009, and this activates the quasi-resonant operation, holding the internal FET off until all the energy is transferred from the primary side of the transformer to the secondary and bias outputs. When all the energy is transferred, the quasi-resonant signal at the FB pin will start to fall until it can no longer supply the 1.35mA required by the IRIS4009 internal latch, and the FET is turned back on. This is also the lowest point of the resonant voltage at the drain pin of the IRIS4009 (shown as point X in fig2), so results in reduced switching losses.

If the AC input voltage changes but the load stays constant, the primary current ramp will now be steeper resulting in a shorter ON time, but still the same off time as it still takes the same amount of time to transfer the same energy to the output. The reduced ON time leads to a higher operating frequency.

If the AC input voltage remains constant, but the load is reduced, the secondary side voltage monitoring circuit (ISO1B/R9/D5/R5/R13/C13) will see an increase in the voltage, as the circuit is still passing the same energy to the secondary side, but less current is being drawn. This causes the LM431 Precision Shunt Regulator (D5) to conduct, causing to a current flow in the optocoupler ISO1B, which in turn gets passed across the transformer boundary to the phototransistor part of the optocoupler ISO1A. This creates a voltage drop across R14, generating an offset voltage at the FB pin thereby reducing the current required through the current sense resistors R15/R16 needed to reach a voltage of 0.73typ (Vth1 threshold) at the FB pin, and hence less energy is put into the transformer, reducing both the ON time and the OFF time.

Mode Switching Circuit Operation

The mode switching circuit consists of Q1/R8/C12/R12/D9/D7/R18/C19/Q2/C18/R17 and is used to switch the operating mode of the IRIS device between quasi-resonant and PRC modes dependent on the output loading, with the aim of reducing the power loss at light or no load.

At full load the bias winding voltage is higher than the switching threshold of the mode switching circuit which is set at about 13V in this circuit, this results in a current through D9/D7/R18/R17 which causes enough voltage across the base emitter junction of Q2 to forward bias it, which in turn allows current to flow through D4/R8/R12 which causes Q1 to be forward biased. The quasi-resonant signal is now allowed to pass through R11/D6 to the FB pin of the IRIS4009K.

If the bias winding voltage is below the threshold, Q1 is off and no quasi-resonant signal is passed. This causes U1 to operate in the PRC mode with a fixed of time of 50us, this results in a further lowering of the Vcc voltage to provide some hysteresis to prevent spurious changing between modes.

Circuit Waveforms

The following plots show waveforms taken from the circuit under various stated conditions

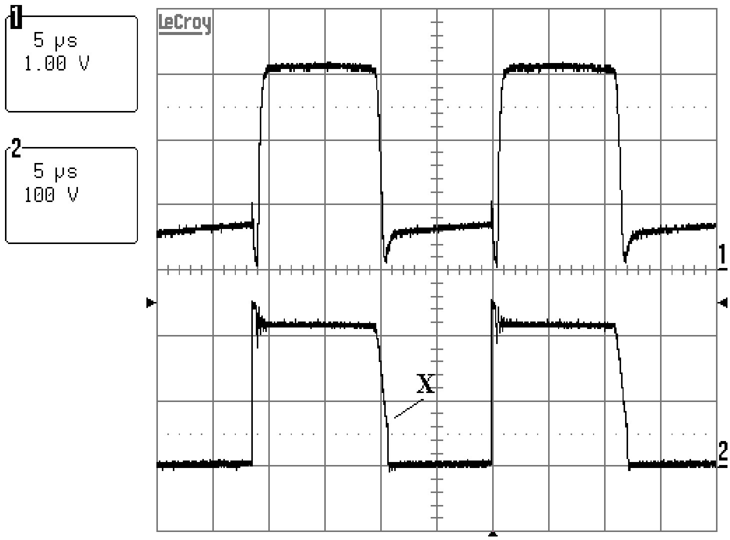


Fig 2) Drain (D) voltage of IRIS4009 (CH2) and FB voltage (CH1) 90VAC in Full load

Fig 2) shows the drain voltage of the IRIS4009 and the FB voltage with full load output at 90VAC input. Note that point X marked on the drain waveform shows the detection point for the quasi-resonant signal which is the lowest point on the drain waveform after the energy is transferred.

Fig 3) shows the drain voltage and the feedback pin (FB) voltage at 265VAC input again with a full load output. Note that at the start of the ON time for the FET the FB pin signal has a higher dv/dt rise. This is due to the feedback signal from the output creating the offset voltage to keep the output power constant. Also note that the on-time is shorter and hence the operating frequency is higher.

