SQ9920

Universal High Integration HV-LEDs Driver

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1. Features

- Universal rectified 85V_{AC} to 265V_{AC} input range
- Fixed frequency 65kHz buck converter
- Integrated 500V power MOSFET
- Programmable output current up to 60mA
- ±3% output LED current accuracy
- Powered from MOSFET drain to reduce chip power consumption and increase efficiency
- Spread Spectrum to reduce EMI filter cost
- Slope compensation
- < 250mS instant power on
- Inherent open loop protection (OLP)
- Internal Over Temperature Protection (OTP)
- Minimum Bill of Material (BOM) for as few as 6 external components
- Available in SO8-EP packages
- RoHS compliant and Pb free

2. Typical Applications

- Decorative low power lighting
- E12/E14/E17/GU10 chandelier lighting
- High Voltage (HV) LED lighting fixtures

3. Product Description

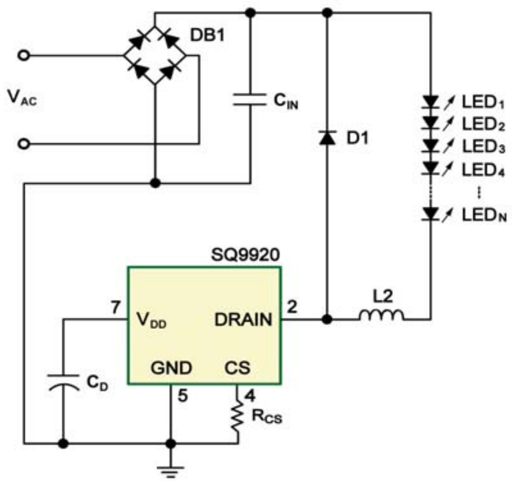
The SQ9920 is a highly integrated Pulse Width Modulated (PWM) high efficiency LED driver IC. It requires as few as 6 external components. This IC allows efficient operation of LED strings from voltage sources ranging up to 500V_{DC}. The SQ9920 includes an internal high voltage switching MOSFET controlled with fixed frequency (f_{OSC}) of approximately 65kHz. The LED string current is set by an external resistor for up to 60mA. The peak current control scheme provides good regulation of the output current throughout the universal AC line voltage range of 85V_{AC} to 265V_{AC} or DC input voltage of 20V_{DC} to 500V_{DC}.

The SQ9920 has pseudo-random oscillator hopping function (Spread Spectrum) to reduce EMI emission so that input EMI filter cost can be reduced. Typical frequency hopping range is approximately 8% around base frequency f_{OSC}. The SQ9920 uses slope compensation to reduce sub-harmonic humming when duty cycle is > 50%.

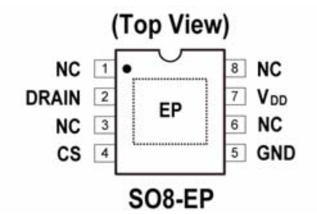
The SQ9920 allows up to > 90% high efficient operation with HV LEDs over the full input voltage range.

The SQ9920 is available in SO8-EP package.

4. Typical Application Circuit



5. Pin Assignments and Ordering Information



Device	Packaging	Quantity of Tape & Reel
SQ9920 MPT	SO8-EP	3000

6. Pin Descriptions

Pin No.	Pin Name	Function
2	DRAIN	**DRAIN input pin** DRAIN terminal of the internal switching MOSFET and a linear regulator input.
4	CS	**Current sensing pin** Senses LED string current. Use an external resistor to set the output current.
5	GND	**Ground pin** Device ground. Common connection for all circuits.
7	V_{DD}	**Internal supply voltage pin** Internally regulated supply voltage at 10V nominal. Power source pin for internal control circuits. Bypass this pin with a 10μF low ESR (Equivalent Series Resistance) capacitor.
1,3,6,8	NC	**NC pin** No connection.
EP	EP Pad	**Exposed pad**

	Package bottom. Connect to GND directly underneath the package.

