General Description

The CS8902A is a PWM high-efficiency low-cost LED driver control IC which provides an efficient solution for off-line high-brightness LED lamps from rectified line voltage ranging from 85VAC up to 305VAC.
The CS8902A control 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 CS8902A topology creates a constant current through the LEDs 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 LEDs current between a few mA and up to more than 1A.
The CS8902A supports a several kHz PWM dimming input and a 0 to 250mV linear dimming input.
The CS8902A provides protection functions including input Under Voltage Lockout (UVLO), output Short Circuit Protection (SCP), Open Loop Protection (OLP) and Over Temperature Protection (OTP). The CS8902A is available in a standard 8-lead SOP plastic (SOP-8) and the thermally enhanced PSOP-8 packages.

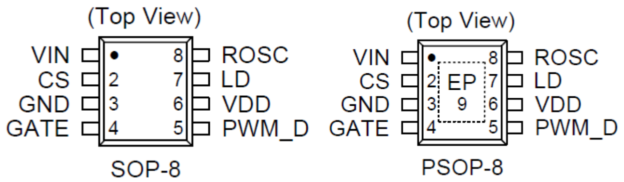
Features

High efficiency up to 90%
± 4% Current sensing voltage variation
Universal rectified $85V_{AC}$ to $305V_{AC}$ input range
DC input voltage range from 9V to 500V
Application from a few mA up to more than 1A
Open loop peak current controller
Support PWM and linear dimming
Input under voltage lockout
Over temperature protection
Output short circuit protection
Output open loop protection
Drive an external low-cost N-channel MOSFET
Available in SOP-8 and PSOP-8 packages
RoHS compliant and halogen free

Applications

Off-line LEDs lamp
Back lighting of flat panel display
Signage and decorative LEDs lighting
General purpose constant current source
Middle voltage (24V/36V) stage LEDs lighting
Low voltage automotive (12V/24V) LEDs lighting
Charger, Stage LEDs lighting