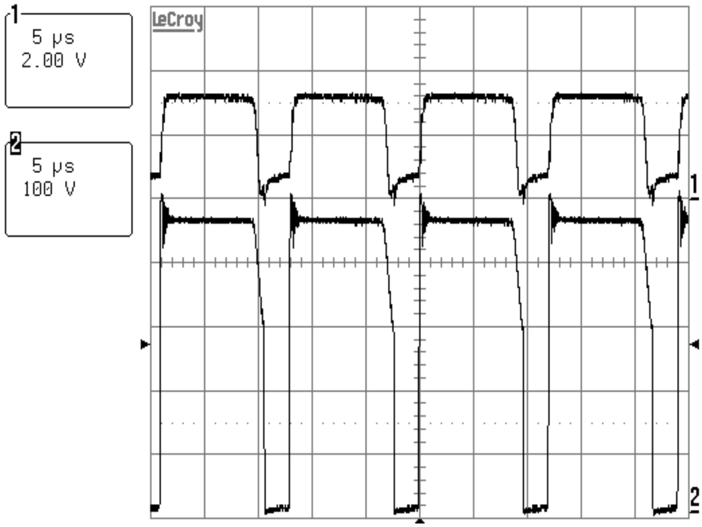


Fig 3)Drain (D) voltage of IRIS4009 (CH2) and the FB pin voltage (CH1) at 265VAC in/Full load output

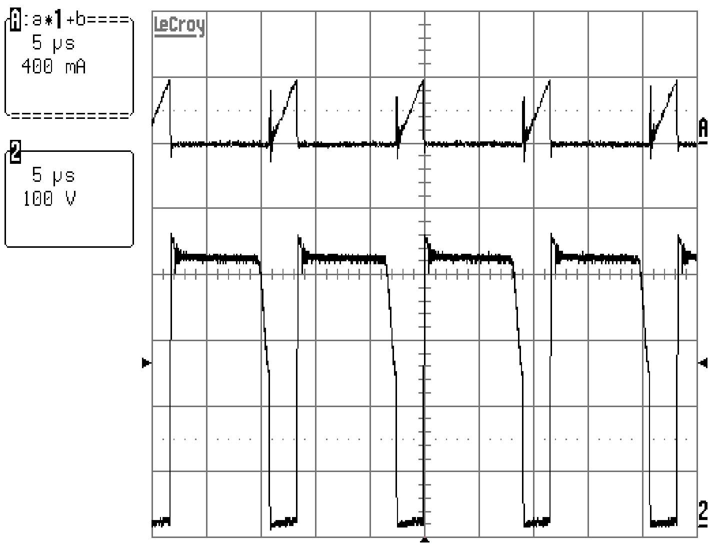


Fig 4) Drain (D) voltage of IRIS4009 (CH2) and the Drain current (CHA) at 230VAC in/Full load output

Fig 4) shows the Drain voltage and the Drain current at 230VAC input and full load output current. The voltage across the current sense resistors was measured and then using the Math function of the Lecroy scope the drain current is calculated and displayed in CHA. There is a small spike at the beginning of the ramp which is due to the discharging of the resonant capacitor and the winding capacitance of the transformer primary winding. Note that if the input voltage was 90VAC and there was a full load output, there would be very little feedback, and the source voltage would ramp all the way to the Vth(1) threshold of the IRIS4009, but in this case the input voltage is 230VAC, so the feedback has generated an offset voltage to reduce the peak current in the transformer, and hence the source voltage ramps to about 0.4V, which keeps the output power constant.

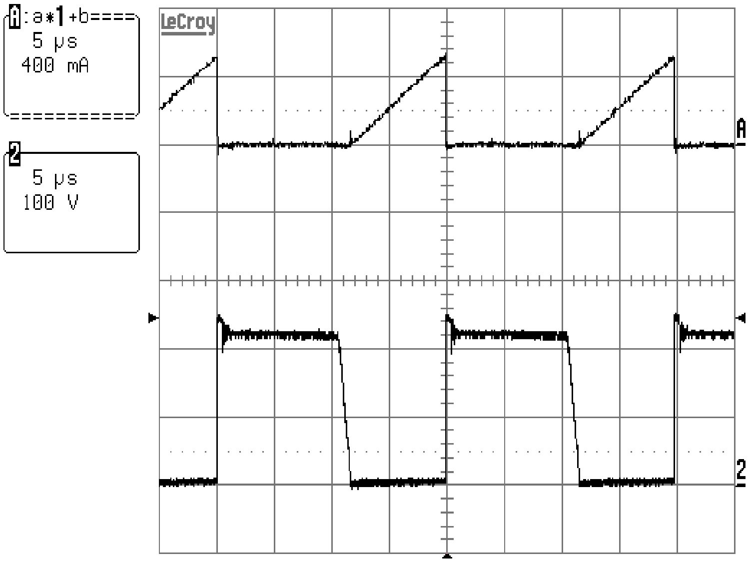


Fig 5) Drain (D) voltage of IRIS4009 (CH1) and the Drain current (CHA) at 90VAC in/Full load output

