Universal High Brightness LED Driver

Feature

- >90% Efficiency
- Universal rectified 85-265VAC input range
- Constant-Current LED driver
- Applications from a few mA to more than 1A output
- LED string from one to hundreds of diodes
- PWM Low-Frequency Dimming via Enable pin
- Input Voltage Surge ratings up to 500V
- Internal thermal overload protection

Product Description

The NU9910 is a PWM high-efficiency LED driver Control IC.

It allows efficient operation of High Brightness (HB) LEDs from voltage sources ranging from 85VAC up to 265VAC.

The NU9910 controls an external MOSFET at fixed switching frequency up to 100KHZ. The frequency can be programmed using a Single external resistor. The LED string is driven at constant current rather than constant voltage, thus providing constant light output and enhanced reliability. The output current can be programmed between a few milliamps and up to more than 1A.

NU9910 uses a rugged high voltage junction isolated process that can withstand an input voltage surge of up to 450V. Output current to an LED string can be programmed to any value between zero and its maximum value by applying an external control voltage at the linear dimming control input of the NU9910. The NU9910 provides a low-frequency PWM dimming input that can accept an external Control signal with a duty ratio of 0-100% and a frequency of up to a few kilohertz.

Applications

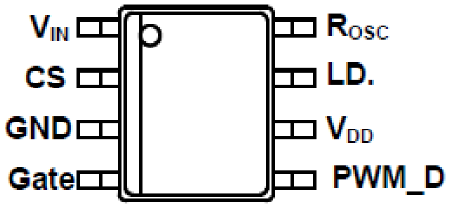
- AC/DC LED Driver applications
- RGB Backlighting LED Driver
- Back Lighting of Flat Panel Displays
- General purpose constant current source
- Signage and Decorative LED Lighting
- Chargers

Package Type

SOP8

Pin Assignment

- SOP 8



Terminal Description

Pin name	Function
V_{IN}	Input voltage
CS	Senses LED string current
GND	Device ground
CATE	Drives the gate of the external MOSFET
PWM_D	Low Frequency PWM Dimming pin, also Enable input.
V_{DD}	Internally regulated supply voltage.7.5V nominal. Can supply up to 1 mA for external circuitry. A sufficient storage capacitor is used to provide storage when the rectified AC input is near the zero crossings.
LD	Linear Dimming by changing the current limit threshold at current sense comparator
ROSC	Oscillator control. A resistor connected between this pin and ground sets the PWM frequency

Absolute Maximum Ratings

Parameter	Value
VIN to GND	-0.5V to +500V
CS, GATE to GND	7V
LD,PWM_D to GND	36V
VDDMAX	36
8Pin SO(derate 6.3mW/℃ above =25℃)	630mW
Operating Temperature Range	-40℃ to +85℃
Junction Temperature	+125℃
Storage Temperature Range	-55℃ to +150℃

Note：

*** The power dissipation values are based on the condition that junction temperature TJ and ambient temperature TA difference is 100°C.**

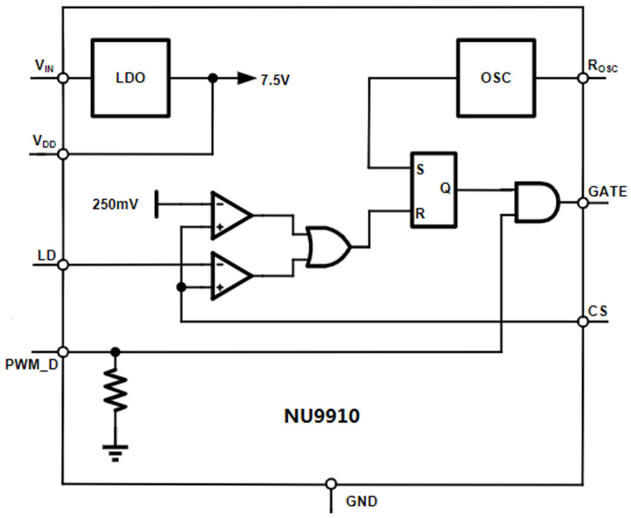
*** Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and function operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum -rated conditions for extended periods may affect device reliability.**

