Universal High Brightness LED Driver

General Description

The SN3910 is an open loop, current mode, control LED driver IC. The SN3910 operates constant off-time mode. It allows efficient operation of High Brightness (HB) LEDs from voltage sources ranging from $8V_{DC}$ up to $450V_{DC}$ or $110V_{AC}/220V_{AC}$. The SN3910 includes a 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. It also includes a 0 - 250mV linear dimming input which can be used both for linear dimming and temperature compensation of the LED current.

The SN3910 is ideally suited for buck LED drivers. Since the SN3910 operates in open loop current mode control, the controller achieves good output current regulation without the need for any loop compensation. PWM dimming response is limited only by the rate of rise and fall of the inductor current, enabling very fast rise and fall times.

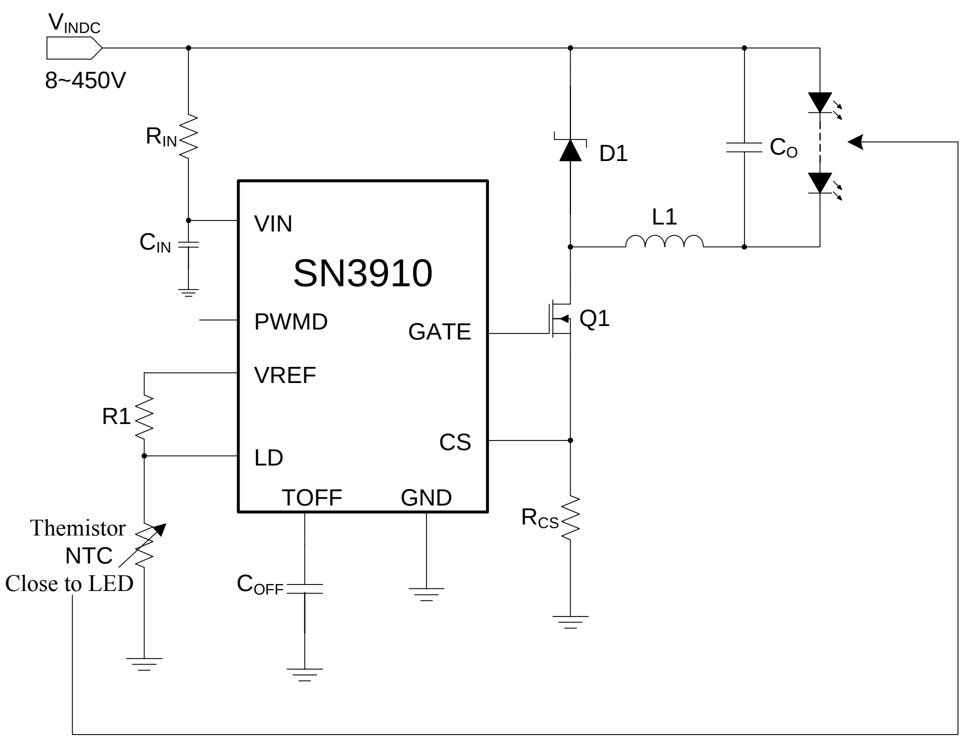
Features

- Switch mode controller for single switch LED drivers
- Open loop peak current controller
- Wide input range from $8V_{DC}$ to $450V_{DC}$ or $110V_{AC}/220V_{AC}$
- Application from a few mA to more than 1A output
- Up to hundreds of LEDs
- Constant off-time operation
- Linear and PWM dimming capability
- Requires few external components for operation
- Temperature compensation to regulate LED current
- SOP-8 package

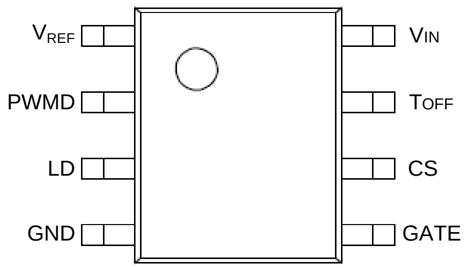
Applications

- DC/DC or AC/DC LED driver applications
- RGB backlighting LED driver
- General purpose constant current source
- Signal and decorative LED lighting