Fig 5) shows the same waveforms as in fig 4), but this time with a 90VAC input and full load output current. Note that under these conditions the current ramp is less steep due to the lower voltage across the transformer primary winding, and The source pin voltage ramps to a higher level in order to get the correct amount of energy into the transformer. Remember that the energy stored is $1/2LI^2$ and V=LdI/dt so with a lower voltage across the transformer the rate of change of current is lower, so it will take longer to reach the same primary current level.

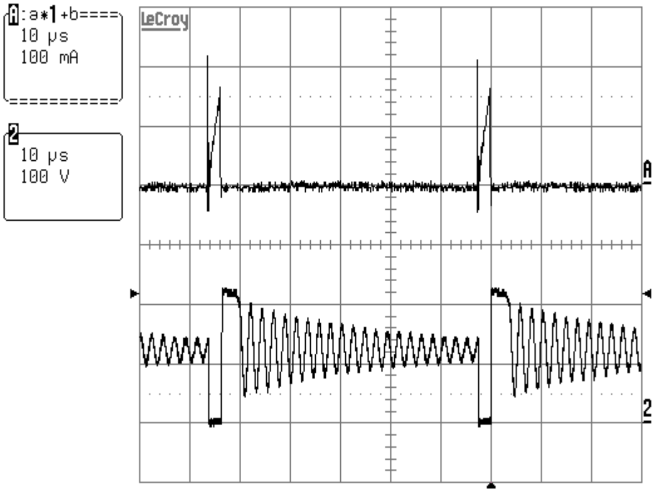


Fig 6) Drain (D) voltage of IRIS4009 (CH2) and the Drain current (CHA) at 90VAC in/no load output

Fig 6) again shows the drain and FB pin voltages, but this time with 90VAC and a no load condition. In this case the circuit is operating in the PRC mode with a fixed off time of 50us as can be seen on the waveform. The on time is very short as the only energy required is the energy needed to keep the circuit operating and hold the output at 15V. Under these conditions the input power consumed is 478mW, which meets the Energystar and Blue Angel Requirements.

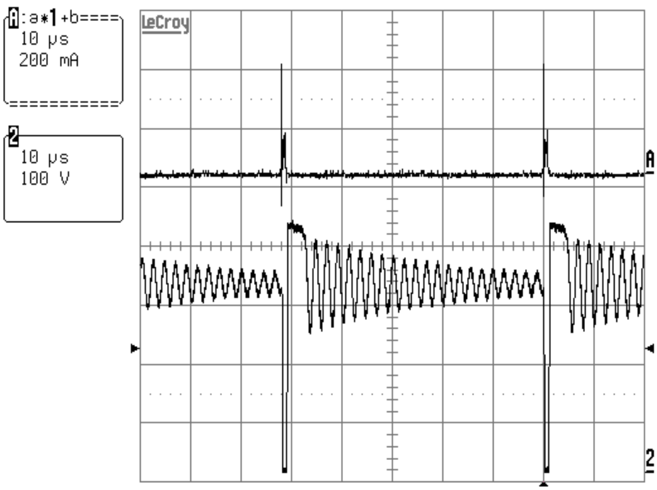


Fig 7)Drain (D) voltage of IRIS4009 (CH2) and the Drain current (CHA) at 230VAC in/no load output

Fig 7) shows the same details as in fig 6, but at 230VAC input, in this case you can see the on time is even shorter as it takes very little time to get the energy required into the transformer. Again the circuit is operating in PRC mode with an input power of 790mW which again meets the Energystar and Blue Angel requirements for no load standby power.

