

Universal High Brightness Off-Line LED Driver Controller (v1.4)

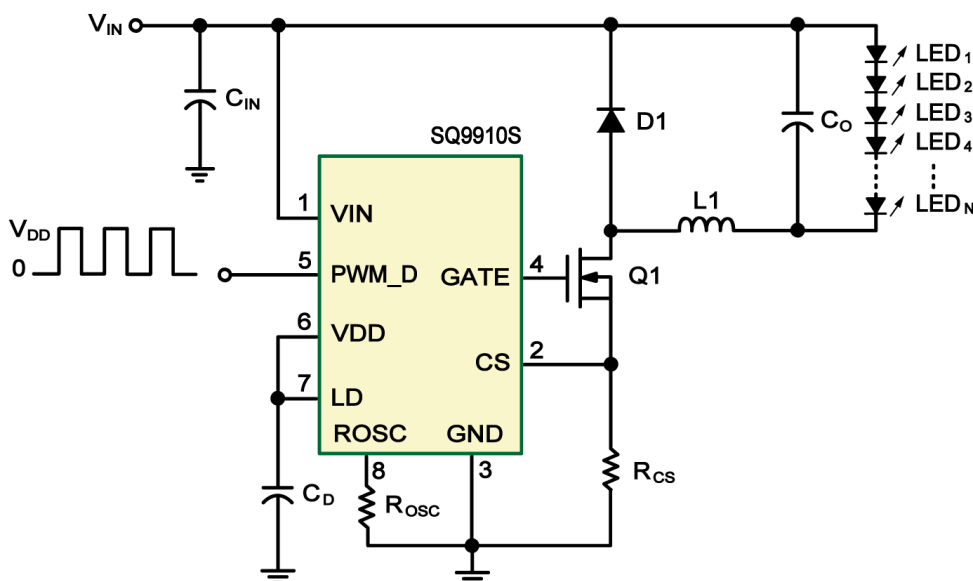
Features

- ◆ High efficiency up to 90%
- ◆ Universal rectified 85V_{AC} to 305V_{AC} input range
- ◆ DC input voltage range from 9V to 500V
- ◆ ± 4% Current sensing voltage variation
- ◆ Applications from a few mA to more than 1A output
- ◆ LED string from one to hundreds of diodes
- ◆ Support PWM and linear dimming
- ◆ Open loop peak current controller
- ◆ Input Under Voltage Lockout (UVLO)
- ◆ Output Short Circuit Protection (SCP)
- ◆ Over Temperature Protection (OTP)
- ◆ Drive an external low-cost N-channel MOSFET
- ◆ Available in SOP-8 and thermally enhanced ESOP-8 packages
- ◆ RoHS compliant and halogen free

Typical Application

- ◆ DC-DC or AC-DC LED Driver application
- ◆ RGB Backlighting LED Driver
- ◆ Back Lighting of Flat Panel Displays
- ◆ General purpose constant current source
- ◆ Signage and Decorative LED Lighting
- ◆ Automotive LED lighting
- ◆ Stage LED lighting

Application Circuit



Product Description

The SQ9910S is a PWM high-efficiency low-cost LED driven controller IC which provides an efficient solution for off-line high-brightness LED lamps from rectified line voltage ranging from 85V_{AC} up to 305V_{AC}.

The SQ9910S drives an external N-channel power MOSFET at a fixed switching frequency up to 600kHz. The switching frequency is determined by an external single resistor. The SQ9910S topology creates a constant current through the LED delivering a more uniform light output. The output current is programmed by one external resistor and is ultimately determined by the external N-channel power MOSFET chosen and therefore allows LED current between a few mA and up to more than 1A.

The SQ9910S supports a several kHz PWM dimming input and a 0 to 250mV linear dimming input. The SQ9910S provides protection functions including input under voltage lockout, output short circuit protection and over temperature protection .

The SQ9910S is available in a standard 8-lead SOP plastic (SOP-8) and the thermally enhanced ESOP-8 packages.



Order Information

<p>(Top View)</p> <p>VIN 1 8 ROOSC CS 2 7 LD GND 3 6 VDD GATE 4 5 PWM_D</p> <p>SOP-8 8-Pin Plastic S.O.I.C.</p>	<p>SQ9910S MST</p>
<p>(Top View)</p> <p>VIN 1 8 ROOSC CS 2 EP 7 LD GND 3 9 6 VDD GATE 4 5 PWM_D</p> <p>ESOP-8 8-Pin Exposed Pad Plastic S.O.I.C.</p>	<p>SQ9910S MPT</p>

Absolute Maximum Ratings (Note 1)

VIN to GND	-0.5V to 525V
CS to GND	-0.3V to (V _{DD} + 0.3V)
LD, PWM_D to GND	-0.3V to (V _{DD} + 0.3V)
GATE to GND	-0.3V to (V _{DD} + 0.3V)
External voltage applied V _{DD_MAX}	13.5V
Continue Power dissipation (T _A = 25°C) (Note 2)	
ESOP-8 (Exposed pad) (derate 9mW/°C above 25°C)	1.67W
8 Pin SO (derate 6.3mW/°C above 25°C)	1.29W
Ambient temperature range	-40°C to 85°C
Junction temperature range	-40°C to 125°C
ESD (Electrostatic Discharge) and latch-up susceptibility (Note 3)	
HBM (Human Body Model with VIN pin)	1.5kV
MM (Machine Model with VIN pin)	200V
Latch-up testing with current trigger (I Trigger)	± 400mA
Latch-up testing with VIN pin over voltage trigger (V Trigger)	+100V (Note 3)

Note 1 : Exceeding these ratings may damage the device.

