Off-Line Current Source Controller

Introduction

The Supertex HV9906DB2V4 demo board is an LED driver circuit using the HV9906. The power converter of the demo board consists of an input buck-boost stage and an output buck stage. The output voltage polarity is negative. Due to the double down conversion topology used, the converter can operate directly off of an AC line to produce low-voltage output without the use of a transformer. The converter does not require any electrolytic capacitors and maintains output current with low peak-to-average ratio.

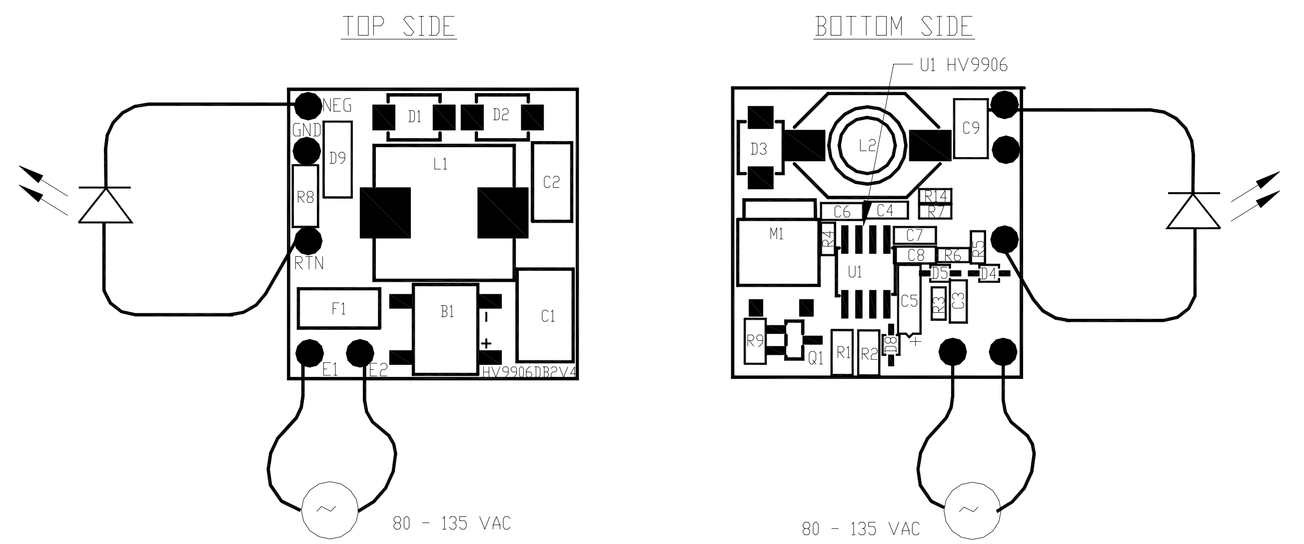
The circuit is practical for up to 5W of output power. It features low cost and very high reliability.

The HV9906DB2 demo board is optimized for driving a 12V 350mA LED array. However, it may be modified to meet custom requirements.

Specification

Input Voltage	80 to 135VAC, 60Hz
Output Current	350mA ±10%
Output Voltage	12V max.
Efficiency	66% typ.

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. Either use an isolation transformer on the AC line, or 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.

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Instructions

NEG, RTN

Connect your LED to these terminals: negative to NEG, positive to RTN.

E1, E2

Connect 80 to 135VAC, 60Hz line source to these terminals: line to E1, neutral to E2. The input is protected with a 0.5A fuse.

GND

This is the common circuit.