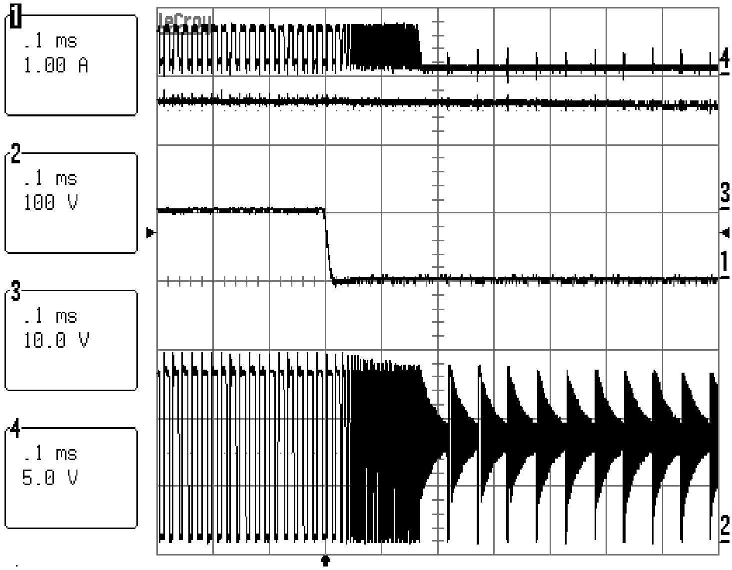


Fig 8)Drain (D) voltage of IRIS4009 (CH2)/Vcc Voltage (CH3)/ FB pin voltage (CH4)/Load Current (CH1) at 120VAC in/no load output

Fig 8) shows the circuit changing from Quasi-resonant mode to PRC mode due to a load change. The load change can be seen by the drop on CH1 from 1A to no load. As this occurs the operating frequency increases (less time needed to transfer energy to output) as the external standby circuit is in the process of cutting off the QR feedback signal to the feedback pin. Eventually the standby circuit completely cuts off the signal and the power supply starts operating again in the PRC mode with no quasi-resonant info on the FB pin.

Efficiency

In this section we will show the efficiency of the circuit under various conditions. Fig 9) shows a graph of the efficiency vs AC input voltage for a full load output. This shows the efficiency well above the 83% level for most of the input range.

Fig 10) shows the efficiency vs load current for various input voltages.

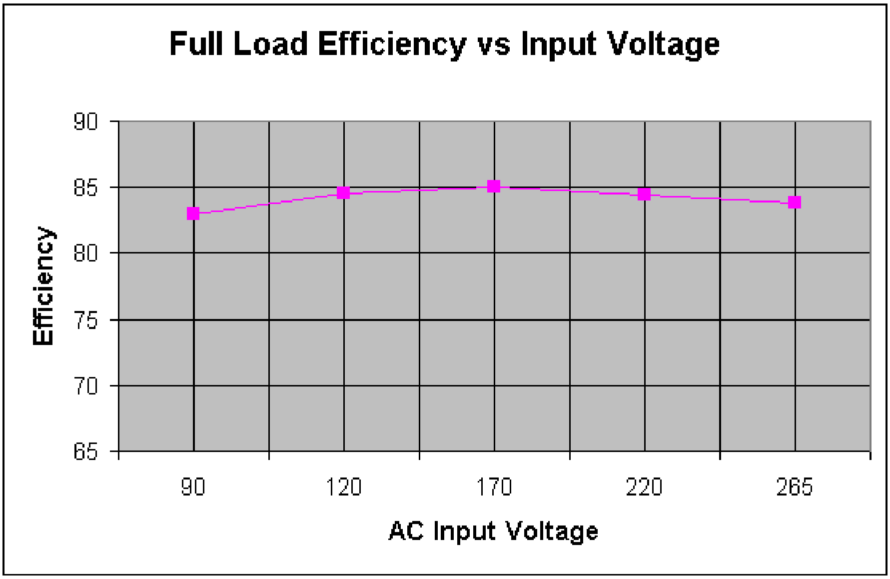

Full Load Efficiency vs Input Voltage
90
85
80
75
70
65
Efficiency
90
120
170
220
265
AC Input Voltage

Fig.9)

