Supertex inc.

HV9906DB7

20W 220VAC Off-Line PFC Current Source Controller

Introduction

The Supertex HV9906DB7 demo board is a power factor corrected (PFC) LED driver using the HV9906 IC. The power conversion topology comprises an input buck-boost stage with an integrated energy storage capacitor and an output buck stage. The output voltage polarity is negative. Due to its double down conversion topology, the converter can operate directly off AC line to produce low-voltage output. By using an integrated non-electrolytic energy storage capacitor, the converter can achieve high power factor, low harmonic distortion of the input AC current while maintaining nearly DC output current.

HV9906DB7 demo board features power factor correction to PF>0.95. The board is optimized for driving a 700mA, 20W LED array. Output 100Hz current ripple is designed to be <30%. However, it can be improved by selecting a larger energy storage capacitor if needed.

Features

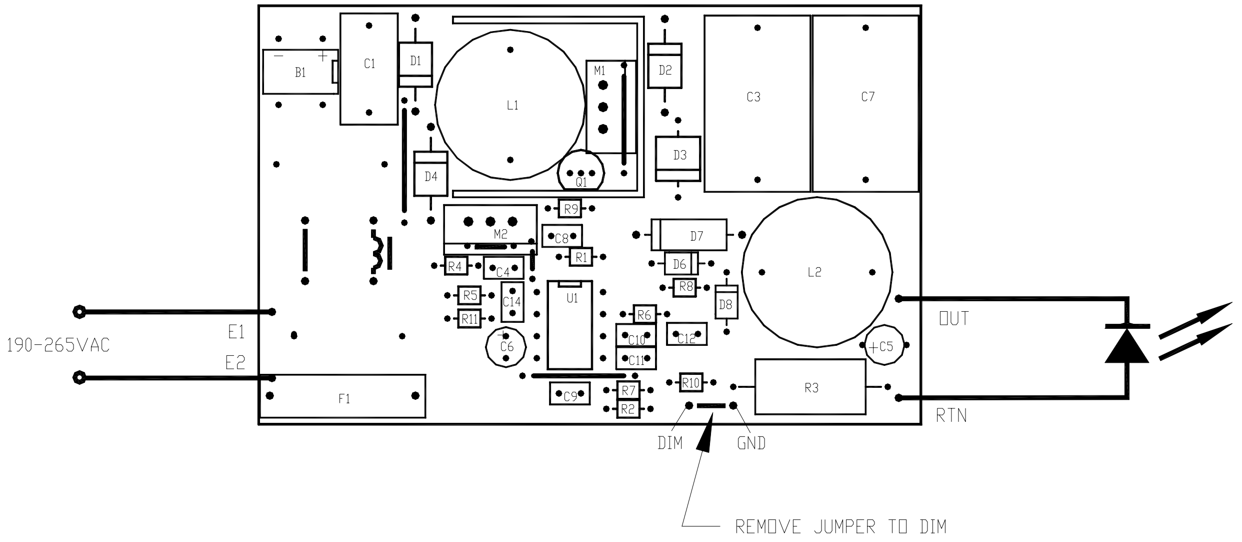
- Off-Line Transformerless Power Conversion
- Power Factor Correction to PF>0.95
- Soft Start
- Low Inrush Current on Start

Specification

Input Voltage	190 to 265VAC, 47-63 Hz or 200 to 400VDC
Output Current Setting	700mA ±10%
Max. Output Current	1.3A*
Max. Output Voltage	30V
Max. Output Power	20W
Power Factor	>0.95
Total AC Line Harmonic Distortion (THD)	<15%
Efficiency	78% typ.**

* Contact the factory for modifications required
** at Vo=28V, Io=0.7A, Vin=220VAC

Board Layout and Connections



WARNING!!!
Do not connect to scope ground or to the ground of other earth-grounded instruments. Doing so will short the AC line, resulting in damage to the circuit and/or instruments. Use either an isolation transformer on the AC line, use a differential probe, or use a floating, battery-powered instrument to make measurements.

WARNING!!!
No galvanic isolation. Dangerous voltages are present when connected to the AC mains.