Note *that since galvanic isolation is not provided, connecting this point to an earth-grounded instrument (such as an oscilloscope) will short the AC line, resulting in circuit and/or instrument damage.*

Also note *that GND may be at higher potential with respect to earth ground, even if the AC is switched off. Use caution!*

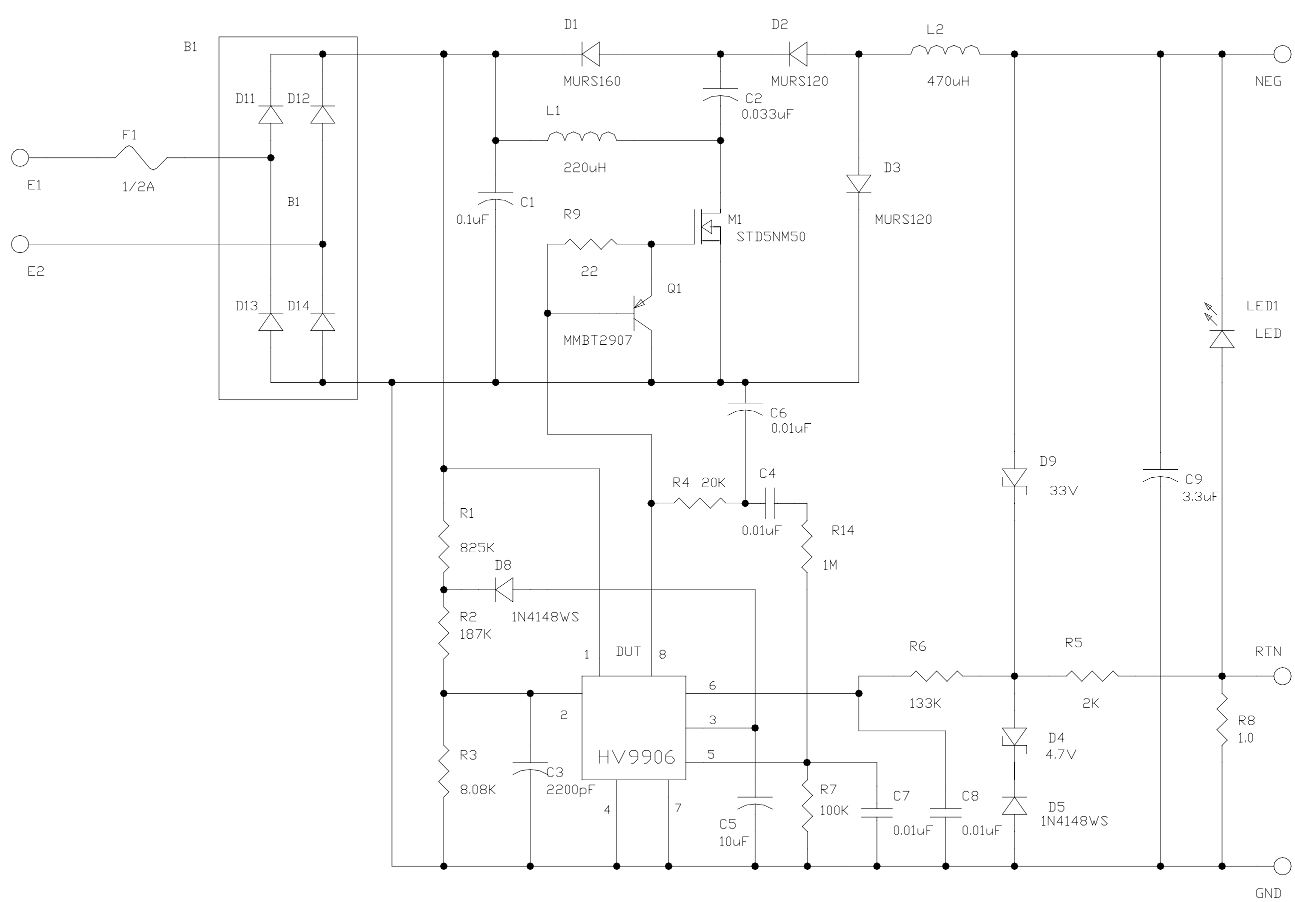
Do not connect to earth-ground.