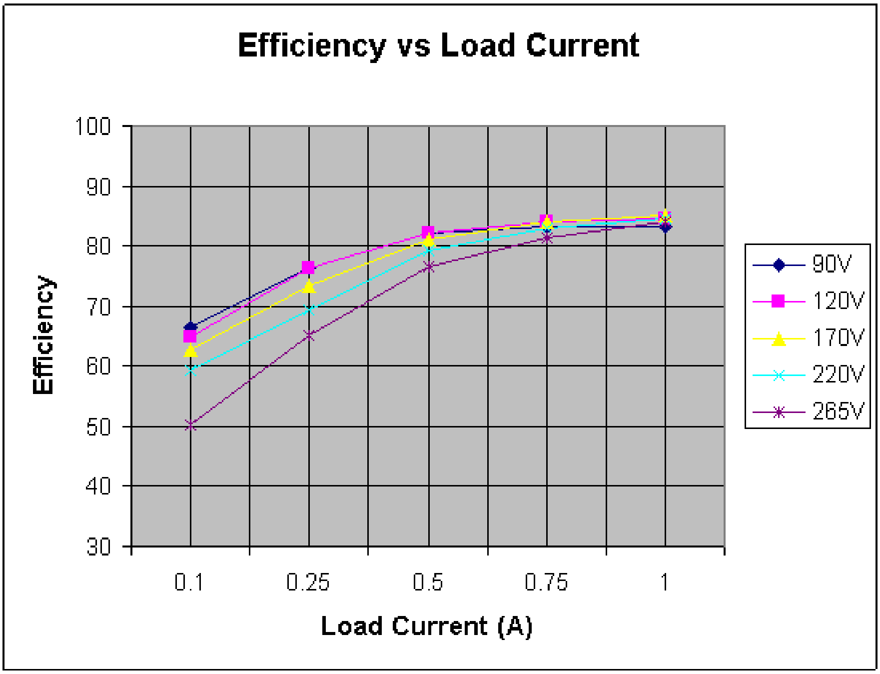

Efficiency vs Load Current
100
90
80
70
60
50
40
30
Efficiency
0.1
0.25
0.5
0.75
1
Load Current (A)
90V
120V
170V
220V
265V

Fig.10)

Standby/No Load Power Consumption

Fig 11) shows the standby or no load power consumption vs AC input voltage, showing that over the entire voltage range the power consumption is less than 1W ensuring it complies with the Energystar/Blue Angel requirements.

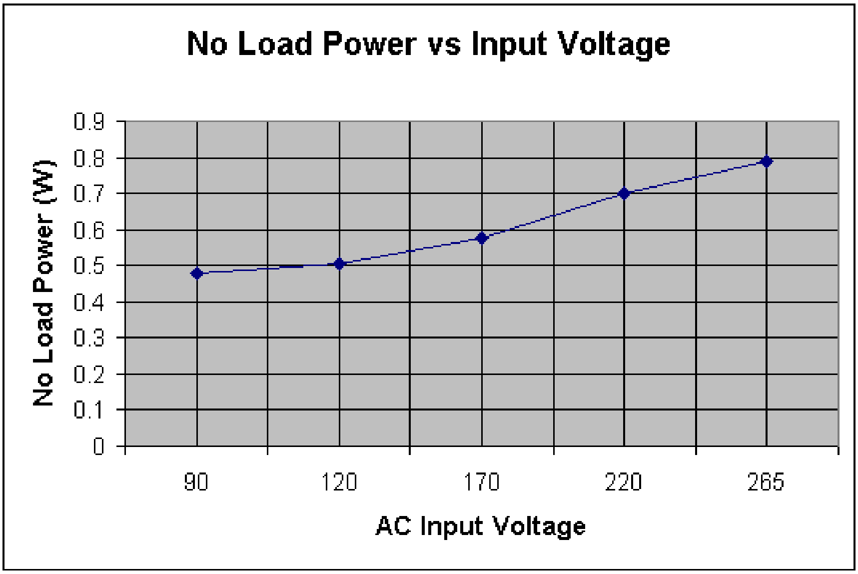
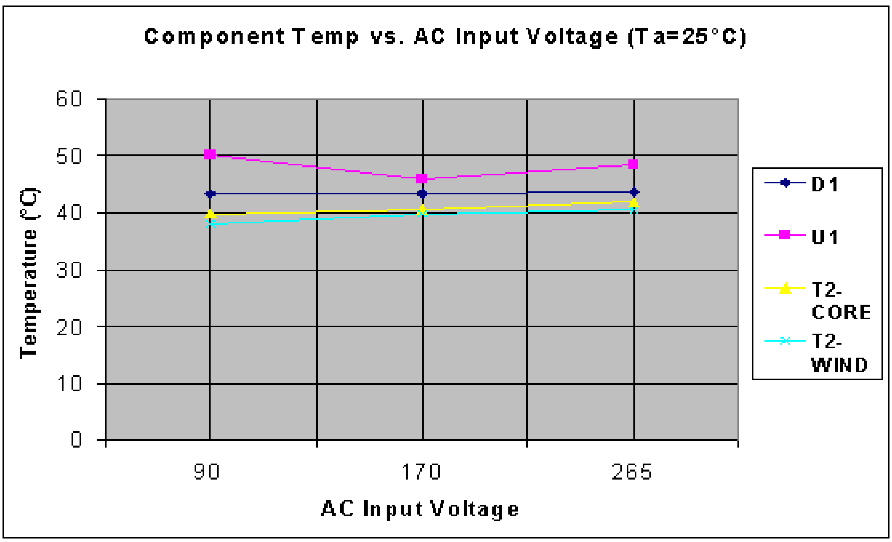


Fig. 11



Output Ripple

Fig 12) shows the output ripple of the power supply with a 90VAC input and full load 4A output. Peak to peak ripple is 45mV. the waveform is shown Bandwidth limited to remove HF noise from the measurement.