Instructions

OUT, RTN

Connect your LED to these terminals. Make sure that it is connected in the polarity shown in the wiring diagram above.

E1, E2

Connect 190 to 265VAC line source to these terminals. The input is fuse protected to 1A.

Setting Output Current and Dimming

Output current is preset to 700mA for this board. Output current can be re-programmed to <700mA by selecting R3 or R8 according to the following equation:

$$\mathbf{I}_{\mathbf{OUT}} = \frac{\mathbf{R}6 + \mathbf{R}8 - (\mathbf{R}7 + \mathbf{R}10)}{(\mathbf{R}7 + \mathbf{R}10) \cdot \mathbf{R}3} \cdot 1\mathbf{V}$$

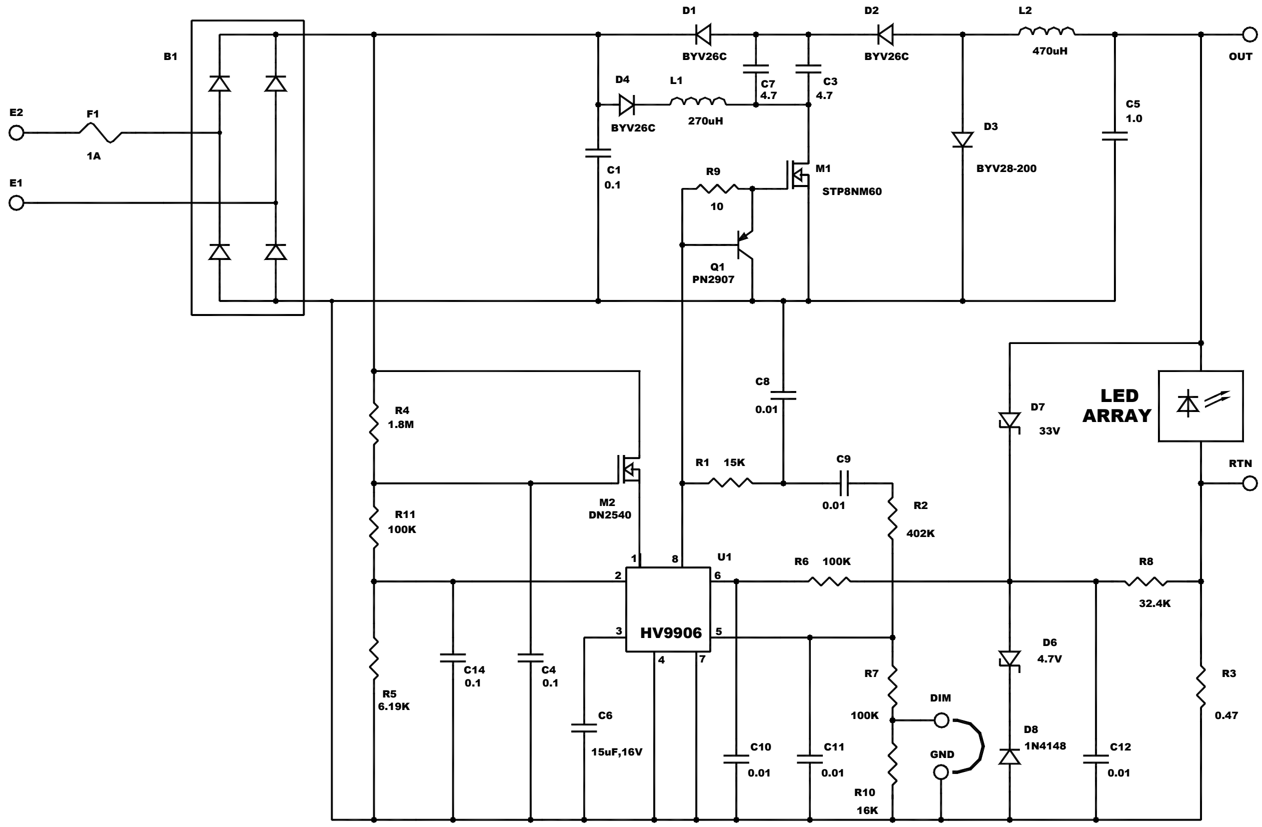
Resistor R10 is 0Ω if no dimming is needed. The board can be optimized to provide up to 1.3A. Contact the factory for the modifications required.