Pin Configurations

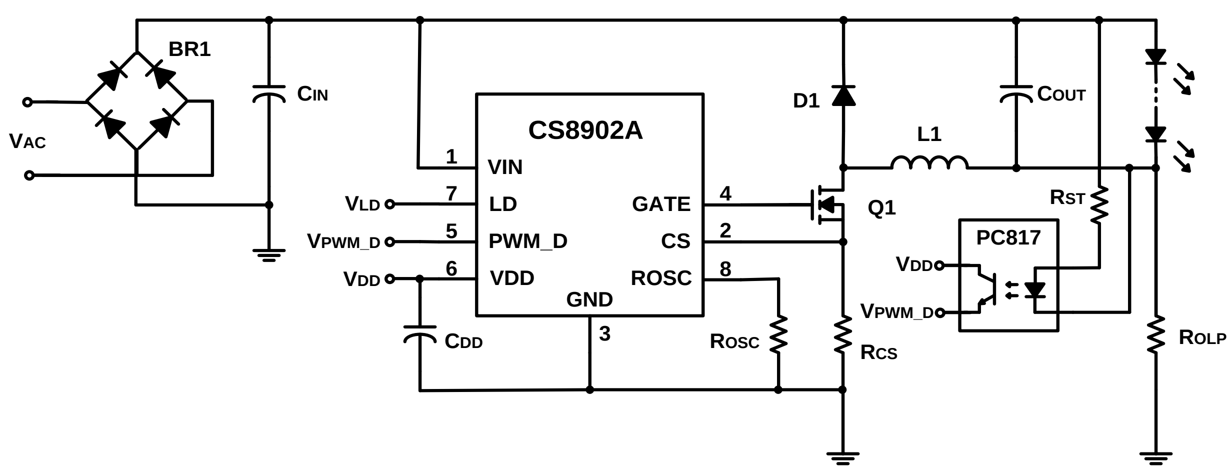


Order Information

CS8902A □□

Package Type
S8:SOP-8
P8:PSOP-8

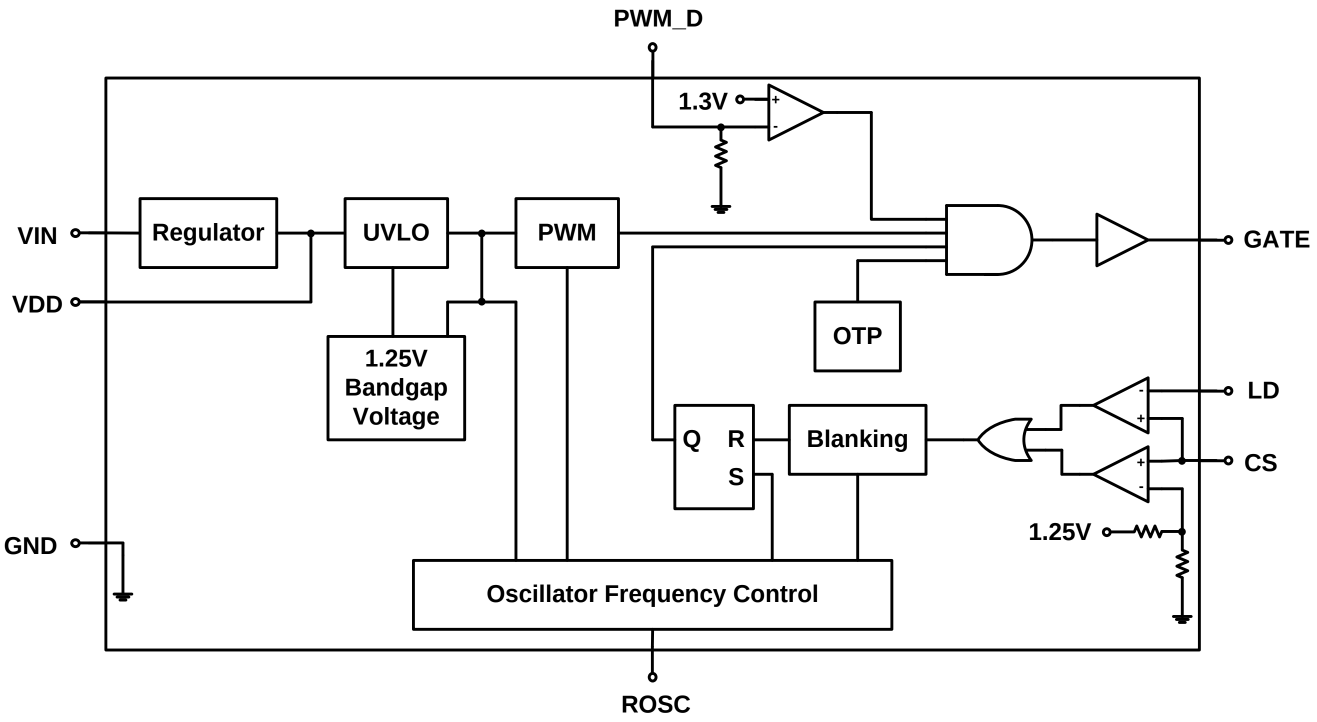
Simplified Application Circuit



Functional Pin Description

Pin Name	Pin No.		Pin Function
	SOP-8	PSOP-8	
VIN	1	1	DC input voltage. This pin is the input of a 9V to 500V high voltage linear regulator.
CS	2	2	LEDs current sensing input. The typical current sensing threshold voltage (V_{CS}) is 250mV between the CS and GND pins.
GND	3	3	Ground of the chip.
GATE	4	4	This pin is the output gate driver for an external N-channel power MOSFET.
PWM_D	5	5	This pin can be used for LEDs short circuit protection with some external circuitry. Low frequency PWM dimming pin, also enable input. Internal 100kΩ pull-down resistor to GND pin.
VDD	6	6	Regulated supply voltage output. Can supply up to 1mA for external circuitry. A sufficient storage low ESR capacitor (~10μF) is used to provide storage when the rectified AC input is near the zero crossing.
LD	7	7	Linear dimming control input pin. Apply a voltage less than V_{CS} ($V_{LD} < V_{CS}$) to dim the LEDs output current.
ROSC	8	8	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.
EP	N/A	9	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



Absolute Maximum Ratings (Note 1)