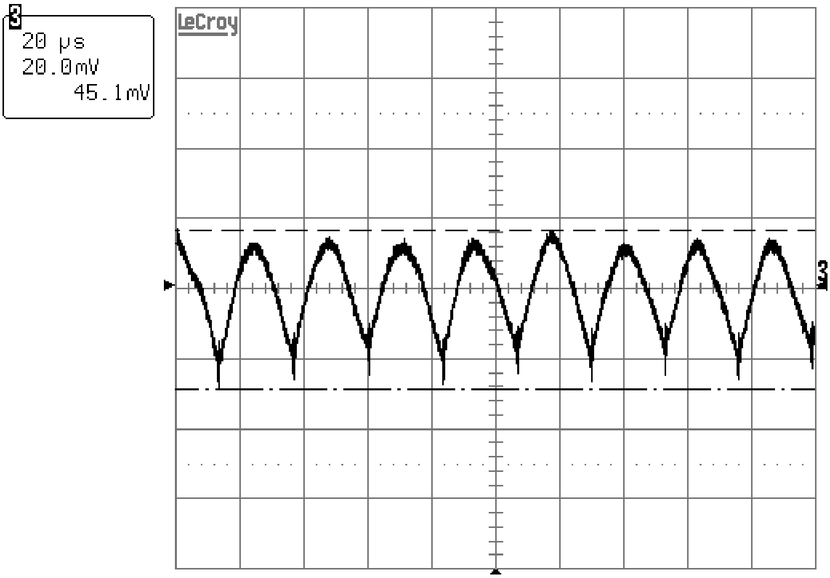


Fig 12) Output Ripple Voltage at 90VAC input / Full Load output

Transient Response

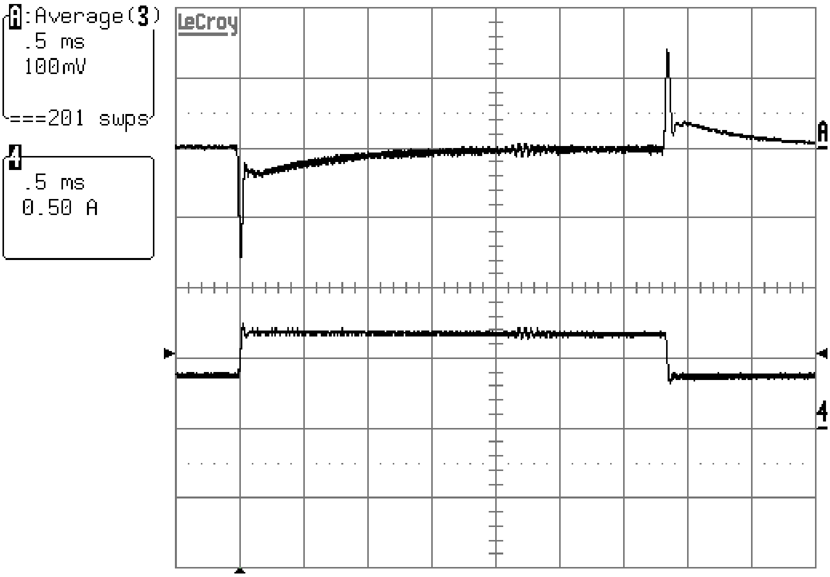
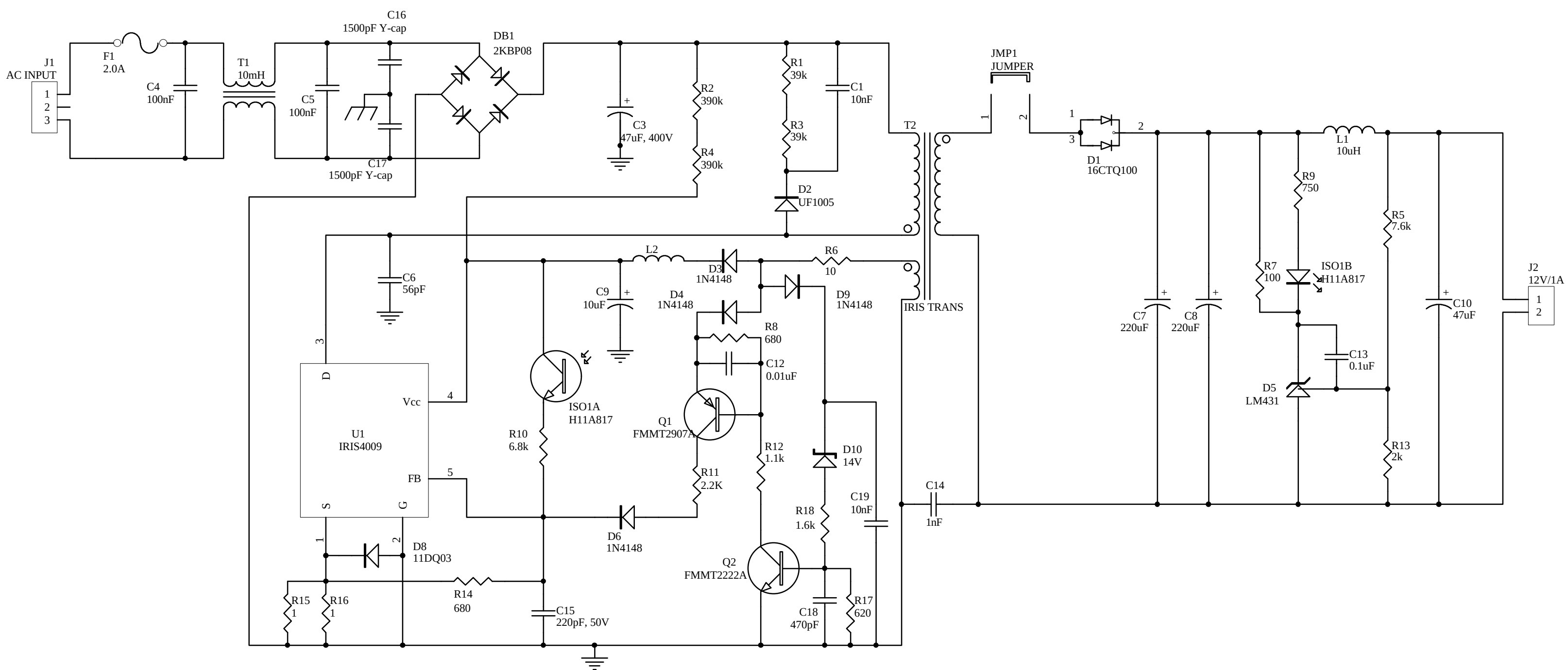