Removing the jumper between DIM and GND reduces the output current to 350mA. Adjustable dimming may be achieved by connecting a potentiometer or an external 0 to 0.3V voltage source to DIM pin with respect to GND.

Controlling Output Current Ripple

Output current ripple (100Hz) can be controlled by selecting an appropriate value of an energy storage capacitor C3/C7. Larger value of C3/C7 improves power factor and THD as well.

Schematic Diagram



Circuit Description

Power Train

The power train of the converter consists of an input buck-boost stage L1/D4/D1/M1, an output buck stage L2/D2/D3/M1 and an energy storage capacitor C3/C7. The output buck stage operates in continuous conduction mode (CCM). Thus the output switching ripple current is low. The input buck-boost stage operates in discontinuous conduction mode (DCM). Both stages share a single active switch M1. When C3/C7 value is selected large enough, the power switch M1 operates at nearly constant duty ratio **D = Ton*Fs** throughout an AC line cycle, where **Ton** is the on-time, **Fs** is the switching frequency. Then peak current **Ipk** in the input buck-boost inductor L1 is proportional to the input AC voltage. Since input current of a buck-boost converter operating in DCM is **Iin = 0.5*Ipk*D**, the converter exhibits a unity power factor (**PF≈1**). Both Ton and Fs are constant for a given input AC line voltage and output current with exception of small 100Hz jitter helping to pass the input EMI requirements.

Feed Forward Circuit

Feed forward circuit R4/R11/R5/C4/C14 sets a voltage level **Von** at pin 2 of HV9906 proportional to the input AC voltage **Vac**. This voltage level determines the on time duration at the gate drive pin 8 according to the following equation:

$$\mathbf{Ton} = 0.085 + \frac{0.65}{\mathbf{Von}} \ (\mu\text{s})$$

Therefore, **Ton*Vac** is nearly constant regardless of the input AC voltage. Then the energy stored in the inductor L1 every switching cycle is not a function of **Vac**, and the switching frequency Fs will be proportional to the output power only. This will mean fixed switching frequency for a given output load.

Integral Locked Loop (ILL) Current Feedback and Compensation

The feedback regulates voltage across the sense resistor R3 by forcing currents sourced by pin 5 and pin 6 of HV9906 to be the same. Two built-in transconductor circuits maintain a 1V voltage level at both pins 5 and 6. These currents are integrated over a switching cycle. The resulting integrals are compared at the end of each switching cycle. If the output voltage of the integrator circuit of pin 5 exceeds the same of pin 6, the switching frequency is incremented by a small increment. The switching frequency is decremented otherwise. Therefore, the output current of the converter is regulated at:

$$\mathbf{Iout} = 1\mathbf{V} \cdot \frac{\mathbf{R}6 + \mathbf{R}8 - \mathbf{R}7}{\mathbf{R}7 \cdot \mathbf{R}3}$$

The output current contains a low frequency ripple component at twice the AC line frequency proportional to the voltage ripple across the energy storage capacitor C3/C7. Many applications can tolerate certain AC ripple current. This permits using non-electrolytic energy storage capacitors for C3/C7, that greatly improves the overall reliability. However, the bandwidth of the current feedback needs to be limited well below twice the AC line frequency in order not to affect the power factor and input current harmonic distortion. This is achieved by adding compensation components R1/C8/C9/R2/R8/C12. The low pass filter R1/C8 forms a continuous error voltage. A single pole at the origin is set by the capacitor C9. A low pass filter R8/C12 contributes a pole in the open loop gain in order to cancel the effect of a zero introduced by the low pass filter R1/C8 and to limit the slew rate of the feedback signal for better ILL tracking.