Note 2 : The maximum allowable power dissipation is a function of the maximum junction temperature T_{J_MAX}, the Junction-to-ambient thermal resistance θ_{JA}, and the ambient temperature T_A. Exceeding the maximum allowable power dissipation will cause excessive die temperature, and the controller will go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.

Note 3 : The HBM test method refers to MIL-STD-883G Method 3015.7. The MM test method refers to JEDEC EIA/JESD22-A115. The latch-up test is based on JEDEC STANDARD EIA/JESD78. +100V is the limit voltage of the latch-up test instrument.



Electrical Characteristics

(T_A = 25°C, unless otherwise noted)

Parameter	Symbol	Min	Typ	Max	Unit	Test Conditions
DC Input						
DC input supply voltage range	V _{IN_DC}	9	--	500	V	DC input voltage
Quiescent current at operation mode	I _Q	--	0.7	1.0	mA	V _{IN} = 9V to 500V, PWM_D pin connect to VDD pin
Quiescent current at shutdown mode	I _{INSD}	--	0.4	0.7	mA	V _{IN} = 9V to 500V, PWM_D pin connect to GND pin
Internal Regulator						
Internally regulated output voltage	V _{DD}	7.0	7.5	8.0	V	V _{IN} = 9V to 500V, I _{DD_EXT} = 0mA, GATE pin is open
V _{DD} under voltage lockout threshold	V _{UVLO}	6.1	6.7	7.3	V	Rising V _{IN}
V _{DD} under voltage lockout hysteresis	ΔV _{UVLO}	--	0.5	--	V	Falling V _{IN}
V _{DD} load regulation	ΔV _{DD}	--	--	100	mV	V _{PWM_D} = V _{DD} , I _{DD_EXT} = 0mA to 1mA, 1nF at GATE pin, R _{OSC} = 226kΩ connect to GND pin
Maximum V _{DD} voltage	V _{DD_MAX}	--	--	13.5	V	When an external voltage is applied to VDD pin
V _{DD} current available for external circuitry ^(Note 4)	I _{DD_EXT}	--	--	1.0	mA	V _{IN} = 9V ~ 100V
Peak Current Sensing Mode						
Current sensing pull-in threshold voltage	V _{CS}	240	250	260	mV	@T _A = -40°C to 85°C
Current sense blanking interval	t _{BLANK}	140	215	280	ns	V _{CS} = 0.5V, V _{LD} = V _{DD}
Delay time from CS trip to GATE low	t _{DELAY}	--	--	300	ns	V _{IN} = 15V, V _{PWM_D} = V _{DD} , V _{LD} = 0.15V, V _{CS} = 0V to 0.22V after t _{BLANK}
Oscillator						
Oscillator frequency	f _{OSC_1M}	20	25	30	kHz	R _{OSC} = 1MΩ connect to GND pin
	f _{OSC_226K}	80	100	120	kHz	R _{OSC} = 226kΩ connect to GND pin
	f _{OSC_19.8K}	480	600	720	kHz	R _{OSC} = 19.8kΩ connect to GND pin
Dimming						
Maximum oscillating PWM duty cycle	D _{MAX_HF}	--	--	100	%	f _{PWM_HF} = 25kHz, at GATE pin, CS pin connect to GND pin
PWM_D pin disable threshold low	V _{EN_LO}	--	--	1.0	V	V _{IN} = 9V ~ 500V
PWM_D pin enable threshold high	V _{EN_HI}	2.4	--	--	V	V _{IN} = 9V ~ 500V

Note 4 : Also limited by package power dissipation limit, whichever is lower.

Electrical Characteristics (Continue)

 (T_A = 25°C, unless otherwise noted)