Fig 13) Transient Response at 90VAC in

Fig 13) shows the transient response of the power supply with a 90VAC input. The load change is set to change from 0.375 to 0.625 which is a 50% load typical setting ±25%.

Bill of materials for IRISMPS4 Reference Design						
Item	Quantity	Reference	Part Type	Description		
1	2	R1, R3	39k	1206 SMD Resistor		
2	2	R2, R4	390k	1206 SMD Resistor		
3	1	R5	7.68k	1206 SMD Resistor 1%		
4	1	R6	10R	Carbon Film Resistor 5% 1/4W		
5	1	R7	100R	1206 SMD Resistor		
6	2	R8, R14	680R	1206 SMD Resistor		
7	1	R9	750R	1206 SMD Resistor		
8	1	R10	6.8k	1206 SMD Resistor		
9	1	R11	2.2k	1206 SMD Resistor		
10	1	R12	1.1k	Carbon Film Resistor 5% 1/4W		
11	1	R13	2k	1206 SMD Resistor 1%		
12	2	R15, R16	1.0R	1206 SMD Resistor		
13	1	R17	620R	1206 SMD Resistor		
14	1	R18	1.6k	Carbon Film Resistor 5% 1/4W		
15	1	C1	1nF	1KV 10% Ceramic Disc Capacitor		
16	1	C2		not fitted		
17	1	C3	47uF	400V Electrolytic Capacitor		
18	2	C4, C5	100nF	250/275VAC Class X2 Capacitor		
19	1	C6	12pF	1KV 10% Ceramic Disc Capacitor		
20	2	C7, C8	220uF	25V High Ripple Current Electrolytic Capacitor		
21	1	C9	10uF	35V Electrolytic Capacitor		
22	1	C10	47uF	25V Electrolytic Capacitor		
23	1	C11		not fitted		
24	1	C12	0.01uF	0.01uF 50V 0805 ceramic capacitor		
25	1	C13	0.01uF	0.01uF 50V 0805 ceramic capacitor		
26	1	C14	1nF	250VAC Y1 ceramic disc capacitor		
27	1	C15	220pF	220pF 1206 50V ceramic capacitor		
28	1	C18	470pF	470pF 1206 50V ceramic capacitor		
29	2	C16, C17	1500pF	1500pF 250V Class Y1 capacitor		
30	1	C19	10nF	0.01uF 50V ceramic capacitor		
31	1	D1	16CTQ100	16A, 100V Schottky Rectifier		
32	1	D2	UF1005	1A, 600V Fast Recovery Rectifier		
33	4	D3,D4,D6, D9	1N4148	500mW Silicon Epitaxial Diode		
34	1	D5	LM431	Precision Shunt Regulator		
35	1	D10	1N5244	14V Zener Diode		
36	1	D8	11DQ03	1.1A 30V Schottky Rectifier		
37	1	F1	2.0A	Fast Acting TR5 Sub-Miniature Fuse		
38	1	T1	10mH	Line Filter		
39	1	T2	EFD25	Transformer		
40	1	L1	10uH	3A Inductor		
41	1	L2	bead	ferrite bead		
42	1	ISO1	H11A817	Optocoupler		
43	1	Q1	MMT2907	SMT PNP transistor		
44	1	Q2	MMT2222	SMT NPN transistor		
45	1	U1	IRIS4009	Switched Mode Power Supply IC		
46	1	DB1	2KBP08	Bridge		
47	2			Heatsink		
48	1	J1		3-Pin Header		
49	1	J2		2-Pin Header		