VIN input pin DC supply voltage, V_{IN} ---------- −0.5V to 525V

CS input pin voltage, V_{CS} ---------- −0.3V to (V_{DD} + 0.3V)

PWM_D input pin voltage, V_{PWM_D} ---------- −0.3V to (V_{DD} + 0.3V)

LD input pin voltage, V_{LD} ---------- −0.3V to (V_{DD} + 0.3V)

GATE output pin voltage, V_G ---------- −0.3V to (V_{DD} + 0.3V)

Power dissipation, P_D @ T_A = 25°C (Note 2)

SOP-8 ---------- 1.29W

PSOP-8 (Exposed pad) ---------- 1.67W

Package thermal resistance (Note 3)

SOP-8, θ_{JA} ---------- 77.6°C/W

SOP-8, θ_{JC} ---------- 10.8°C/W

PSOP-8 (Exposed pad), θ_{JA} ---------- 60°C/W

PSOP-8 (Exposed pad), θ_{JC} ---------- 2°C/W

Junction temperature, T_J ---------- 150°C

Lead temperature (Soldering, 10 sec.) ---------- 260°C

Storage temperature range ---------- −65°C to 150°C

ESD (Electrostatic Discharge) susceptibility (Note 4)

HBM (Human Body Model with VIN pin) ---------- 1.5kV

MM (Machine Model with VIN pin) ---------- 200V

Recommended Operating Conditions (Note 5)

Supply DC input voltage range, V_{IN} ---------- 9V to 500V

LD input pin voltage range, V_{LD} ---------- 0V to V_{DD}

PWM_D input pin voltage range, V_{PWM_D} ---------- 0V to V_{DD}

Junction temperature range, T_J ---------- −40°C to 125°C

Ambient temperature range for SOP-8 package (Note 6), T_A ---------- −40°C to 85°C

Ambient temperature range for PSOP-8 package (Note 6), T_{AP} ---------- −40°C to 105°C

Notes :

(1). Exceeding these ratings may damage the device.

(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.

(3). Measured on JEDEC 51-7 thermal measurement standard, 4-layer PCB. The PCB dimension is 114.3 x 76.2 x 1.6 mm^3.

(4). Semiconductor devices are ESD sensitive. Handling precaution is recommended.

(5). The device function is not guaranteed outside of the recommended operating conditions.

(6). Maximum ambient temperature range is limited by allowable power dissipation. The exposed pad package PSOP-8 with its lower package thermal resistance allows the variants using this package to extend the allowable maximum ambient temperature range.

Electrical Characteristics

(T_A = 25°C, unless otherwise noted)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
DC Input						
DC input supply voltage range	VIN	DC input voltage	9	--	500	V
Quiescent current at operation mode	IQ	V_{IN} = 9V to 500V, PWM_D pin connect to VDD pin	--	0.7	1.0	mA
Quiescent current at shutdown mode	ISHDN	V_{IN} = 9V to 500V, PWM_D pin connect to GND pin, T_A = −40°C to 85°C	--	0.4	0.7	mA
Internal Regulator						
Internally regulated output voltage	VDD	V_{IN} = 9V to 500V, I_{DD_EXT} = 0mA, GATE pin is open	7.0	7.5	8.0	V
V_{DD} under voltage lockout threshold	VUVLO	Rising VIN	6.1	6.7	7.3	V
V_{DD} under voltage lockout hysteresis	ΔVUVLO	Falling V_{IN}	--	0.5	--	V
V_{DD} load regulation	ΔVDD	V_{PWM_D} = V_{DD}, I_{DD_EXT} = 0mA to 1mA, 1nF at GATE pin, R_{OSC} = 226kΩ connect to GND pin	--	--	100	mV
Maximum V_{DD} voltage	VDD_MAX	When an external voltage is applied to VDD pin	--	--	13.5	V
V_{DD} current available for external circuitry (Note 7)	IDD_EXT	V_{IN} = 9V to 100V	--	--	1	mA
Peak Current Sensing Mode						
Current sensing pull-in threshold voltage	VCS	V_{IN} = 9V to 500V, T_A = −40°C to 85°C	240	250	260	mV
Current sense blanking interval	tLEB	V_{CS} = 0.5V, V_{LD} = V_{PWM_D} = V_{DD}	150	215	280	ns
Delay time from CS trip to GATE low	tD	V_{IN} = 12V, V_{PWM_D} = V_{DD}, V_{LD} = 0.15V, V_{CS} = 0V to 0.22V after t_{LEB}	--	--	300	ns
Oscillator						
Oscillator frequency	fOSC1	R_{OSC} = 1MΩ connect to GND pin	20	25	30	kHz
	fOSC2	R_{OSC} = 226kΩ connect to GND pin	80	100	120	kHz
	fOSC3	R_{OSC} = 19.8kΩ connect to GND pin	480	600	720	kHz
Dimming						
Maximum oscillating PWM duty cycle	DMAX_HF	f_{PWM_HF} = 25kHz, at GATE pin, CS pin connect to GND pin	--	--	100	%
PWM_D pin enable threshold high	VEN_HI	V_{IN} = 9V to 500V	2.4	--	--	V
PWM_D pin disable threshold low	VEN_LO	V_{IN} = 9V to 500V	--	--	1.0	V
PWM_D pin pull-down resistance	RPWM_D	V_{PWM_D} = 5V	50	100	150	kΩ
LD pin dimming voltage range	VLD	VIN = 9V to 500V	0	--	250	mV