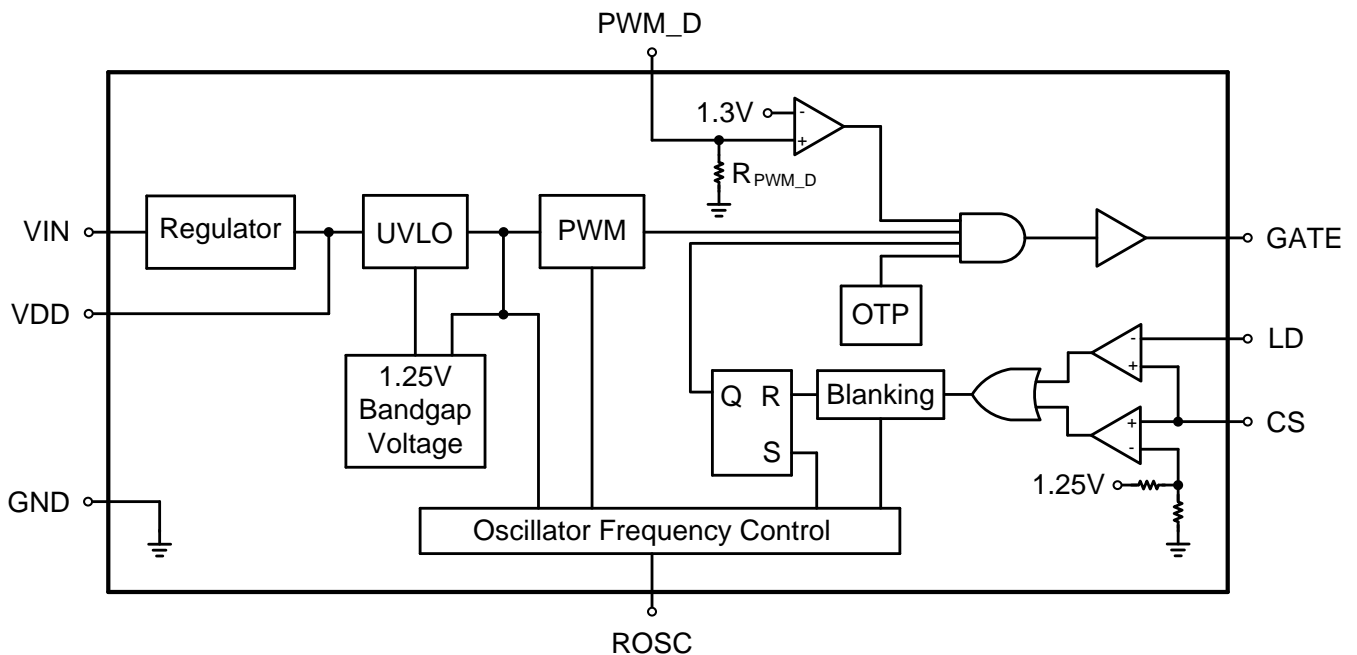
Parameter	Symbol	Min	Typ	Max	Unit	Test Conditions
PWM_D pin pull-down resistance	R _{PWM_D}	50	100	150	kΩ	V _{PWM_D} = 5V
LD pin dimming voltage range	V _{LD}	0	--	250	mV	@T _A < 85°C, V _{IN} = 9V ~ 500V
GATE Pin Driving Output						
GATE pin high output voltage	V _{GATE_HI}	V _{DD} - 0.1	--	V _{DD}	V	I _{GATE} = 10mA
GATE pin low output voltage	V _{GATE_LO}	0	--	0.1	V	I _{GATE} = -10mA
GATE pin output rise time	t _{RISE}	--	15	20	ns	V _{DD} = 7.5V, C _{GATE} = 1nF
GATE pin output fall time	t _{FALL}	--	20	30	ns	V _{DD} = 7.5V, C _{GATE} = 1nF
Protections						
Thermal shutdown threshold (Note 5)	T _{SD}	--	150	--	°C	
Thermal shutdown hysteresis (Note 5)	ΔT _{SD}	--	30	--	°C	

Note 5 : Guaranteed by design.

Functional Pin Description

Pin No.	Pin Name	Pin Function
1	VIN	DC input voltage. This pin is the input of a 9V to 500V high voltage linear regulator.
2	CS	LED current sensing input. The typical current sensing threshold voltage (V_{CS}) is 250mV between the CS and GND pins.
3	GND	Ground of the chip.
4	GATE	This pin is the output gate driver for an external N-channel power MOSFET.
5	PWM_D	This pin can be used for LED short circuit protection with some external circuitry. Low frequency PWM dimming pin, also enable input. Internal 100k Ω pull-down resistor to GND pin.
6	VDD	Regulated supply voltage output. Can supply up to 1mA for external circuitry. A sufficient storage low ESR capacitor ($\sim 10\mu\text{F}$) is used to provide storage when the rectified AC input is near the zero crossing.
7	LD	Linear dimming control input pin. Apply a voltage less than V_{CS} ($V_{LD} < V_{CS}$) to dim the LED output current.
8	ROSC	This pin sets the oscillator frequency. A external oscillating resistor (R_{OSC}) connected between this pin to GND pin sets the oscillator PWM frequency. The controller can be switched into constant off-time (PFM) mode by connecting the external oscillating resistor between ROSC pin and the gate of the external power MOSFET.
9	EP	Exposed pad (Bottom of package). This pad must be soldered to a large PCB and connected to GND directly for maximum thermal dissipation.

Function Block Diagram



OTP : 150°C



Application Information

AC-DC Off-Line Application

The SQ9910S is a low-cost off-line buck or boost converter control IC specifically designed for driving multi-LED strings or arrays. It can be operated from either universal AC line or any DC voltage between 9V and 500V. 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 SQ9910S can drive up to hundreds of High-Brightness (HB) LED or multiple strings of HB LED. The LED arrays can be configured as a series or series/parallel connection. The SQ9910S regulates constant current that ensures controlled brightness and spectrum of the LED, and extends their lifetime. The SQ9910S features an enable pin (PWM_D) that allows PWM control of brightness.