Application Circuit



Pin Configurations

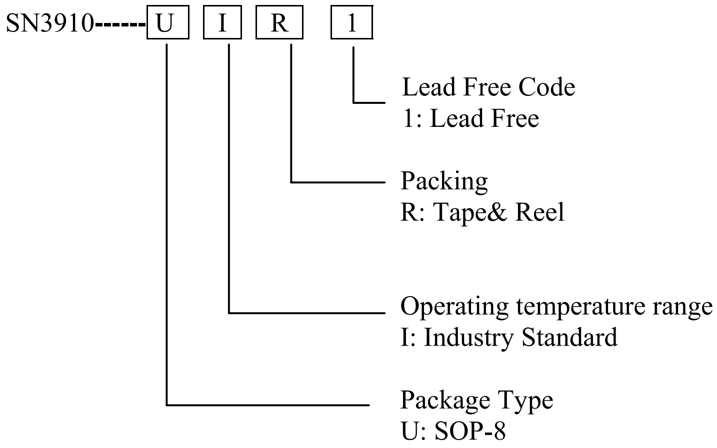
Package	Pin Configurations
SOP-8	

Pin Description

Pin	Pin No.	Description
V_{REF}	1	This pin provides reference voltage about 1.25V, no bypass capacitor is needed.
PWMD	2	This is the PWM dimming input of the IC. When this pin is pulled to GND, the gate driver is turned off. When the pin is pulled high, the gate driver operates normally.
LD	3	This pin is the linear dimming input and sets the current sense threshold as long as the voltage at the pin is less than 250mV (typ). It can also used as temperature compensation threshold voltage.
GND	4	Ground return for all internal circuitry. This pin must be electrically connected to the ground of the power train.
GATE	5	This pin is the output gate driver for an external N-channel power MOSFET.
CS	6	This pin is the current sense pin used to sense the FET current by means of an external sense resistor. When this pin exceeds the lower of either the internal 250mV or the voltage at the LD pin, the gate output goes low.
T_{OFF}	7	This pin sets the off time of the power mos and this chip operates in constant off time mode. It can be floating with the internal set off time 510ns. When a capacitor is connected between TOFF and GND, the off time is increased.
V_{IN}	8	This pin is the input of an 8V – 450V voltage supply through a resistor, it must be bypassed with a capacitor to GND.

Ordering Information

Order Number	Package Type	Operating Temperature range
SN3910UIR1	SOP-8	-40 °C to 125°C



Absolute Maximum Ratings

Parameter	Value
V_{IN} pin voltage to GND	-0.3V to 8V
CS, LD, PWMD, GATE, TOFF, CS1, CS2,VREF pin voltage to GND	-0.3V to 6V
V_{IN} pin Input Current Range ***(Note1)***	1mA to 10mA
Junction Temperature Range	-40°C to 150°C
Storage Temperature Range	-65°C to 150°C
ESD Human Model	2000V

Electrical Characteristics ***(The specifications are at T_A=25°C and V_{INDC}=10V (Note2), R_{IN} =2K, unless otherwise noted)***

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
V_{INDC}	Input DC supply voltage range	Connect a decent resistor from DC supply voltage to V_{IN} pin	8		450	V
V_{IN_clamp}	V_{IN} clamp voltage			7.5		V
I_{IN}	Operation current range	V_{IN}=6V GATE floating		0.5	1	mA
UVLO	Undervoltage lockout threshold	V_{IN} rising		6.4		V
△UVLO	Undervoltage lockout hysteresis	V_{IN} falling		500		mV
$V_{EN(lo)}$	Pin PWMD input low voltage				1.0	V
$V_{EN(hi)}$	Pin PWMD input high voltage		2			V
R_{EN}	Pin PWMD pull-up resistance			100		KΩ
$V_{CS,TH}$	Current sense pull-in threshold voltage			240		mV
V_{LD}	Linear Dimming pin voltage range		0.05		0.25	mV
V_{OFFSET}	Offset voltage for LD comparator			10		mV
T_{BLANK}	Current sense blanking interval		156	244	358	ns
t_{DELAY}	Delay to output	V_{CS}=$V_{CS,TH}$+50mV after T_{BLANK}		30	50	ns
T_{OFF}	Off Time	T_{OFF} pin Floating		510		ns
t_{RISE}	GATE output rise time	C_{GATE}=500pF		42	60	ns
t_{FALL}	GATE output fall time	C_{GATE}=500pF		29.3	45.3	ns
V_{REF}	REF pin voltage			1.2		V
I_{REF}	Reference output current range		-0.15		2.0	mA
$V_{REFLOAD}$	Load regulation of reference voltage	I_{REF}=0~500uA, PWMD=5.0V	0		1	mV