Input Under Voltage Lockout (UVLO) Circuit

The UVLO circuit is formed by a voltage divider / low pass filter R4/R11/R5/C4 and the depletion mode FET M2. When the input AC line voltage drops approximately below 170VAC, voltage at pin 1 of HV9906 drops below 8.5V. This condition will trigger an under voltage comparator monitoring the bias voltage at pin 3 and disable switching. Under the normal operating condition, the pass element M2 will dissipate most of the power loss in the bias supply for HV9906.

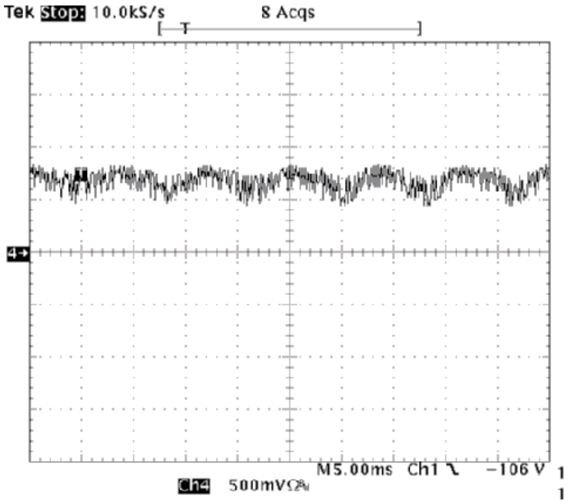
Output Open Circuit Protection

Adding a simple circuit consisting of D6, D7 and D8 protects the converter from output open circuit condition. When this condition occurs, the output voltage becomes clamped at the total Zener voltage of D6 and D7. The voltage drop of about 5V across D6 and D8 will be introduced into the current feedback forcing the HV9906 into its minimum switching frequency of approximately 15kHz. Therefore, power dissipation in D6/D7/D8 is minimized.

Typical Performance Characteristics

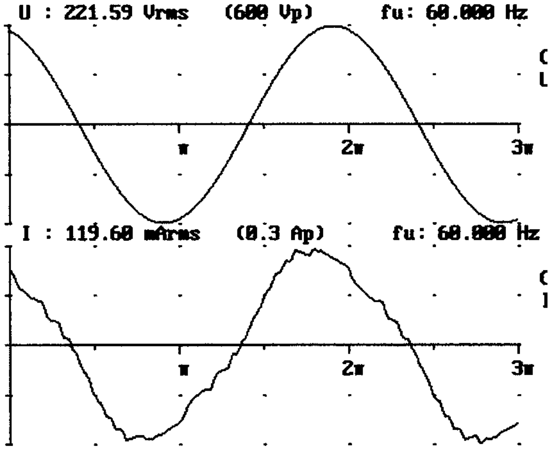
Output Current

(Io = 700mA, Vo = 28V, Vin = 220VAC)



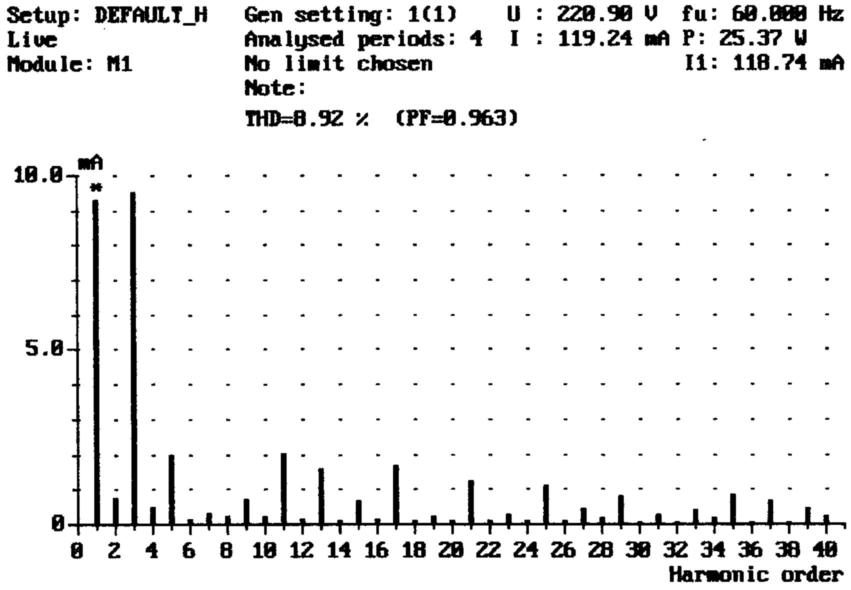
Input AC Voltage and Current

(Io = 700mA, Vo = 28V, Vin = 220VAC)