7. Absolute Maximum Ratings (Note 1)

Symbol	Parametar	Ratings	Unit
V_{DRAIN}	DRAIN input voltage range, DRAIN to GND	-0.5 ~ +520	V
$V_{DD(MAX)}$	Maximum V_{DD} pin voltage relative to GND	13.5	V
	Continuous power dissipation (T_A = +25°C)		
	8 Pin SO-EP (de-rating 16mW/°C above +25°C)	1.6	W
T_J	Junction temperature	+150	°C
T_{STG}	Storage temperature range	-40 ~ +150	°C
$\theta_{JA(EP)}$	Junction-to-ambient thermal resistance for SO8-EP	60	°C/W

Note :

1. Exceeding these ratings could cause damage to the device. All voltages are with respect to ground. Currents are positive into, negative out of the specified terminal.

8. Recommended Operating Conditions

Symbol	Parametar	Min.	Max.	Unit
V_{DRAIN}	DRAIN input voltage range, DRAIN to GND	20	500	V
T_A	Ambient temperature range (Note 2)	-40	+85	°C

Note:

2. Maximum ambient temperature range is limited by allowable power dissipation.

9. Electrical Characteristics

(Over recommended operating conditions unless otherwise specified. V_{DRAIN} = 50V, T_A = +25°C)

Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Regulator (V_{DD})						
DRAIN input supply voltage	V_{DRAIN}	20		500	V	
Internally regulated voltage	V_{DD}	9	10	11	V	
V_{DD} current available for external circuitry (Note 3)	$I_{DD(EXT)}$		2	3	mA	$V_{DD(EXT)}$ 12V，V_{DRAIN} 50V
Turn-on threshold	$V_{DD(ON)}$	8	8	9	V	V_{DD} rising
Turn-off threshold	$V_{DD(OFF)}$	6	6	7		V_{DD} falling
Hysteresis	ΔV_{DD}		2		V	
Output (DRAIN)						
Breakdown voltage (Note 4)	V_{BR}	525			V	
On-resistance	R_{ON}			250	Ω	I_{DRAIN} = 60mA
Output capacitance (Note 4)	C_{DRAIN}		5		pF	V_{DRAIN} = 50V
MOSFET saturation current (Note 4)	I_{SAT}		100		mA	
Current sense comparator						
Current sensing threshold voltage	V_{CS}	235	250	265	mV	T_A = - 40°C ~ +85°C
Current sensing blanking interval	t_{BLANK}		500		ns	

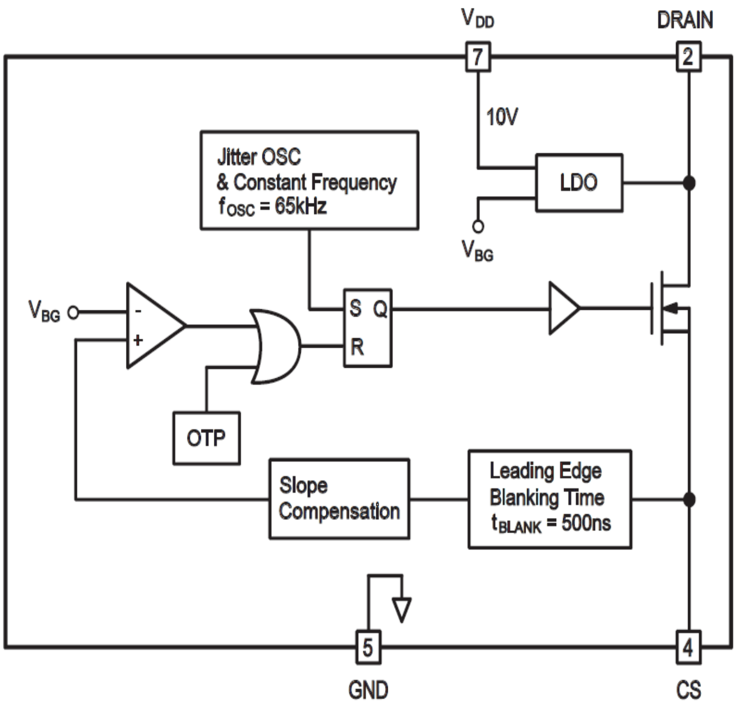
Minimum on-time (Note 4)	$t_{ON(MIN)}$	650			ns
Oscillator					
Oscillator frequency (Note 4)	f_{OSC}		65		kHz
Maximum PWM duty cycle	D_{MAX}			75	%
Frequency hopping range (Note 4)	$\Delta f_{OSC} / f_{OSC}$		8		%
Protections					
Thermal shut down	T_{SD}		150		°C
Thermal shut down hysteresis	ΔT_{SD}		50		°C