Note:

1. Beyond the input current range, V_{IN} may not clamp at 7.5V.

2, V_{INDC} is the power supply to LED, and there should be an appropriate resistor between V_{INDC} and V_{IN}. Refer to the application circuit for the detail place of V_{INDC}.

Application Information

The SN3910 is optimized to drive buck LED drivers using open-loop peak current mode control. This method of control enables fairly accurate LED current control without the need for high side current sensing or the design of any closed loop controllers. The IC uses very few external components and enables both Linear and PWM dimming of the LED current.

A capacitor connected to the T_{off} pin programs the off-time. The oscillator produces pulses at regular intervals. These pulses set the SR flip-flop in the SN3910 which causes the GATE driver to turn on. When the FET turns on, the current through the inductor starts ramping up. This current flows through the external sense resistor R_{CS} and produces a ramp voltage at the CS pin. The comparators are constantly comparing the CS pin voltage to both the voltage at the LD pin and the internal 250mV. Once the blanking timer is complete, the output of these comparators is allowed to reset the flip flop. When the output of either one of the two comparators goes high, the flip flop is reset and the GATE output goes low. The GATE goes low until the SR flip flop is set by the oscillator. Assuming a 30% ripple in the inductor, the current sense resistor R_{CS} can be set using:

$$R_{CS} = \frac{0.25V(or V_{LD})}{1.15 \bullet I_{LED}(A)}$$

A constant off-time peak current control scheme can easily operate at duty cycles greater then 0.5 and also gives inherent input voltage rejection making the LED current almost insensitive to input voltage variations.

Input Voltage Regulator

When a voltage is applied at the decent resistor, the SN3910 maintains a constant 7.5V at the V_{IN} pin. This voltage is used to power the IC and any external resistor dividers needed to control the IC. The V_{IN} pin must be bypassed by a low ESR capacitor to provide a low impedance path for the high frequency current of the output GATE driver.

The input current drawn from the VIN pin is a sum of the 1.0mA current drawn by the internal circuit and the current drawn by the GATE driver (which in turn depends on the switching frequency and the GATE charge of the external FET).

$$I_{IN} \approx 1.0mA + Q_G \bullet f_S$$

In the above equation, f_S is the switching frequency and Q_G is the GATE charge of the external FET (which can be obtained from the datasheet of the FET).

Current Sense

The current sense input of the SN3910 goes to the noninverting inputs of two comparators. The inverting terminal of one comparator is tied to an internal 250mV reference whereas the inverting terminal of the other comparator is connected to the LD pin. The outputs of both these comparators are fed into an OR GATE and the output of the OR GATE is fed into the reset pin of the flip-flop. Thus, the comparator which has the lowest voltage at the inverting terminal determines when the GATE output is turned off.

The outputs of the comparators also include a 150-280ns blanking time which prevents spurious turn-offs of the external FET due to the turn-on spike normally present in peak current mode control. In rare cases, this internal blanking might not be enough to filter out the turn-on spike. In these cases, an external RC filter needs to be added between the external sense resistor (R_{CS}) and the CS pin.

Please note that the comparators are fast (with a typical 80ns response time). A proper layout minimizing external inductances will prevent false triggering of these comparators.