***Stresses exceeding Maximum Ratings may damage the device. Maximum Ratings are stress ratings only. Functional operation above the recommended operating conditions is not implied. Extended exposure to stresses above the Recommended Operating Conditions may affect device reliability.**

Electrical Characteristics and Recommended Operating Conditions

Characteristic	Symbol	Condition	Min.	Typ.	Max.	Unit
Input DC supply voltage range	VINDC	DC input voltage	8.0	-	450	V
Shut-Down mode supply current	IINSD	Pin PWM_D to GND,VIN=8V	-	0.1	0.2	mA
Internally regulated voltage	VDD	VIN=8-450V		7.5		V
Maximum pin VDD voltage	VDDmax	When an external voltage applied to pin VDD	-	-	32	V
VDD under voltage lockout threshold	UVLO	VIN rising	-	6.5	-	V
VDD under voltage lockout threshold	△UVLO	VIN falling	-	500	-	mV
Pin PWM_D input low voltage	VEN(IO)	VIN=8-450V	-	-	0.8	V
Pin PWN_D input high voltage	VEN(hi)	VIN=8-450V	2.0	-	-	V
Current sense pull-in Threshold voltage	Vcs(hi)	@TA=-40℃to+85℃	235	245	255	mV
GATE high putput Voltage	VGATE(hi)		VDD -0.3	-	VDD	V
GATE low output Voltage	VGATE(lo)		0	-	0.3	V
Oscillator frequency	fosc	Rosc=1.00MΩ	-	20	-	kHZ
		Rosc=226KΩ	70	83	96	
Maximum Oscillator PWM Duty Cycle	DMAXhf	HV floating	-	90	-	%
Linear Dimming pin Voltage range	VLD	@TA=<85℃,Vin=20V	0	-	250	mV
Current sense blanking interval	TBLANK	Vcs=0.55VLD, VLD=VDD	-	500	-	ns
GATE output rise time	tRISE	CGATE=500PF	-	50	-	ns
GATE output fall time	tFALL	CGATE=500PF	-	50	-	ns
Thermal shut down	TSD		-	155		℃