Note :

3. Also limited by package power dissipation limit, whichever is lower.

4. Parameters guaranteed by design, functionality tested in production.

10. Functional Block Diagram



11. Application Information

11.1. Function Descriptions

The SQ9920 is a PWM peak current driver IC for controlling a buck topology in Continuous Conduction Mode (CCM). The output current is set by an external resistor. When the input voltage of $20V_{DC}$ to $500V_{DC}$ appears at the DRAIN pin, the internal high-voltage linear regulator seeks to maintain a voltage of 10V at the V_{DD} pin. This 10V drives all internal circuits and MOSFET to assure lower $R_{DS(ON)}$. Until this voltage exceeds the internally programmed turn-on threshold ($V_{CC(ON)}$), the output switching MOSFET is non-conductive. When the threshold voltage is exceeded, the gate drive of MOSFET is enabled. The input current begins to flow into the DRAIN pin. Hysteresis voltage is provided in the turn-off threshold ($V_{CC(OFF)}$) voltage comparator to prevent oscillation.

The SQ9920 has special regulator on chip to power the internal circuits. Since the power comes from DRAIN pin which toggles on-and-off during normal operation, therefore, this regulator has to maintain the V_{DD} level when internal MOSFET is on and the DRAIN pin is nearly at zero volt below V_{DD} level. A 10μF capacitor is recommended at V_{DD} pin. The SQ9920 starts operating when V_{DD} travels above 8V as DRAIN voltage is increasing. The SQ9920 shuts off when V_{DD} drops below 6V. There is a 2V hysteresis.

In order to ensure that the regulator works, the duty cycle has to be less than 75%

At initial power start, the switching inductor current is not established yet and it is at zero current, and since the SQ9920 power is supplied from DRAIN pin which is connected to the output terminal of the switching inductor, this inductor inhibits any sudden increase of the current, thus, the surge current can be suppressed and hence soft start feature is implemented

The SQ9920 operates at fixed frequency internally set at 65kHz. When the output LED current exceeds the internal preset level at 250mV, a current sensing comparator resets an RS flip-flop, and the MOSFET turns off until next cycle starts. A leading edge blanking delay of 500ns is provided that prevents false triggering of the current sensing comparator due to the leading edge spike caused by parasitical circuit.
The oscillator incorporates circuitry that introduces a small amount of frequency jitter, typically 8% frequency hopping range of base frequency (f_{OSC}) at 65kHz, 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 voltage emissions.

The SQ9920 has internal slope compensation circuit for V_{CS} fold back when output voltage is too high. The high output voltage may cause the duty cycle > 50% and thus sub-harmonic humming noises can be generated. The slope compensation is activated when duty cycle is > 40%.

SQ9920 provide an inherent open loop protection because when output LED string is not connected, the IC cannot be powered from the DRAIN pin, thus, this IC is not functional. As soon as the LED string is connected, then, SQ9920 starts working.

The over temperature protection shut down feature is provided for thermal protection when junction temperature (T_J) reaches 150°C in case the heat dissipation is not sufficient. There is a 50°C hysteresis to re-start the internal MOSFET.

The SQ9920 is a low cost off-line buck converter IC specifically designed for driving HV LED strings. It can be operated from either universal AC line range of 85V_{AC} to 265V_{AC}, or 20V_{DC} to 500V_{DC}. This part is available in SO8-EP package. Please refer to Figure 1 for example for the calculation of values of components.