Electrical Characteristics (Continue)

(T_A = 25°C, unless otherwise noted)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
GATE Pin Driving Output						
GATE pin high output voltage	VG_HI	V_{IN} = 0V, V_{DD} = 7.5V, I_G = 10mA	7.4	--	7.5	V
GATE pin low output voltage	VG_LO	V_{IN} = 0V, V_{DD} = 7.5V, I_G = −10mA	0	--	0.1	V
GATE pin output rise time	tR	V_{DD} = 7.5V, 1nF at GATE pin	--	15	20	ns
GATE pin output fall time	tF	V_{DD} = 7.5V, 1nF at GATE pin	--	20	30	ns
Protections						
PWM_D pin short circuit protection threshold voltage	$V_{PWM\_D\_TH}$	Refer to Figure 5 on page 11	--	1.3	--	V
Thermal shutdown threshold (Note 8)	TSD		--	150	--	°C
Thermal shutdown hysteresis (Note 8)	ΔTSD		--	30	--	°C

Notes :

(7). Also limited by package power dissipation limit, whichever is lower.

(8). Guaranteed by design.

Typical Application Circuit

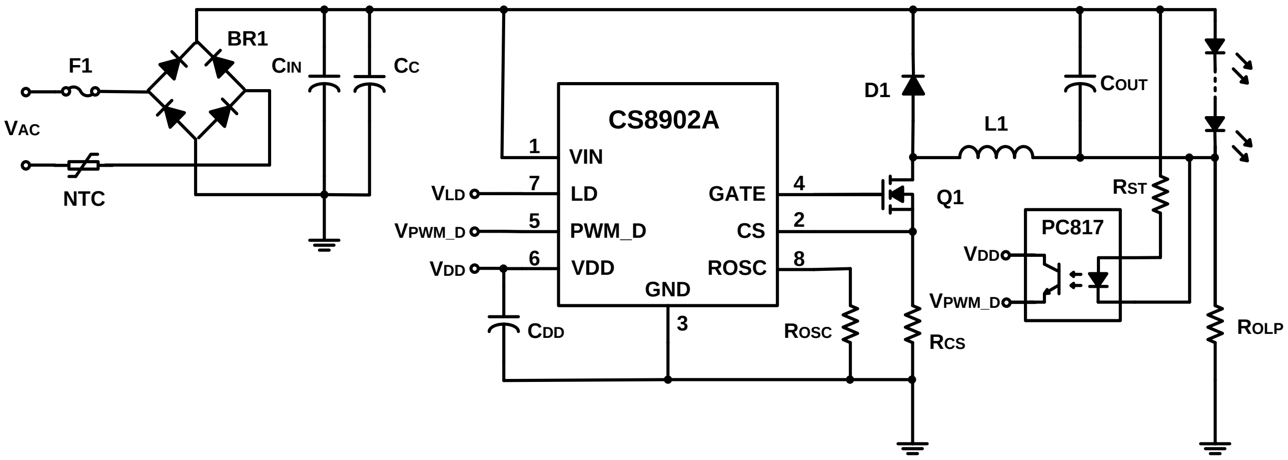


Figure 1. Typical Application Circuit without PFC

Table 1. Recommend Component Selection

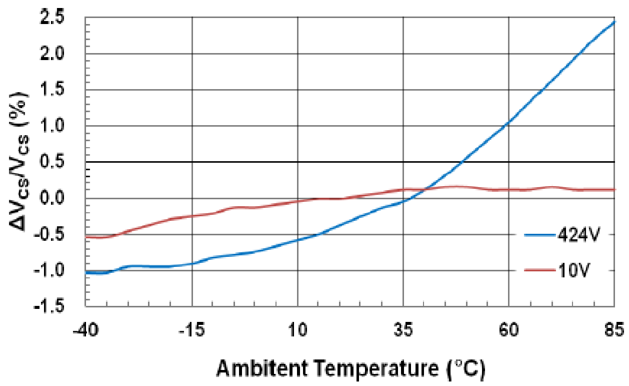
(For AC input voltage from 85VAC to 264VAC)

VLED (V)	ILED (mA)	F1 (A/V)	NTC	BR1	CIN (µF/V)	CC (µF/V)	CDD (µF/V)
24	350	2/250	SCK052	B6S	22/400	0.01/400	10/25
COUT (µF/V)	**L1 (mH)**	**D1**	**Q1 (A/V)**	**ROSC (kΩ)**	**RCS (Ω)**	**RST (kΩ)**	**ROLP (MΩ)**
4.7/400	4.5	ES1J	4/600	510	0.615 (Note 9)	24	1

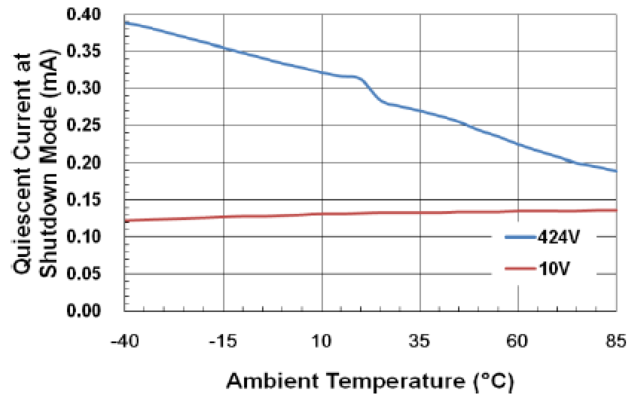
Note :

(9). Considering power consumption, use one 1.6Ω resistor and two 2.0Ω resistors with 1206 package in parallel for LED current sensing resistor (RCS).