The SQ9910S can also control brightness of LED by programming continuous output current of the LED driver (so-called linear dimming) when a control voltage is applied to the LD pin.

The SQ9910S is offered in a standard 8-pin SOIC and thermally enhanced exposed pad ESOP-8 packages.

The SQ9910S 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 SQ9910S 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 LED. 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 LED (Flyback mode of operation).

When the voltage at the VDD pin exceeds the V_{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 SQ9910S. 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. Additionally, 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 3.

Supply Current

A current of 0.7mA is needed to start the SQ9910S. As shown in the block diagram on page 5, this current is internally generated in the SQ9910S without using bulky startup resistors typically required in the offline applications. Moreover, in many applications the SQ9910S can be continuously powered using its internal linear regulator that provides a regulated voltage of 7.5V for all internal circuits.

Setting LED Output Current

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 (R_{CS}) should be as follows :

$$R_{CS} = \frac{0.25V}{0.5A + [0.5 \times (0.5A \times 0.3)]}$$

$$= 0.43 \Omega$$

Dimming Application

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 LD 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 SQ9910S. By using the PWM control method of the SQ9910S, 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 percentage of the low frequency duty cycle. PWM dimming of the LED light can be achieved by turning on and off the converter with low frequency 50Hz to 1kHz TTL logic level signal.

Programming Operating Frequency

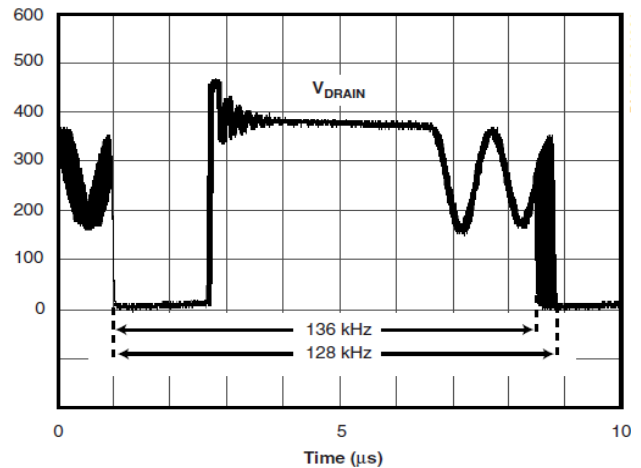
The SQ9910S is capable of operating over a 25kHz and 600kHz switching frequency range. The switching frequency is programmed by connecting an external resistor between ROSC pin and ground. The corresponding oscillator frequency is as follows :

$$f_{OSC} = \frac{25000}{R_{OSC} + 22} \text{ (kHz)}$$

Be noted, R_{OSC} shall be $820k\Omega \sim 1M\Omega$ for the case of $V_{LED} < 7V$ because it has to satisfy the condition of $t_{ON} > t_{BLANK}$. The efficiency can be improved as well.

Spread Spectrum

The oscillator incorporates circuitry that introduces a small amount of frequency jitter, typically 8% frequency swing, to minimize EMI emission. The modulation rate of the frequency jitter is set by pseudo-random frequency hopping to optimize EMI reduction for both average and quasi-peak emissions. The frequency jitter should be measured with the oscilloscope triggered at the falling edge of the DRAIN waveform. The waveform in Figure below illustrates the frequency jitter.



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 SQ9910S typical application circuit in Figure 3 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

The buck circuit is usually selected and it has two operation modes : continuous and discontinuous conduction modes. A buck power stage can be designed to operate in continuous mode for load current above a certain level usually 15% to 30% of full load. Usually, the input voltage range, the output voltage and load current are defined by the power stage specification. This leaves the inductor value as the only design parameter to maintain continuous conduction mode. The minimum value of inductor to maintain continuous conduction mode can be determined by the following example.

Referring to the typical buck application circuit on Figure 1 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 LED and each diode has a forward voltage drop of 3.0V at its nominal current ; the total LED voltage V_{LED} is 30V.



$$D = \frac{V_{LED}}{V_{IN}}$$

$$t_{ON} = \frac{D}{f_{OSC}}$$

$$L_{MIN} = \frac{(V_{IN} - V_{LED}) \times t_{ON}}{0.3 \times I_{LED}}$$

$$R_{CS} = \frac{0.25}{I_{LED} + [0.5 \times (I_{LED} \times 0.3)]}$$

Assuming the nominal rectified input voltage $V_{IN} = 120V \times 1.4142 = 169V$, the switching duty ratio can be determined, as :

$$D = \frac{V_{LED}}{V_{IN}} = 0.177$$

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

$$t_{ON} = \frac{D}{f_{OSC}} = 3.5 \text{ ms}$$

The required value of the inductor is given by :

$$L_{MIN} = \frac{(V_{IN} - V_{LED}) \times t_{ON}}{0.3 \times I_{LED}} = 4.6 \text{ mH}$$