11.2. Setting Lighting 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 set at 30%or 18mA, to get an average 60mA LED current, the sensing resistor should be as follows :

$$R_{CS} = \frac{250mV}{60mA + 0.5 \times 18mA} = 3.62\Omega \qquad (1)$$

11.3. Selecting output inductor (L2) and diode (D1)

Trade-off has to be considered between optimal sizing of the output inductor L2 and the tolerated output current ripple. The required minimum value of L2 is inversely proportional to the ripple current (ΔI_{LED}) which is normally set at 30% of output current (I_{LED}) and the equation can be expressed as below :

$$L2 \geq \frac{(V_{IN} - V_{LED}) \times t_{ON}}{\Delta I_{LED}} \qquad (2)$$

where V_{LED} is the total forward voltage of the LED string. t_{ON} is the on-time which depends on duty ratio (D), as well as operation frequency (f), and it can be expressed by $t_{ON} = D/f$.

Adding a filter capacitor across the LED string can reduce the output current ripple even further, thus it allows a reduced value of L2.

Another important aspect of designing an LED driver with the SQ9920 is related to certain parasitic elements of the circuit, including distributed coil capacitance (C_{L2}) of L2, junction capacitance (C_J) at reverse recovery of the rectifier diode D1, capacitance of the printed circuit board traces (C_{PCB}) and output capacitance (C_{DRAIN}) of the driver itself. These parasitic elements affect the efficiency of the switching converter and could potentially cause false triggering of the current sensing comparator if not properly managed.

Coil capacitance of inductors is typically provided in the manufacturer's data books either directly or in terms of the self-resonant frequency (SRF).

$$SRF = \frac{1}{2\pi\sqrt{L2 \times C_{L2}}} \qquad (3)$$

where L2 is the inductance value and C_{L2} is the coil capacitance. Charging and discharging this capacitance every switching cycle causes high-current spikes in the LED string. Thus, connecting a small capacitor (C_O) (~10nF) is recommended to bypass these spikes.

Using an ultra-fast rectifier diode for D1 is recommended to achieve high efficiency and it reduces the risk of false triggering of the current sensing comparator. Using diodes with shorter reverse recovery time (t_{RR}) and lower junction capacitance achieves better performance. The reverse voltage rating V_R of the diode must be greater than the maximum input voltage of the LED lamp.

The total parasitic capacitance present at the DRAIN pin of this device can be calculated as :

$$C_P = C_{DRAIN} + C_{PCB} + C_{L2} + C_J \qquad (4)$$

When the switching MOSFET turns on, the capacitance C_P is discharged into the DRAIN pin of the IC. The discharge current is limited to about 100mA typically. However, it may become lower at increased junction temperature. The duration of the leading edge current spike can be estimated as :

$$t_{SPIKE} = \frac{V_{IN} \times C_P}{I_{SAT}} + t_{RR} \qquad (5)$$

In order to avoid false triggering of the current sensing comparator, C_P must be minimized in accordance with the following expression :

$$C_P < \frac{I_{SAT} \times (t_{BLANK(MIN)} - t_{RR})}{V_{IN(MAX)}} \qquad (6)$$

where $t_{BLANK(MIN)}$ is the minimum blanking time of 500ns, and $V_{IN(MAX)}$ is the maximum instantaneous input voltage.

11.4. EMI Filter

As with all off-line converters, selecting an input filter is critical to obtaining good EMI. A switching side capacitor, albeit of small value, is necessary in order to ensure low impedance to the high frequency switching currents of the converter. As a rule of thumb, this capacitor should be approximately 0.1μF/W ~ 0.2μF/Wof LED output power. Since frequency jittering is adopted in this chip, a lower cost EMI filter can be used. Generally, this 8% jittering can product -5 to -10 dB harmonic noise reduction. A recommended input filter is shown in Figure 1 for the following design example.