AC Current Harmonics

(Io = 700mA, Vo = 28V, Vin = 220VAC)



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Setup: DEFAULT_H   Gen setting: 1(1)     U : 220.90 V  fu: 60.000 Hz
Live               Analysed periods: 4   I : 119.24 mA P: 25.37 W
Module: M1         No limit chosen                     I1: 118.74 mA
                   Note:
                   THD=8.92 %  (PF=0.963)
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Parts List

Item	Reference	Description	Manufacturer	Part No.
1	B1	Diode Bridge	Diodes Inc. or equivalent	DF06M
2	C1	0.1 uF, 400V, 10%	Panasonic MP Film	ECQ-E4104KF
4	C3	4.7 uF, 250V, 10%	Panasonic MP Film	ECQ-E2475KF
5	C7	4.7 uF, 250V, 10%	Panasonic MP Film	ECQ-E2475KF
6	C4	0.1uF, 63V, 5%	WIMA MP Film	MKS 02 .1/63
7	C5	1.0 uF, 50V, 10%	Kemet or equivalent	
8	C6	15 uF, 16V, 10%, Tantalum	Kemet or equivalent	T350E156K016AS
9	C8	0.01uF, 63V, 5%	WIMA MP Film	MKS 02 .01/63
10	C9	0.01uF, 63V, 5%	WIMA MP Film	MKS 02 .01/63
11	C10	0.01uF, 63V, 5%	WIMA MP Film	MKS 02 .01/63
12	C11	0.01uF, 63V, 5%	WIMA MP Film	MKS 02 .01/63
13	C12	0.01uF, 63V, 5%	WIMA MP Film	MKS 02 .01/63
14	C14	0.1uF, 63V, 5%	WIMA MP Film	MKS 02 .1/63
15	D1	Ultra Fast, 600V, 1A	Philips	BYV26C
16	D2	Ultra Fast, 600V, 1A	Philips	BYV26C
17	D3	Ultra Fast, 200V, 3A	Philips	BYV28-200
18	D4	Ultra Fast, 600V, 1A	Philips	BYV26C
19	D6	Zener, 4.7V 250mW	Diodes Inc. or equivalent	
20	D7	TVS, 33V 5W	GI or equivalent	
21	D8	1N4148	On Semi or equivalent	1N4148
22	F1	1A, Slow Blow, 5mmX15mm	Bussmann or equivalent	
23	L1	270uH	204 turns 29AWG, Micrometals T60-2	
24	L2	470uH	95 turns 24AWG, Micrometals T60-52	
25	M1	MOSFET, 600V, 8A, 0.9Ω	ST Microelectronics	STP8NM60
26	M2	MOSFET, 400V, 25Ω DEPL	Supertex, Inc.	DN2540N5
27	Q1	BJT, PNP	On Semi or equivalent	PN2907
28	R1	15K, 1%	Panasonic or equivalent	
29	R2	402K, 1%	Panasonic or equivalent	
30	R3	0.47, 1%	Panasonic or equivalent	
31	R4	1.8 M, 1%	Panasonic or equivalent	
32	R5	6.19 K, 1%	Panasonic or equivalent	
33	R6	100K, 1%	Panasonic or equivalent	
34	R7	100K, 1%	Panasonic or equivalent	
35	R8	32.4K, 1%	Panasonic or equivalent	
36	R9	10, 5%	Panasonic or equivalent	
37	R10	16K, 5%	Panasonic or equivalent	
38	R11	100K, 1%	Panasonic or equivalent	
39	U1	PWM/PFM IC	Supertex, Inc.	HV9906P