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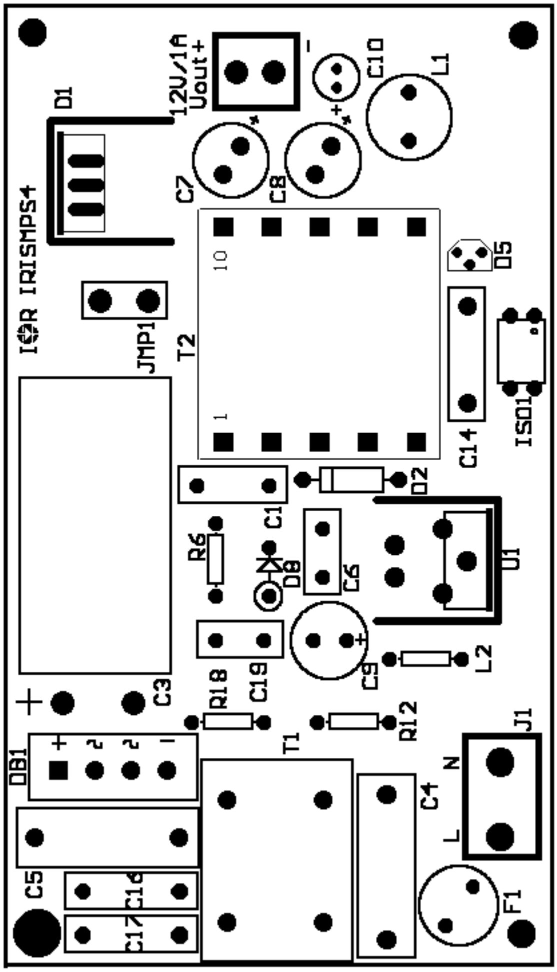
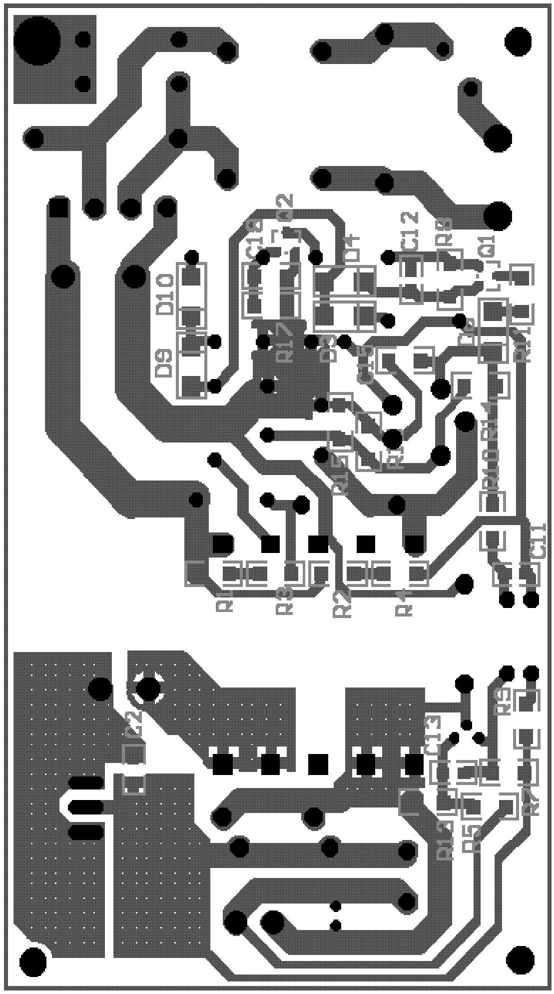
Top Board Layout



Bottom Board Layout



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