11.5. Design Example

Let us design a LED lamp driver with the SQ9920 to meet the following specifications :

Input : Universal AC,85V_{AC} ~ 265V_{AC}
Output : 60mA
Loading : String of 12 LED (V_F = 3.4V max. each)

Step 1.

Calculating the output inductance L2
The output voltage V_{LED} = 12 × V_F = 40.8V (max.)
Assuming a 30% peak-to-peak ripple.

$$L2_{MIN} = \frac{(V_{IN} - V_{LED}) \times t_{ON}}{\Delta I_{LED}} = \frac{(265 \times \sqrt{2} - 40.8) \times 1.69\mu}{0.3 \times 60mA} = 31mH$$

where D = 40.8 / (265 × 1.414) = 0.109,
and t_{ON} = D / f_S = 0.109 / 65k = 1.69μs

Select L2 = 31mH. Typical SRF = 170kHz. From equation (3), the coil capacitance can be calculated by

$$C_{L2} = \frac{1}{L2 \times (2\pi \times SRF)^2} = \frac{1}{31m \times (2\pi \times 170k)^2} = 28.3pF$$

So, select C_{L2} = 30pF

Step 2.

Selecting D1
Usually, the reverse recovery characteristics of ultra-fast rectifiers at I_F = 20mA ~ 50mA is not provided in the manufacturer's data books. The designer may want to experiment with different diodes to achieve the best performance. Normally, a less than 35ns fast recovery diode can be used with good result. In this example, we can select MUR160 with VR 600V, $t_{RR} \approx$ 20ns (I_F = 20mA, I_{RR} < 100μA) and $C_J \approx$ 8pF (V_{RR} > 50V) as D1.

Step 3.

Calculating total parasitic capacitance using equation

(4)

$$\begin{aligned} C_P &= C_{DRAIN} + C_{PCB} + C_{L2} + C_J \\ &= 5pF + 5pF + 30pF + 8pF \\ &= 48pF \end{aligned}$$

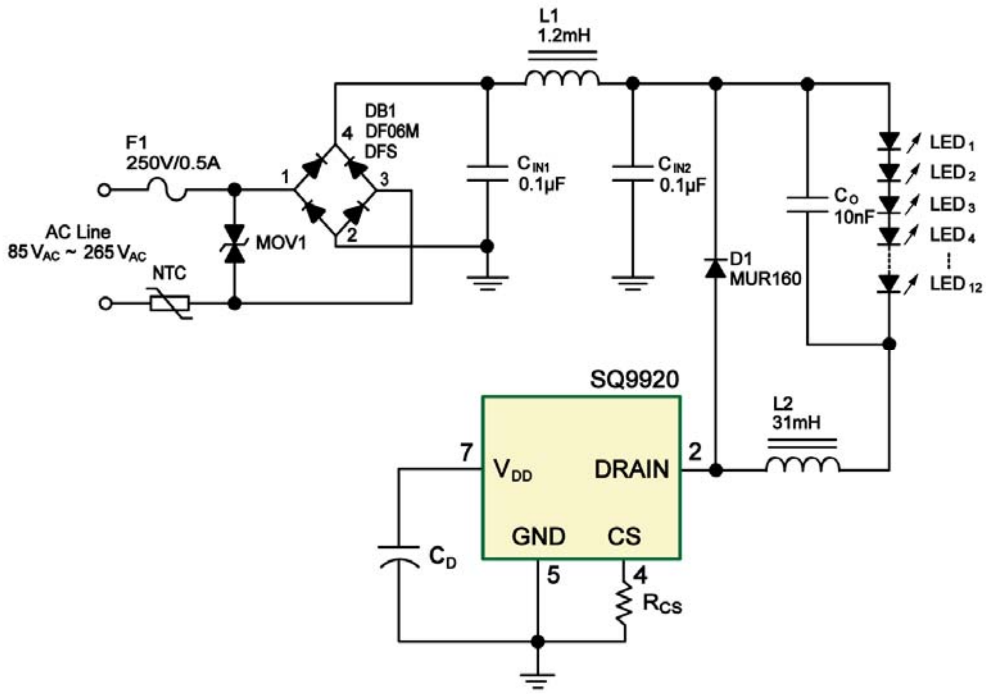
Step 4.