Block diagram



Typical Application Circuit

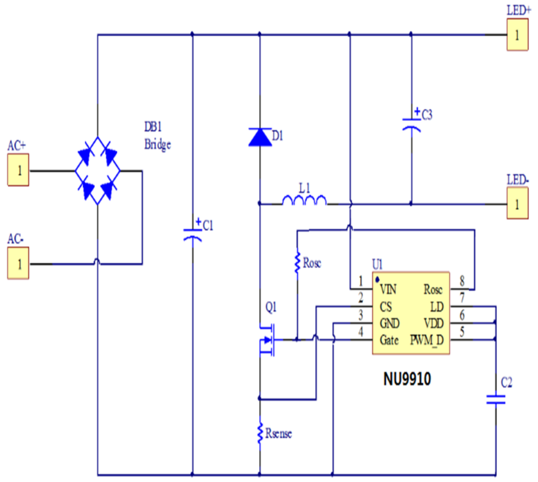


Figure 1: Constant-off time frequency mode

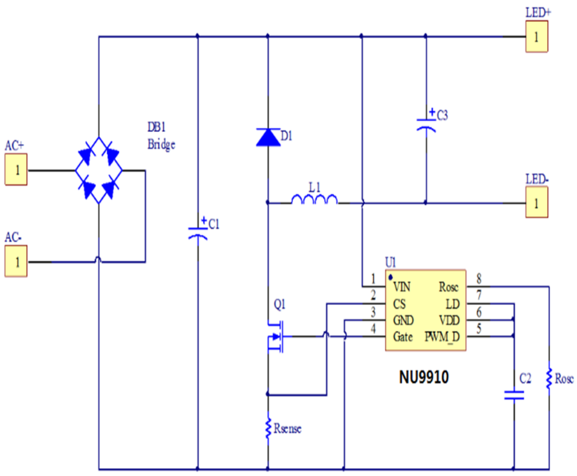


Figure 2: Constant frequency mode

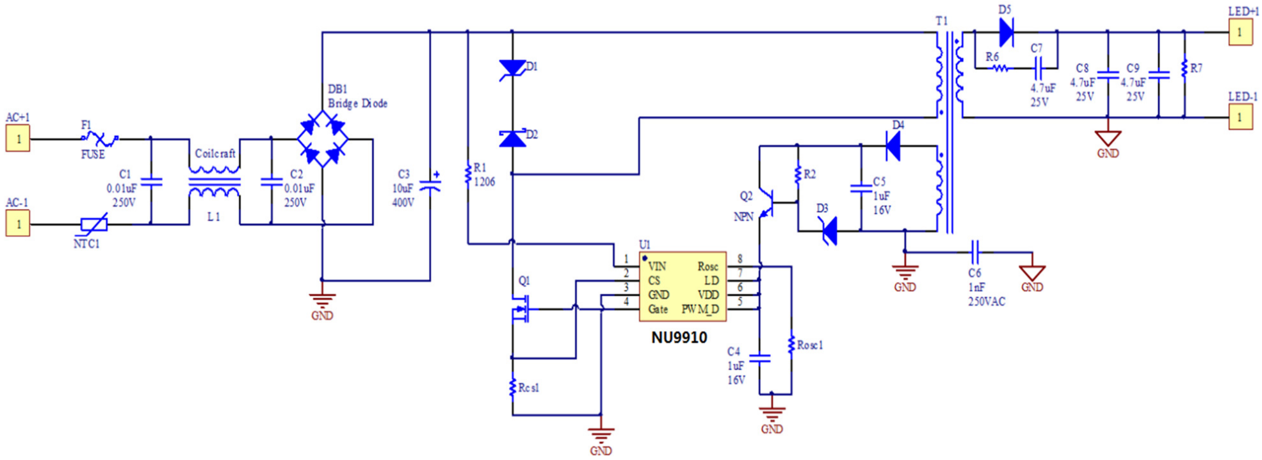


Figure 3: Isolated Circuit

Application Information

AC/DC Off-Line Applications

The NU9910 is a low-cost off-line buck or boost converter control IC specifically designed for driving multi-LED stings or arrays. It can be operated from either universal AC line or any DC voltage between 8-450V. Optionally, a passive power factor correction circuit can be used in order to pass the AC harmonic limits set by EN 61000-3-2 Class C for lighting equipment having input power less than 25W.
The NU9910 can drive up to hundreds of High-Brightness (HB) LEDs or multiple strings of HB LEDs. The LED arrays can be configured as a series or series/parallel connection. The NU9910 regulates constant current that ensures controlled brightness and spectrum of the LEDs, and extends their lifetime. The NU9910 features an enable pin (PWM_D) that allows PWM control of brightness.
The NU9910 can also control brightness of LEDs by programming continuous output current of the LED driver (so-called linear dimming) when a control voltage is applied to the LD pin.
The NU9910 includes an internal high-voltage linear regulator that powers all internal circuits and can also serve as a bias supply for low voltage external circuitry.

LED Driver Operation

The NU9910 can control all basic types of converters, isolated or non-isolated, operating in continuous or discontinuous conduction mode. When the gate signal enhances the external power MOSFET, the LED driver stores the input energy in an inductor or in the primary inductance of a transformer and, depending on the converter type, may partially deliver the energy directly to LEDs The energy stored in the magnetic component is further delivered to the output during the off cycle of the power MOSFET producing current through the string of LEDs (Flyback mode of operation).

When the voltage at the VDD pin exceeds the UVLO threshold the gate drive is enabled. The output current is controlled by means of limiting peak current in the external power MOSFET. A current sense resistor is connected in series with the source terminal of the MOSFET. The voltage from the sense resistor is applied to the CS pin of the NU310.

When the voltage at CS pin exceeds a peak current sense voltage threshold, the gate drive signal terminates, and the power MOSFET turns off. The threshold is internally set to 250mV, or it can be programmed externally by applying voltage to the LD pin. When soft start is required, a capacitor can be connected to the LD pin to allow this voltage to ramp at a desired rate, therefore, assuring that output current of the LED ramps gradually.