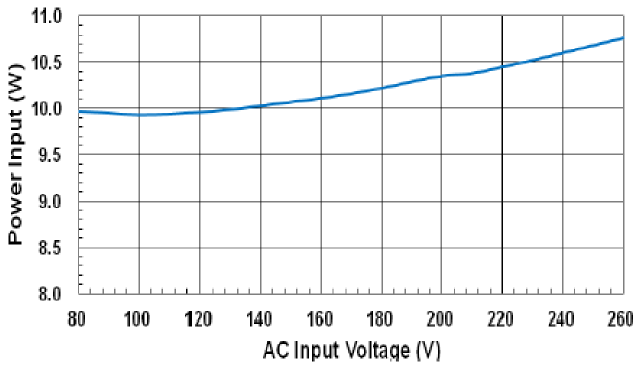
Typical Operating Characteristics



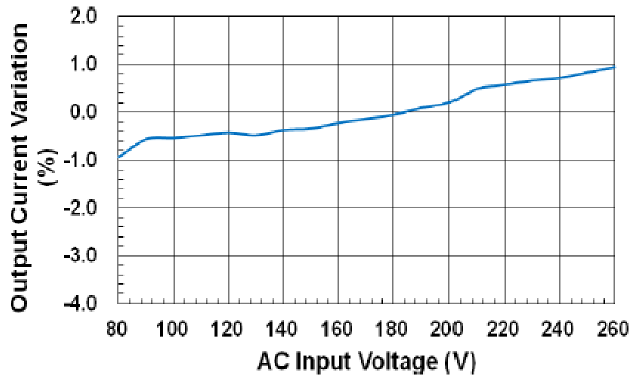
Variation of Current Sensing Pull-in Threshold Voltage (ΔV_{CS} / V_{CS}) versus Ambient Temperature (T_A), V_{IN} = Parameter



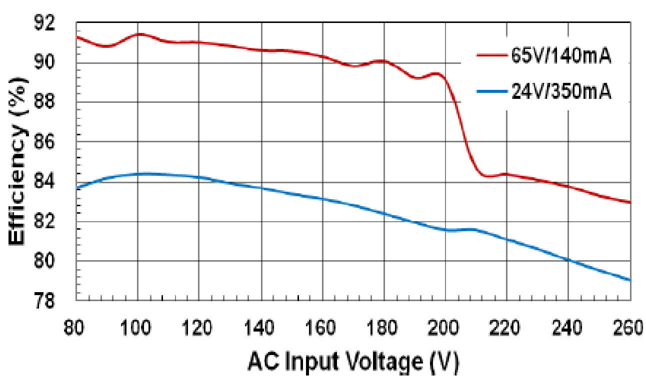
Quiescent Current at Shutdown Mode (I_{SHDN}) versus Ambient Temperature (T_A), V_{IN} = Parameter



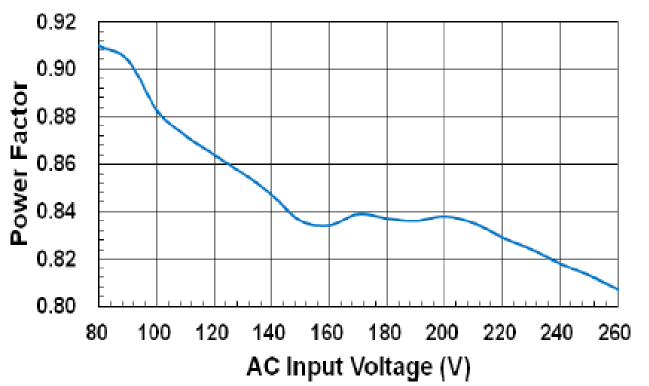
Power Input (P_{IN}) versus AC Input Voltage (V_{AC}), V_{LED} = 24V, I_{LED} = 350mA



Output Current Variation (ΔI_{LED}/I_{LED}) versus AC Input Voltage (V_{AC}), V_{LED} = 24V, I_{LED} = 350mA