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 :

$$C_{IN} \geq \frac{P_{IN} \times (1 - D_{CH})}{\sqrt{2} \times V_{AC_MIN} \times 2f_L \times \Delta V_{DC_MAX}}$$

Where

D_{CH} : C_{IN} capacity charge work period, generally about 0.20 ~ 0.25,

f_L : input line frequency (47Hz ~ 63Hz) for full AC line voltage range ($85V_{AC} \sim 264V_{AC}$),

ΔV_{DC_MAX} : should be set 10% ~ 15% of ($\sqrt{2} \times V_{AC_MIN}$)

$$C_{IN_MIN} = \frac{I_{LED} \times V_{LED} \times 0.06}{V_{IN}^2} = 22 \mu F$$

A value 22 μF /250V can be used.

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

Enable Control

The SQ9910S can be turned off by pulling the PWM_D pin to ground. When disabled, the SQ9910S draws quiescent current of less than 0.7mA.

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 Applications

Buck Converter Operation

The SQ9910S is an offline AC-DC solution for LED lighting system. Due to its simplicity of buck topology when the LED string voltage is needed to be lower than the input supply voltage, this solution can be designed to meet various non-isolation application including T8, LED lamps.

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 LED. This limitation is related to the output current instability that may develop when the SQ9910S 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.



Benefiting from SQ9910S inherited high voltage feature, rectified DC high voltage ($V_{IN_DC} = V_{AC} \times 1.4142$) can be directly fed into power pin of it to achieve high duty cycle, which is only limited by V_{LED} / V_{IN_DC} , to optimize design efficiency. This solution can easily achieve above 90% efficiency. However, if the duty cycle is configured to reach above more than 50%, some instability called **Sub-harmonics Oscillation (SBO)** will occur.

The best solution is to adopt the so-called **Constant Off-Time** operation as shown in Figure 2. The resistor (R_{OSC}) is, connected to ground by default, to set operating frequency. We can alternatively connect this resistor to gate of MOSFET to force SQ9910S to enter constant off time mode which will decrease duty cycle from 50% by increase total period, $t_{OFF} + t_{ON}$.

One of the major scenarios which might induce SBO is that when SQ9910S is biased right after passive PFC stage. The DC voltage rail, V_{IN} , is halved which will easily increase duty cycle up to more than 50%.

For general LED lighting application, PFC becomes a necessary factor in order to meet the emergent international standard of solid state lighting. The following example as shown in Figure 2 can explain it in more details where R_{OSC} is connected between pin#8 - ROSC, and pin#4 - GATE to set SQ9910S to operate in constant off-time mode.

Example :

At $V_{AC} = 110V$ with passive PFC.

V_{LED} consists of 1W HB LED with nominal $V_F = 3.3V$.

V_{IN_DC} , after rectified and passive PFC stage, the actual DC rail will become

$$V_{IN_DC} = 110V \times 1.4142 / 2 = 77.7 V_{DC}$$

The duty cycle, $D = V_{LED} / V_{IN_DC}$, will reach above 50% when voltage drop of LED string, as the V_{LED} , is more than $77.7 / 2 = 38.8V$. Another word, if any string consisting of $38.8 / 3.3 = 12$ LEDs in a series, SBO will occur.