Optionally, a simple passive power factor correction circuit, consisting of 3 diodes and 2 capacitors, can be added as shown in the typical application circuit diagram of Figure 1.

Supply Current

A current of 1mA is needed to start the NU9910. As shown in block diagram, this current is internally generated in NU9910 without using bulky startup resistors typically required in the offline applications. Moreover, in many applications the NU9910 an be continuously powered using its internal linear regulator that provides a regulated voltage of 7.5V for all internal circuits.

Setting Light Output

When the buck converter topology of Figure 1 is selected, the peak CS voltage is a good representation of the average current in the LED. However, there is a certain error associated with this current sensing method that needs to be accounted for. This error is introduced by the difference between the peak and the average current in the inductor.

For example if the peak-to-peak ripple current in the inductor is 150mA, to get a 500mA LED current, the sense resistor should be 245mV/(500mA+ 0.5*150mA) ≈ 0.43Ω.

Dimming

Dimming can be accomplished in two ways, separately or combined, depending on the application. Light output of the LED can be controlled either by linear change of its current, or by switching the current on and off while maintaining it constant. The second dimming method (so-called PWM dimming) controls the LED brightness by varying the duty ratio of the output current.

The linear dimming can be implemented by applying a control voltage from 0 to 250mV to the LD pin. This control voltage overrides the internally set 250mV threshold level of the CS pin and programs the output current accordingly.

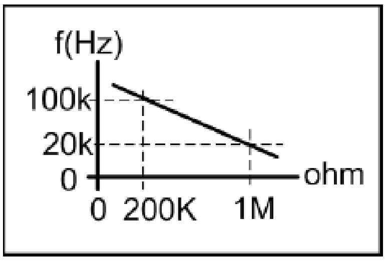
For example, a potentiometer connected between VDD and ground can program the control voltage at the CS pin. Applying a control voltage higher than 250mV will not change the output current setting. When higher current is desired, select a smaller sense resistor.

The PWM dimming scheme can be implemented by applying an external PWM signal to the PWM_D pin. The PWM signal can be generated by a microcontroller or a pulse generator with a duty cycle proportional to the amount of desired light output. This signal enables and disables the converter modulating the LED current in the PWM fashion. In this mode, LED current can be in one of the two states: zero or the nominal current set by the current sense resistor. It is not possible to use this method to achieve average brightness levels higher than the one set by the current sense threshold level of the NU310. By using the PWM control method of the NU310, the light output can be adjusted between zero and 100%. The accuracy of the PWM dimming method is limited only by the minimum gate pulse width, which is a fraction of a percent of the low frequency duty cycle.

Some of the typical waveforms illustrating the PWM dimming method used with the application circuit of Figure 1 are given below.

Programming Operating Frequency

The NU9910 can generate oscillator frequency by setting Rosc pin external resistor. It can reference the following diagram to set switching frequency.



$R_{OSC}(K\Omega) = 1200 – 10 * F_{OSC}(KHz)$

$(F_{OSC} < 100KHz)$

Power Factor Correction

When the input power to the LED driver does not exceed 25W, a simple passive power factor correction circuit can be added to the NU9910 typical application circuit of Figure 1 in order to pass the AC line harmonic limits of the EN61000-3-2 standard for Class C equipment. The typical application circuit diagram shows how this can be done without affecting the rest of the circuit significantly. A simple circuit consisting of 3 diodes and 2 capacitors is added across the rectified AC line input to improve the line current harmonic distortion and to achieve a power factor greater than 0.85.

Inductor Design

Referring to the typical application circuit below the value can be calculated from the desired peak-to-peak LED ripple current in the inductor. Typically, such ripple current is selected to be 30% of the nominal LED current. In the example given here, the nominal current I_{LED} is 350mA.

The next step is determining the total voltage drop across the LED string. For example, when the string consists of 10 High-Brightness LEDs and each diode has a forward voltage drop of 3.0V at its nominal current; the total LED voltage V_{LEDS} is 30V.