Oscillator

The oscillator in the SN3910 is controlled by a single capacitor connected at the T_{off} pin. The equation governing the Toff-time of oscillation period is given by:

$$T_{OFF\_TIME} = 0.51 \times 10^{-6} \times (1 + \frac{C_{OFF}}{10pF})$$

Linear Dimming

The Linear Dimming pin is used to control the LED current. There are two cases when it may be necessary to use the Linear Dimming pin.

► In some cases, it may not be possible to find the exact RCS value required to obtain the LED current when the internal 250mV is used. In these cases, an external voltage divider from the VDD pin can be connected to the LD pin to obtain a voltage (less than 250mV) corresponding to the desired voltage across RCS.

► Linear dimming may be desired to adjust the current level to reduce the intensity of the LEDs. In these cases, an external 0-250mV voltage can be connected to the LD pin to adjust the LED current during operation.

To use the internal 250mV, the LD pin can be connected to VDD.

PWM Dimming

PWM Dimming can be achieved by driving the PWMD pin with a low frequency square wave signal. When the PWM signal is zero, the GATE driver is turned off and when the PWMD signal if high, the GATE driver is enabled. Since the PWMD signal does not turn off the other parts of the IC, the response of the SN3910 to the PWMD signal is almost instantaneous. The rate of rise and fall of the LED current is thus determined solely by the rise and fall times of the inductor current.

To disable PWM dimming and enable the SN3910 permanently, connect the PWMD pin to VDD.

Thermal Compensation

Refer to application figure, applying a decent NTC resistor close to the LEDs string will realize the temperature compensation of LEDs current. If the temperature of LEDs rises above a threshold as the current increases, the value of NTC will fall and the voltage of LD pin will fall below 0.25V.Then the current of LEDs will decrease according to the Linear Dimming section.

Make sure the value of R1 is more the 1K.

Example

DC input voltage: V_{INDC}=310V

Output LED strings: V_O=120V (40 LEDs in series, 3V for each one),

I_{O_AVG}=60mA (3 parallels LEDs, 20mA for each one)

IC input resistor (R_{IN}) and Hold Capacitor (C_{IN})

$$R_{IN} = \frac{V_{INDC} - V_{IN}}{I_{IN}}$$

$$P_{R1} = I_{IN}^2 \times R_{IN}$$

Typically, the range of IC input resistor is 100k to 300k with 2W. And a 1uF 30V hold capacitor is always appropriate.

T_{off} Time regulation capacitor (Coff) and Toff Time

For higher output voltage, lower output current application, we need shorter T_{off} Time to obtain the application inductor smaller. In SN3910,

$$T_{OFF\_TIME} = 0.51 \times 10^{-6} \times (1 + \frac{C_{OFF}}{10pF})$$

So, apply Coff = 0pF (T_{OFF} pin floating), then T_{off}=510ns

Current Sense Resistor (Rcs)

Normally, 20% Current Ripple is ok for LEDs. Since the output average I_{O_AVG} = 60mA, then

$$I_{Ripple} = 0.5 \bullet 20\% \bullet 60mA = 6mA$$

$$I_{O\_PEAK} = 66mA$$

$$R_{CS} = \frac{0.25V}{66mA} = 3.8\Omega$$

The Inductor (L1)

The inductor value depends on the ripple current in the LEDs.

$$L = \frac{V_O \times T_{OFF}}{I_{Ripple}} = 10mH$$

Lower inductor value will lead to higher LEDs ripple current, which will decrease the output LEDs average current I_{O_AVG}. Moreover, a bypass capacitor is used to reduce ripple current if necessary.

FET (Q1) and Diode (D1)

The peak voltage seen by the FET is equal to the maximum input voltage. Using a 50% safety rating,

$$V_{FET} = 1.5 \times V_{INDC}$$

The maximum RMS current through the FET depends on the maximum duty cycle, which is 50% by design. Hence, the current rating of the FET is