Calculating the leading edge spike duration using equations (5) and (6)

$$\begin{aligned} t_{SPIKE} &= \frac{V_{IN} \times C_P}{I_{SAT}} + t_{RR} \\ &= \frac{265 \times \sqrt{2} \times 48p}{120m} + 20n \\ &\approx 168ns < t_{BLANK}\ \text{(Typical 500ns)} \end{aligned}$$

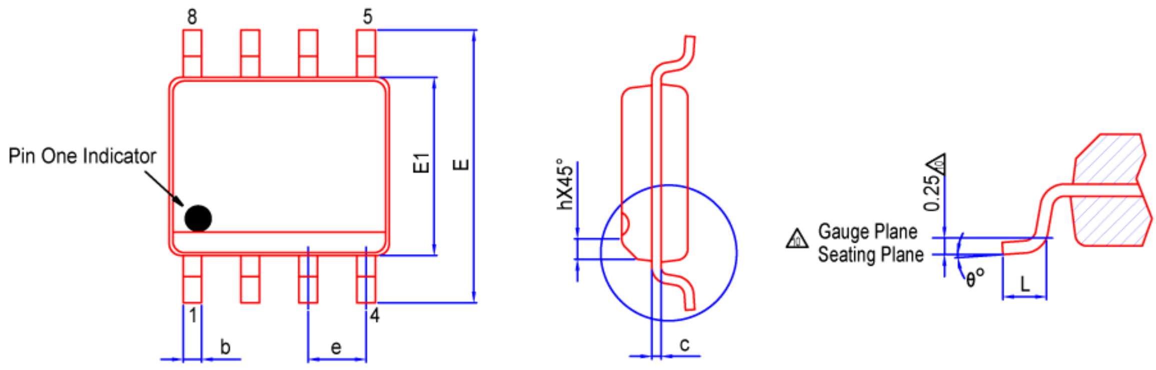
Therefore, it is safe.

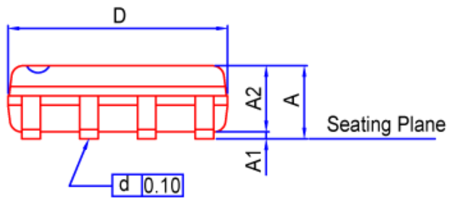
Figure 1. Universal $85V_{AC}$ ~ $265V_{AC}$ LED Lamp Driver Using the SQ9920

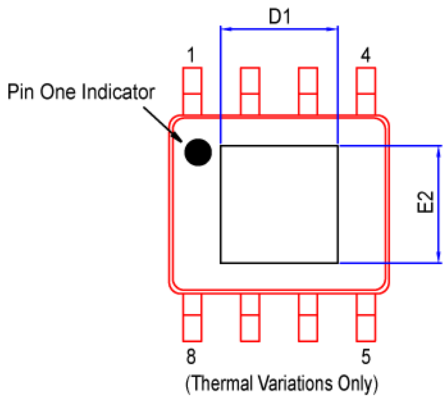


12. Package Outline Dimensions

Package Type : SO8-EP







	Thermal	
Symbols	Min.	Max.
A	–	1.70
A1	0.00	0.15
A2	1.25	–
b	0.31	0.51
c	0.10	0.25
D	4.90 BSC	
E	6.00 BSC	
E1	3.90 BSC	
e	1.27 BSC	
L	0.40	1.27
h	0.25	0.50
θ°	0	8

Unit : mm

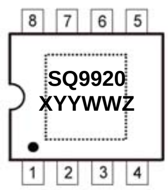
Thermally Enhanced Dimensions

Pad Size	E2		D1	
	Min.	Max.	Min.	Max.
90X90E	1.94	2.29	1.94	2.29

Unit : mm

Marking Information

SO8-EP



X = A/T Site, YY = Year, WW = Working Week, Z= Device Version

13. Statement

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