Setting Output Current

Output current is preset to 350mA for this board. Output current can be re-programmed according to the following equation:

$$\mathbf{Iout} = \frac{\mathbf{R}5 + \mathbf{R}6 - \mathbf{R}7}{\mathbf{R}7 \cdot \mathbf{R}8} \cdot 1\mathbf{V}$$

Schematic Diagram



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Circuit Description

Power Train

The power train of the converter consists of an input buck-boost stage L1/D1/C2/M1 and an output buck stage L2/D2/D3/M1. 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. The double conversion structure of the converter's power train permits operation at low output voltage without a power transformer.

Feed Forward Circuit

Feed forward circuit R1/R2/R3 sets a voltage level Von at pin 2 of HV9906 proportional to the instantaneous input voltage Vin. This voltage level determines the on-time duration at the gate drive pin 8 according to the following equation:

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

Therefore, Ton*Vin is nearly constant at any input voltage. Then the energy stored in the inductor L1 every switching cycle is not a function of Vin, and the switching frequency Fs will be proportional to the output power only. Thus, fixed switching frequency for a given output load is achieved.

The capacitor C3 is for de-coupling of high frequency noise.

When the input voltage drops below a certain level, the inductor L1 may enter a continuous conduction mode. If this occurs, the inductor current is no longer related to Ton, and the above feed forward equation is no longer optimal. This condition may cause output current spikes during the AC line cusps. Therefore, a minimum feed forward voltage clamp is needed. Diode D8 limits the minimum Von at 0.2V. This corresponds to Vin ≈ 50V. Adding this feed forward clamp ensures discontinuous conduction mode of L1.

Integrating Lock Loop Current Feedback and Compensation

The feedback regulates voltage across the sense resistor R8 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:

$$\mathbf{Iout} = 1\mathbf{V} \cdot \frac{\mathbf{R}6 + \mathbf{R}5 - \mathbf{R}7}{\mathbf{R}7 \cdot \mathbf{R}8}$$

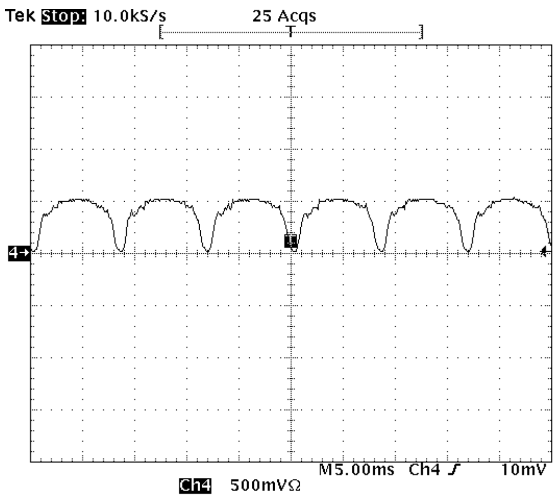
The converter control loop is stable and does not require compensation. However, disruptions in the power transfer near the AC line cusps create transients in the control loop and may cause output current to overshoot. Therefore, it is recommended to add a feedback circuit C4/R14 in order to limit the bandwidth of the output current control loop to a few hundred Hertz. The low pass filter R4/C6 is used to develop a continuous error signal from the gate drive output.

Output Open Circuit Protection

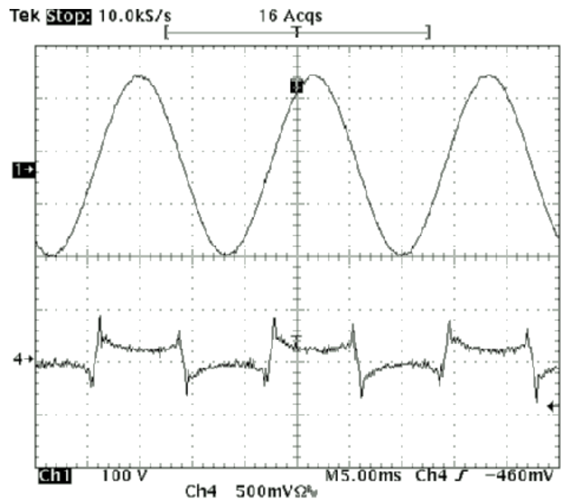
Adding a simple circuit consisting of D4, D5 and D9 protects the converter from the output open circuit condition. When this condition occurs, the output voltage becomes clamped at the total Zener voltage of D4 and D9 and the forward voltage of D5. The voltage drop of about 5V across D4 and D5 will be introduced into the current feedback forcing the HV9906 into its minimum switching frequency of approximately 15kHz. Therefore, power dissipation in D4/D5/D9 is minimized.