$$I_{FET} = I_{O\_AVERAGE}$$

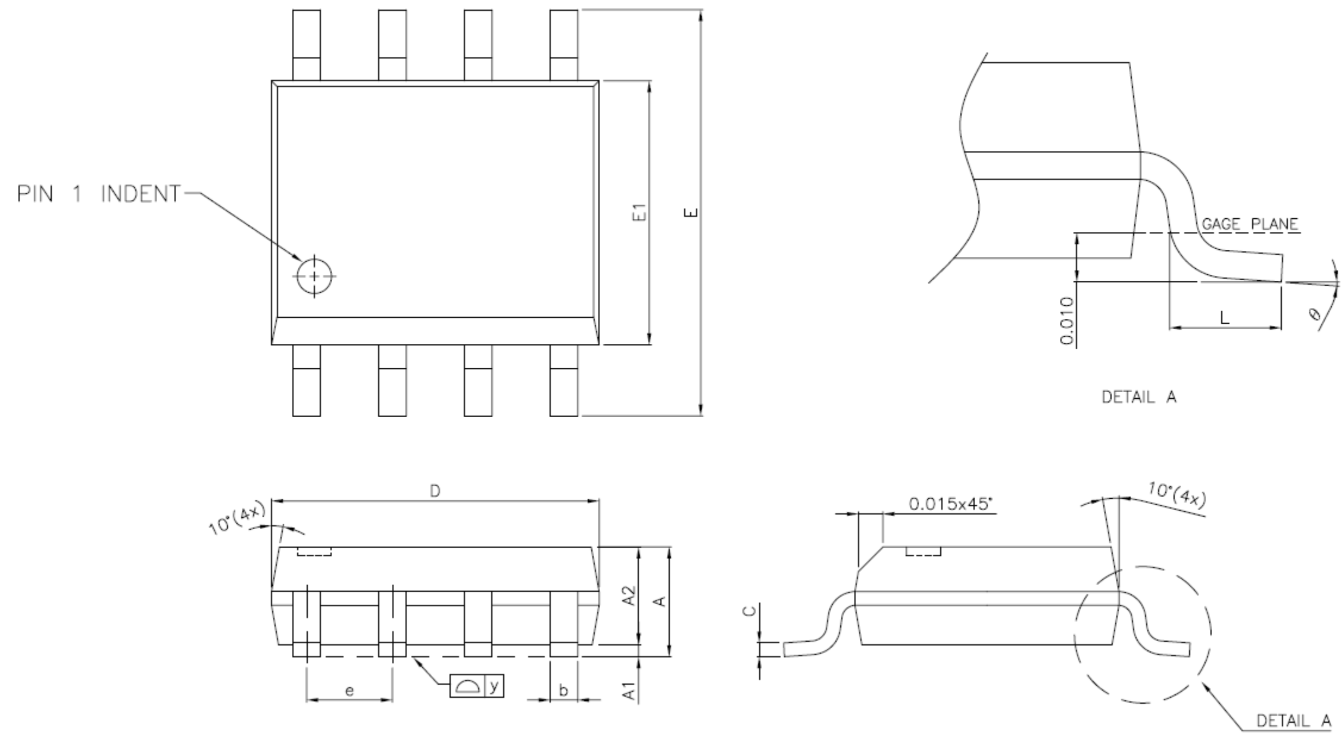
For this application, choose a MOSFET 600V, 0.1A to 0.5A. 2N60 or 2N40 are good choice.

The peak voltage rating of the diode is the same as the FET. The current range of the diode is:

$$I_{diode} = I_{O\_AVERAGE}$$

For this example, 600V/1A is ok. Fast recovery diode is recommended.

Package Information:



SYMBOLS	Dimensions in Millimeters			Dimensions in Inches		
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	1.47	1.60	1.73	0.058	0.063	0.068
A1	0.10	——	0.25	0.004	——	0.010
A2	——	1.45	——		0.057	——
b	0.33	0.41	0.51	0.013	0.016	0.020
C	0.19	0.20	0.25	0.0075	0.008	0.0098
D	4.80	4.85	4.95	0.189	0.191	0.195
E	5.80	6.00	6.20	0.228	0.236	0.244
E1	3.80	3.90	4.00	0.150	0.154	0.157
e	——	1.27	——	——	0.050	——
L	0.40	0.71	1.27	0.016	0.028	0.050
y	——		0.076			0.003
θ	0°		8°	0°		8°