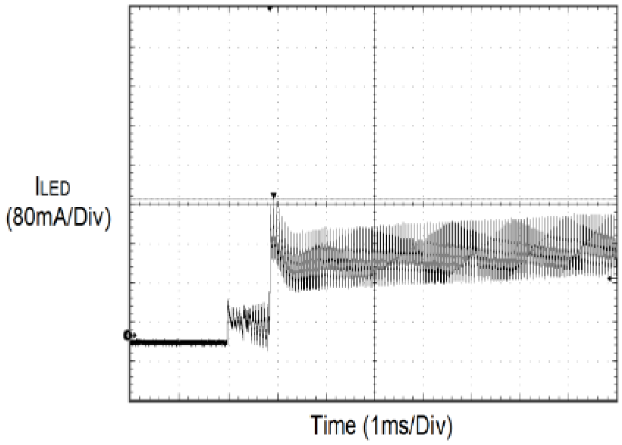


Efficiency versus AC Input Voltage (V_{AC}), V_{LED} / I_{LED} = Parameter

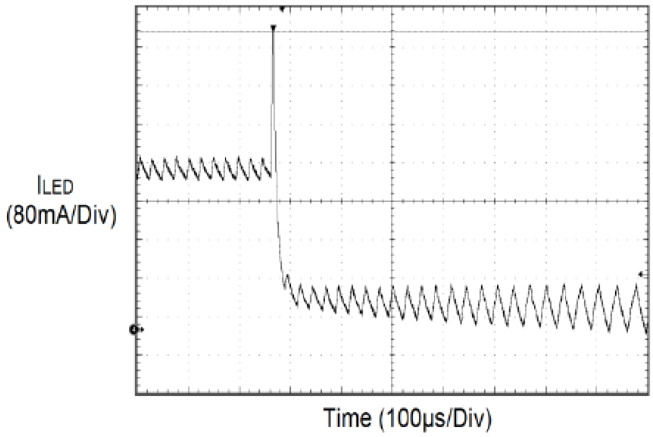


Power Factor versus AC Input Voltage (V_{AC}), V_{LED} = 24V, I_{LED} = 350mA with Passive PFC (Refer to Figure 6)

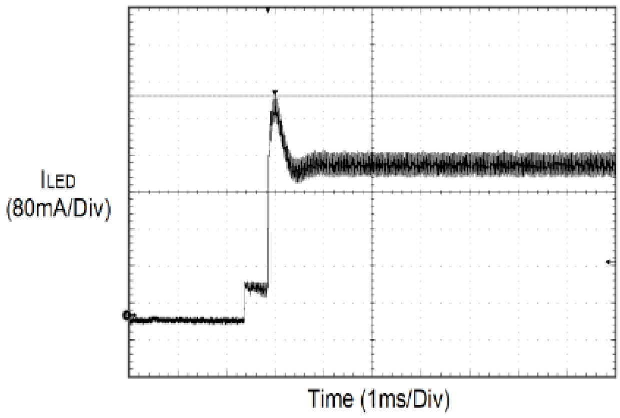
Typical Operating Characteristics (Continued)



Waveform of Soft Start, V_{LED} = 24V, I_{LED} = 250mA, R1 = 6k , R2 = 178k , C_{DD} = 10μF, C_{LD} = 1μF (Refer to Figure 2)



Waveform of Output Short Circuit Protection, V_{LED} = 24V, I_{LED} = 350mA (Refer to Figure 5)



Waveform of Re-start at Output Short Circuit Protection, V_{LED} = 24V, I_{LED} = 350mA (Refer to Figure 5)

Application Information

General Description

The CS8902A is very versatile and is capable of operating in isolated or non-isolated topologies. It can also be made to operate in continuous as well as discontinuous conduction mode. The CS8902A contains a high voltage linear regulator (see Function Block Diagram on page 2) the output of the regulator provides a power rail to the internal circuitry including the gate driver. A UVLO on the output of the regulator prevents incorrect operation at low input voltage to the VIN pin.

In a non-isolated buck LEDs driver when the GATE pin goes high, it results in the external power MOSFET (Q1) is turned on causing current to flow through the LEDs, inductor (L1) and current sensing resistor (R_{CS}). When the voltage across R_{CS} exceeds the current sensing threshold voltage (V_{CS}) of the controller, the external power MOSFET is turned off. The stored energy in the inductor causes the current to continue to flow through the LEDs via diode (D1).

The CS8902A linear regulator provides all power to the rest of the IC including GATE drive this removes the need for large high power start-up resistors. This means that operate correctly it requires around 0.7mA from the high voltage power rail. The linear regulator can also be used to supply up to 1mA to external circuits.

The CS8902A operates and regulates by limiting the peak current of the external power MOSFET; the peak current sensing threshold voltage is nominally set at 250mV.

The same basic operation is true for isolated topologies; however in these the energy stored in the transformer delivers energy to LEDs during the off-cycle of the external power MOSFET.

Setting the LEDs Current

In the non-isolated buck converter topology as Figure 1 on page 6, the average LEDs current is not the peak current divided by 2 – however, there is a certain error due to the difference between the peak and the average current in the inductor. The following equation accounts for this error :

$$Rcs = \frac{0.25}{\text{ILED} + [0.5 \text{ X } (\text{ILED X } 0.3)]}$$

Assume the ripple current is selected to be 30% of the nominal LEDs current. I_{LED} unit is Ampere.