Knowing the nominal rectified input voltage V_{IN} = 120V*1.414 = 170V, the switching duty ratio can be determined, as:

$D = V_{LEDs} / V_{IN} = 30/170 = 0.176$

Then, given the switching frequency, in this example: f_{OSC} = 50KHz, the required on-time of the MOSFET transistor can be calculated:

$T_{ON} = D/f_{OSC} = 3.52$ microsecond

The required value of the inductor is given by:

$L = (V_{IN} - V_{LEDs}) * T_{ON} / (0.3 * I_{LED}) = 4.69mH$

Input Bulk Capacitor

An input filter capacitor should be designed to hold the rectified AC voltage above twice the LED string voltage throughout the AC line cycle. Assuming 15% relative voltage ripple across the capacitor, a simplified formula for the minimum value of the bulk input capacitor is given by:

$C_{MIN} = I_{LED}*V_{LEDs}*0.06/V_{IN}\hat{}2$

C_{MIN} = 22 µF, a value 22µF/250V can be used.

A passive PFC circuit at the input requires using two series connected capacitors at the place of calculated C_{MIN}. Each of these identical capacitors should be rated for 1/2 of the input voltage and have twice as much capacitance.

Enable

The NU9910 can be turned off by pulling the PWM_D pin to ground. When disabled, the NU9910 draws quiescent current of less than 1mA.

Output Open Circuit Protection

When the buck topology is used, and the LED is connected in series with the inductor, there is no need for any protection against an open circuit condition in the LED string. Open LED connection means no switching and can be continuous.

DC/DC Low Voltage Applications

Buck Converter Operation

The buck power conversion topology can be used when the LED string voltage is needed to be lower than the input supply voltage. The design procedure for a buck LED driver outlined in the previous chapters can be applied to the low voltage LED drivers as well. However, the designer must keep in mind that the input voltage must be maintained higher than 2 times the forward voltage drop across the LEDs. This limitation is related to the output current instability that may develop when the NU9910 buck converter operates at a duty cycle greater than 0.5. This instability reveals itself as an oscillation of the output current at a sub-harmonic of the switching frequency.

Flyback Operation

This power conversion topology can be used when the forward voltage drop of the LED string is higher, equal or lower than the input supply voltage. For example, the buck-boost topology can be appropriate when input voltage is supplied by an automotive battery (12V) and output string consists of three to six HB LEDs, as the case may be for tail and break signal lights.

In the buck-boost converter, the energy from the input source is first stored in the inductor or a Flyback transformer when the switching transistor is ON. The energy is then delivered to the output during the OFF time of the transistor. When the energy stored in the Flyback inductor is not fully depleted by the next switching cycle (continuous conduction mode) the DC conversion between input and output voltage is given by:

$V_{OUT} = - V_{IN} *D/ (1-D)$

The output voltage can be either higher or lower than the input voltage, depending on duty ratio. Let us discuss the above example of an automotive LED driver that needs to drive three HB LEDs at 350mA. Knowing the nominal input voltage V_{IN}=12V, the nominal duty ratio can be determined, as

$D= V_{LEDs} / (V_{IN} + V_{LEDs}) =9/ (12+9) =0.43$

Then, given the switching frequency, in this example f_{OSC}=50KHz, the required on-time of the MOSFET transistor can be calculated:

$T_{ON} =D/f_{OSC}$=8.6 microsecond

The required value of the inductor is given by:

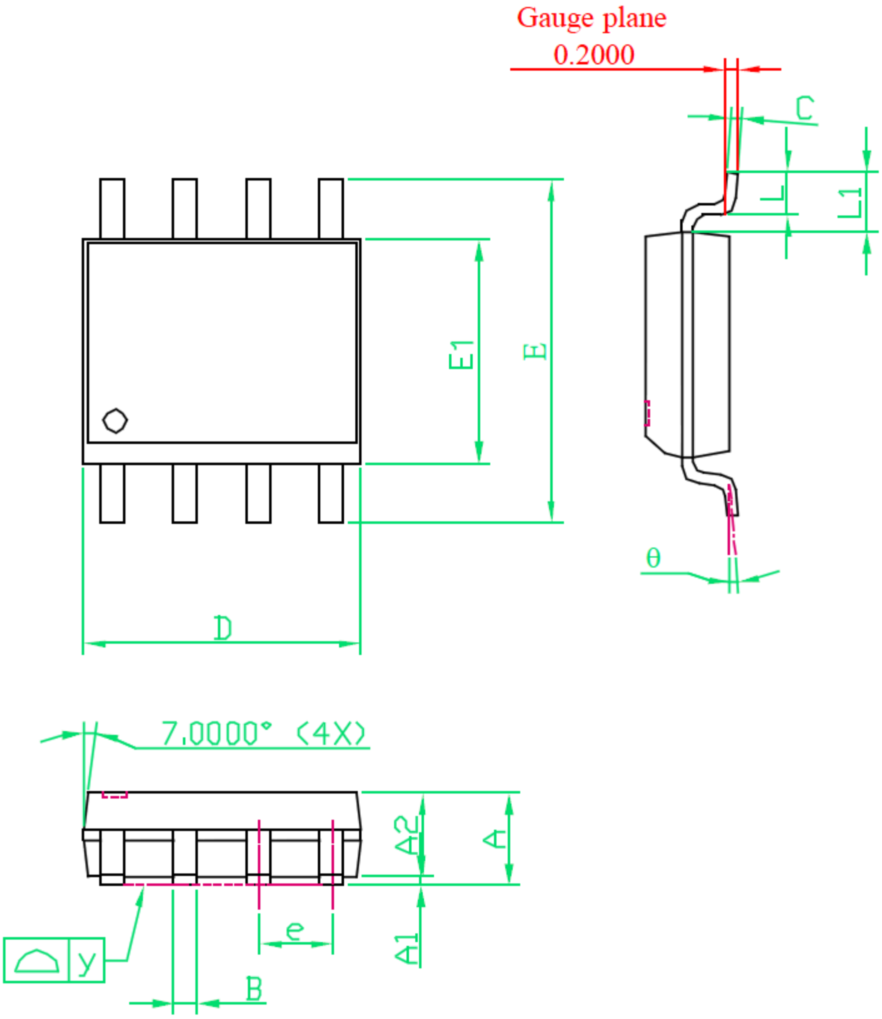
$L = V_{IN} * T_{ON} / (0.3 * I_{LED}) = 0.98$mH, use 1mH

Output Capacitor

Unlike the buck topology, the buck-boost converter requires an output filter capacitor to deliver power to the LED string during the ON time of switching the transistor, when the Flyback inductor current is diverted from the output of the converter. In order to average the current in the LED, this capacitor must present impedance to the switching output AC ripple current that is much lower than the dynamic impedance R_{OUT} of the LED string. If we assume R_{OUT} =3 Ohm in our example, in order to attenuate the switching ripple by a factor of 10, a capacitor with equivalent series resistance (ESR) of 0.3 Ohm is needed. A chip SMT tantalum capacitor can be selected for this purpose.

Package Dimensions

SOP-8



SYMBOLS	DIMENSIONS IN MILLIMETER			DIMENSIONS IN INCH		
	MIN	NOM	MAX	MIN	NOM	MAX
A	1.35	1.60	1.75	0.053	0.063	0.069
A1	0.10	---	0.25	0.004	---	0.010
A2	---	1.45	---	---	0.057	---
B	0.33	---	0.51	0.013	---	0.020
C	0.19	---	0.25	0.007	---	0.010
D	4.80	---	5.00	0.189	---	0.197
E1	3.80	3.90	4.00	0.150	0.153	0.157
e	---	1.27	---	---	0.050	---
E	5.80	6.00	6.20	0.228	0.236	0.244
L	0.40	---	1.27	0.016	---	0.050
y	---	---	0.10	---	---	0.004
θ	0°	---	8°	0°	---	8°
L1	0.95	1.05	1.15	0.037	0.041	0.045

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