Typical Performance Characteristics

Output current
(Io = 350mA, Vo = 12V, Vin = 120VAC)



Input AC Voltage and Current
(Io = 350mA, Vo = 12V, Vin = 120VAC)



Parts List

Item	Reference	Part	Package	Manufacturer	Part Number
1	B1	Diode Bridge		Diodes Inc.	DF04S
2	C1	Cap, PEN Film 0.1uF 250V	SMD2420	Panasonic	ECW-U2104KC9
3	C2	Cap, PEN Film 0.033uF 250V	SMD1913	Panasonic	ECW-U2333KC9
4	C3	Cap, C0G 2200pF 5%	SMD0805	Panasonic or equiv.	
5	C4	Cap, PEN Film 0.01uF, 16V	SMD0805	Panasonic	ECH-U1C103JX5
6	C5	10 uF, 16V Tantalum Chip	Size B	Panasonic or equiv.	
7	C6	Cap, PEN Film 0.01uF, 16V	SMD0805	Panasonic	ECH-U1C103JX5
8	C7	Cap, PEN Film 0.01uF, 16V	SMD0805	Panasonic	ECH-U1C103JX5
9	C8	Cap, PEN Film 0.01uF, 16V	SMD0805	Panasonic	ECH-U1C103JX5
10	C9	3.3 uF, 35V Tantalum Chip	Size B	Panasonic or equiv.	
11	D1	Diode, Ultra Fast, 600V 1A	SMA	On Semi	MURS160T3
12	D2	Diode, Ultra Fast, 200V 1A	SMA	On Semi	MURS120T3
13	D3	Diode, Ultra Fast, 200V 1A	SMA	On Semi	MURS120T3
14	D4	Diode, Zener 4.7V 200mW	SOD-323	Diodes Inc.	BZT52C4V7S
15	D5	Diode, 75V 200mW	SOD-323	Diodes Inc.	1N4148WS
16	D8	Diode, 75V 200mW	SOD-323	Diodes Inc.	1N4148WS
17	D9	Diode, Zener 15V 1W	DL-41	Diodes Inc.	ZM4744A
18	F1	Fuse, 1/2A, Slow Blow		Littelfuse	R452.500
19	L1	220uH, 1.2A		Central Technologies	CTCDRH127-221
20	L2	470uH, 0.5A		Coilcraft	DO3316P-471
21	M1	MOSFET, 500V	D-PAK	ST Microelectronics	STD5NM50

22	Q1	BJT, PNP	SOT-23	On Semi	MMBT2907
23	R1	825K ohm, 1%, 1/8W	SMD0805		
24	R2	187K ohm, 1%, 1/8W	SMD0805		
25	R3	8.08K ohm, 1%, 1/8W	SMD0603		
26	R4	20K ohm, 1%, 1/8W	SMD0603		
27	R5	2.0K ohm, 1%, 1/8W	SMD0603		
28	R6	133K ohm, 1%, 1/8W	SMD0603		
29	R7	100K ohm, 1%, 1/8W	SMD0603		
30	R8	1.0 ohm, 1%, 1/4W	SMD1206		
31	R9	22 ohm, 1%, 1/8W	SMD0805		
32	R14	1.0M ohm, 1%, 1/8W	SMD0603		
33	U1	PWM/PFM IC	SOIC-8	Supertex, Inc.	HV9906

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