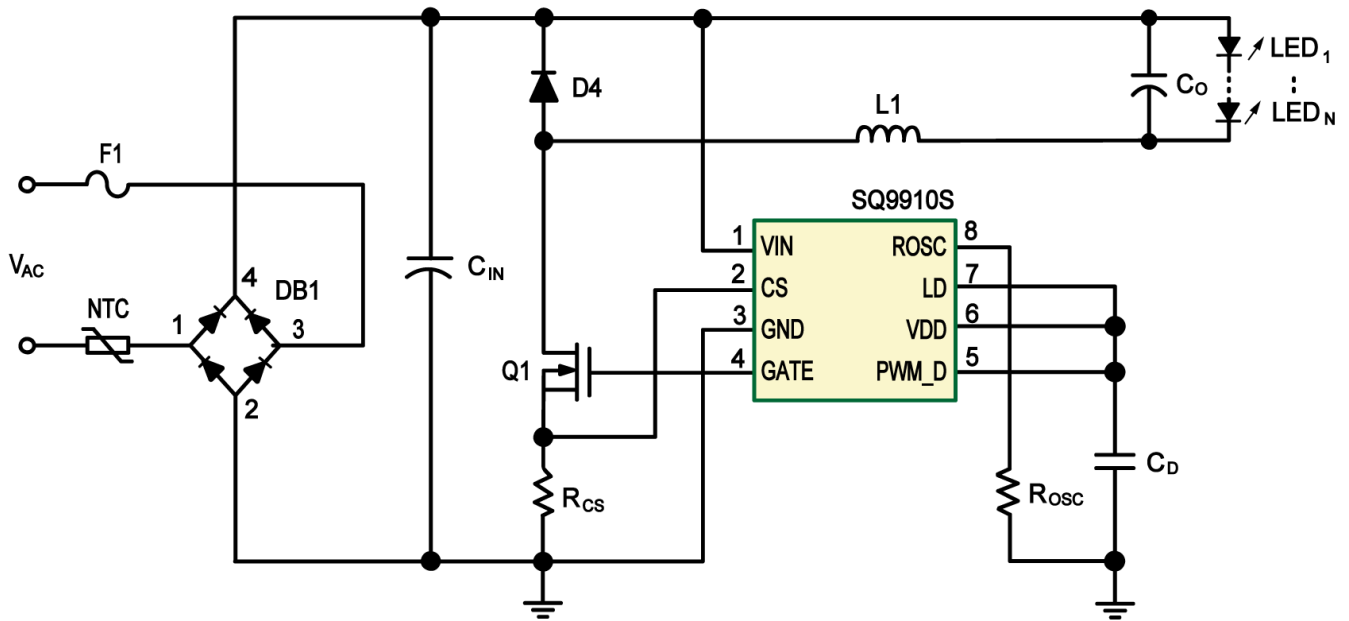


Figure 1 : Typical Application Circuit (without PFC)

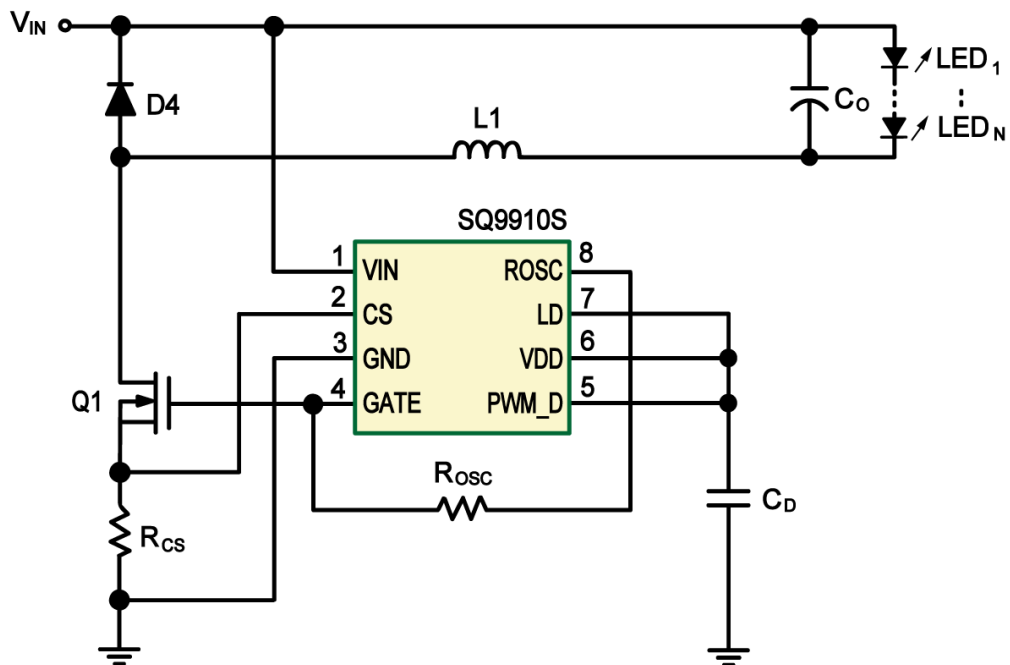


Figure 2 : Constant OFF-Time Mode

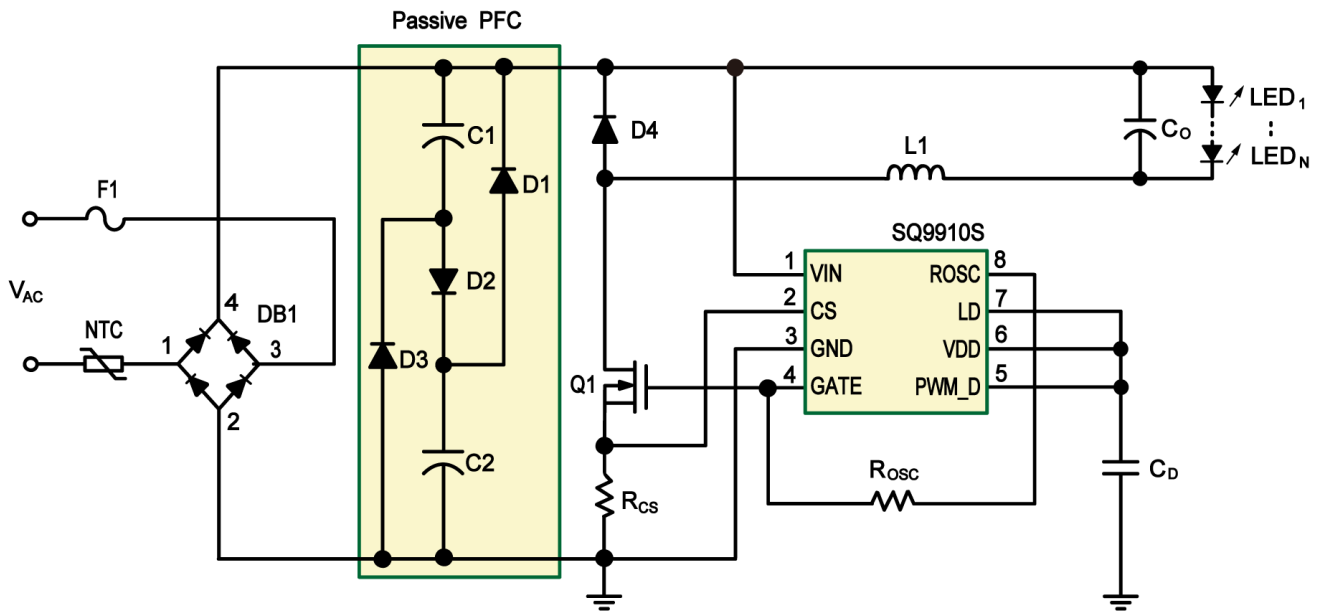
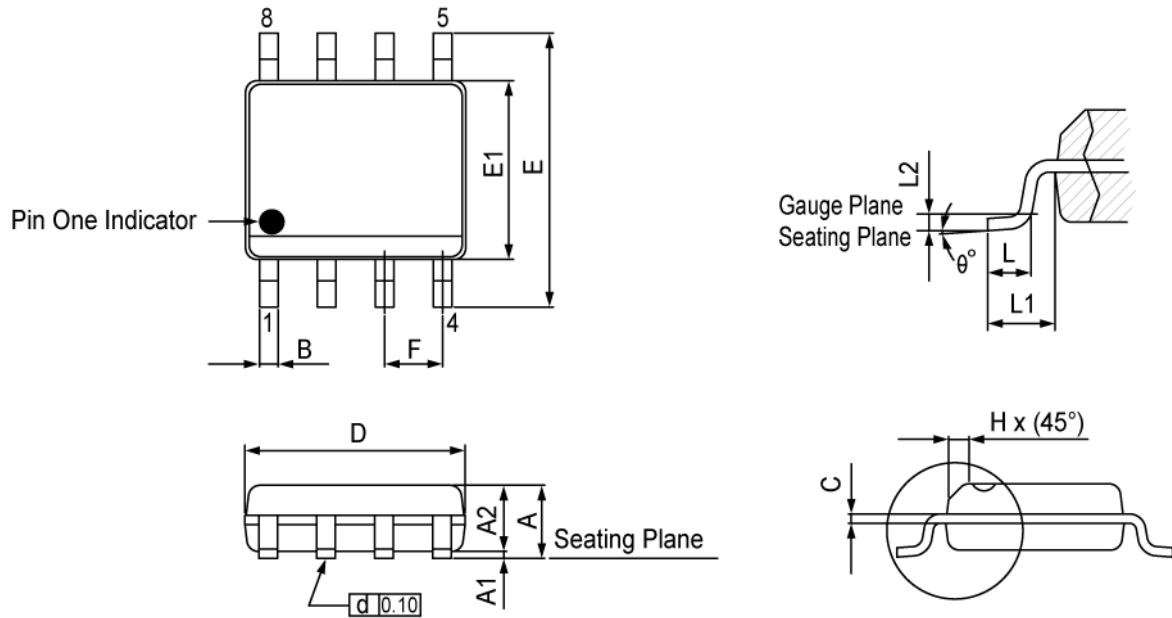


Figure 3 : Typical Application Circuit (with Passive PFC)



Package Outline Dimension

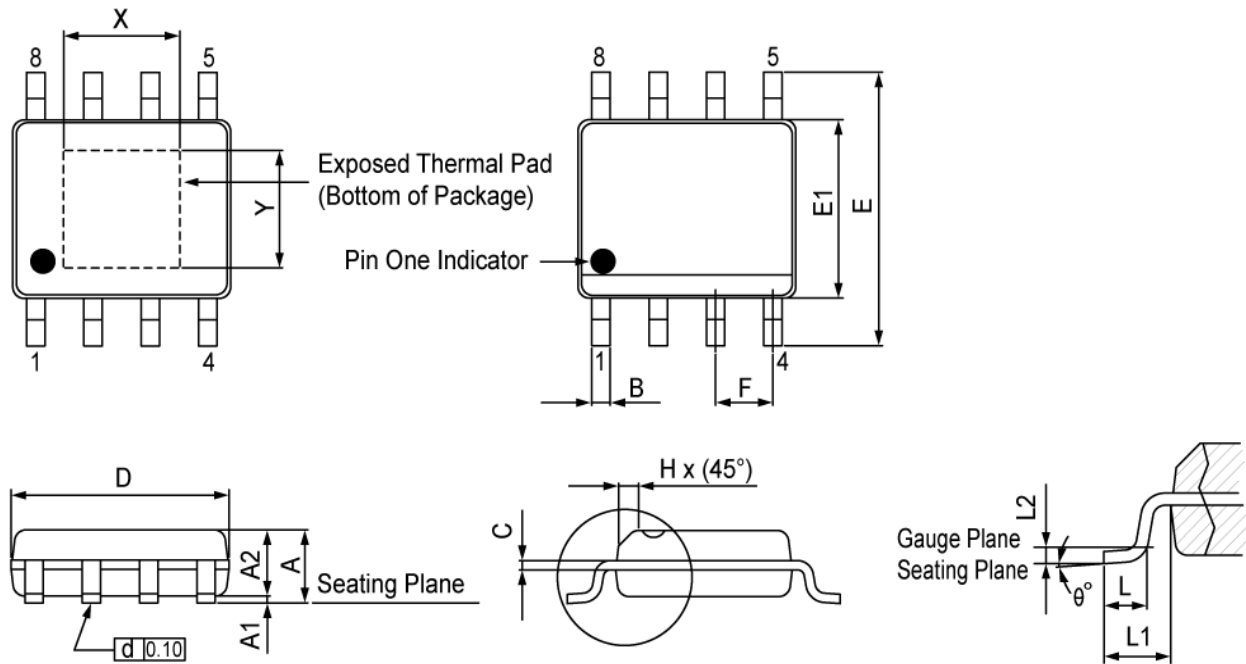
(1). SOP-8 : 8-Lead SOP Plastic Package



Symbol	Dimensions in millimeters		Dimensions in inches	
	Min	Max	Min	Max
A	--	1.750	--	0.069
A1	0.100	0.250	0.004	0.010
A2	1.250	--	0.049	--
B	0.310	0.510	0.012	0.020
C	0.170	0.250	0.007	0.010
D	4.900 BSC		0.193 BSC	
E	6.000 BSC		0.236 BSC	
E1	3.900 BSC		0.154 BSC	
F	1.270 BSC		0.050 BSC	
H	0.250	0.500	0.010	0.020
L	0.400	1.270	0.016	0.050
L1	1.040 REF		0.041 REF	
L2	0.250 BSC		0.010 BSC	
θ°	0	8	0	8





(2). ESOP-8 : 8-Lead SOP Exposed Pad (Heat Sink) Plastic Package



Symbol	Dimensions in millimeters		Dimensions in inches	
	Min	Max	Min	Max
A	--	1.750	--	0.069
A1	0.100	0.250	0.004	0.010
A2	1.250	--	0.049	--
B	0.310	0.510	0.012	0.020
C	0.170	0.250	0.007	0.010
D	4.900 BSC		0.193 BSC	
E	6.000 BSC		0.236 BSC	
E1	3.900 BSC		0.154 BSC	
F	1.270 BSC		0.050 BSC	
H	0.250	0.500	0.010	0.020
L	0.400	1.270	0.016	0.050
L1	1.040 REF		0.041 REF	
L2	0.250 BSC		0.010 BSC	
θ°	0	8	0	8
X	2.186	2.386	0.086	0.094
Y	2.186	2.386	0.086	0.094



Marking Information

SOP- 8	ESOP-8
	

A = Assembly house code, YY = Working Year, WW = Working Week

Packing Method Informaion

Product Order Code	Package Type	Quantity of Packing			
		PCs/Tape & Reel	Reel/Box	Box/Carton	PCs/Carton
SQ9910S MST	SOP-8	3,000	2	5	30,000
SQ9910S MPT	ESOP-8	3,000	2	5	30,000



Sequoia Microelectronics Corp. (Hereinafter referred to as Sequoia) reserves the right to make changes to its data sheets and/or products or to discontinue any integrated circuit product or service without notice, and advises its customers to obtain the latest version of relevant information to verify, before placing orders, that the information being relied on is current and complete. Any products are sold subject to the terms and conditions of sales supplied at the time of order acknowledgement, including those pertaining to warranty, patent infringement and limitation of liability.

Sequoia warrants performance of its products to the specifications applicable at the time of sales in accordance with Sequoia's standard warranty. Testing and other quality control techniques are utilized to the extent Sequoia deems necessary to support this warranty. Specific testing of all parameters of each device is not necessarily performed, except those mandated by government requirements.

Customer acknowledges that Sequoia products are not designed, manufactured, intended, authorized, or warranted to be suitable for use in any systems or products intended for use in connection with life support or other hazardous activities or environments in which the failure of the Sequoia products could involve potential risks of death, personal injury, or severe property or environmental damage ("High Risk Activities"). Sequoia hereby disclaims all warranties, and Sequoia will have no liabilities to customer or any third party, relating to the use of Sequoia's products in connection with any High Risk Activities.

Any support, assistance, recommendation or information that Sequoia may provide to customer (including, without limitation, regarding the design, development or debugging of customer circuit board or other application) is provide "AS IS". Sequoia does not make, and hereby disclaims, any warranties regarding any such support, including, without limitation, any warranties of merchantability or fitness for a particular purpose, and any warranty that such support will be accurate or error free or that customer circuit board or other application will be operational or functional. Sequoia will have no liability to customer under any legal theory in connection with customer use of or reliance on such support.

Copyright © 2018, Sequoia Microelectronics Corp.