Soft Start

Referring to the detail circuit in Figure 2. The LD pin provides a simple cost effective solution to soft start; by connecting a capacitor (C_{LD}) to the LD pin down to ground at initial power up the LD pin will be held low causing the current sensing threshold voltage to be low. As the capacitor charges up, the current sensing threshold voltage will increase thereby causing the average LEDs current to increase.

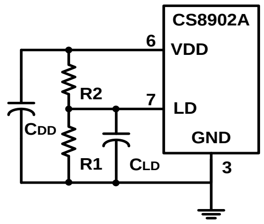


Figure 2. Soft Start Circuit

Input Under Voltage Lockout Protection

The CS8902A has implemented input under voltage lockout to protect the sufficient V_{DD} power supply. When the V_{DD} is rising above the higher UVLO threshold voltage (V_{UVLO}), the CS8902A starts to operate. If the V_{DD} drops below the threshold voltage ($V_{UVLO} - \Delta V_{UVLO}$), the CS8902A shutdowns.

Setting Operating Frequency

The CS8902A 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:

$$\text{Fosc} = \frac{25000}{\text{Rosc} + 22}$$

Where f_{OSC} unit is in kHz. R_{OSC} unit is in kΩ. Typical values for R_{OSC} vary from 19kΩ to 1MΩ.

When driving smaller numbers of LEDs, care should be taken to ensure that $t_{ON} > t_{LEB}$. The simplest way to do this is to reduce/limit the switching frequency by increasing the R_{OSC} value. Reducing the switching frequency will also improve the efficiency.

When operating in buck mode the designer must keep in mind that the minimum input DC 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 CS8902A operates at a duty cycle greater than 0.5. This instability reveals itself as an oscillation of the output current at a Sub-Harmonic Oscillation (SBO) of the switching frequency.
The best solution is to adopt the so-called constant off-time operation as shown in Figure 3. The resistor (R_{OSC}) is, connected to ground by default, to set operating frequency. To force the CS8902A to enter constant off-time mode R_{OSC} is connected to the gate of the external power MOSFET. This will decrease the duty cycle from 50% by increasing the total period, t_{OFF} + t_{ON}.

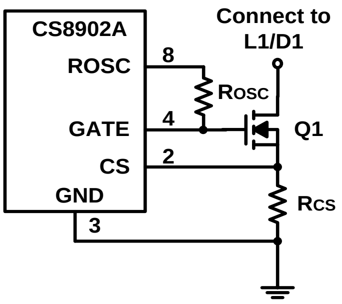


Figure 3. Constant Off-Time Circuit

The oscillator period equation above now defines the CS8902A off-time, t_{OFF}. When using this mode the nominal switching frequency is chosen and from the nominal input and output voltages the off-time can be calculated :

$$\mathrm{Toff} = (1 - \frac{VLED}{VIN})X\frac{1}{Fosc}$$

From this the timing resistor, R_{OSC}, can be calculated as follows :

$$\mathrm{Rosc} = (\mathrm{Toff}\ x25) - 22$$

Where Toff unit is μs. R_{OSC} unit is in kΩ.

Inductor Selection

The non-isolated buck circuit in Figure 1 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.
The required minimum inductor value is determined from the desired peak-to-peak LEDs ripple current in the inductor; typically around 30% of the nominal LEDs current.

$$Lmin = \frac{(\mathrm{Vin} - \mathrm{VLED})\mathrm{x\ Ton}}{0.3\ \mathrm{x\ ILED}}$$

The next step is determining the total voltage drop across the LEDs string. For example, when the string consists of 8 high-brightness LEDs and each diode has a forward voltage drop of 3.0V at its nominal current; the total LEDs voltage V_{LED} is 24V.

Linear Dimming

The LEDs brightness can be dimmed either linearly (using the LD pin) or via pulse width modulation (using the PWM_D pin); or a combination of both – depending on the application. Pulling the PWM_D pin to ground will turn off the CS8902A. When disabled, the CS8902A quiescent current is typically 0.4mA. Reducing the LD voltage will reduce the LEDs current but it will not entirely turn off the external power MOSFET and hence the LEDs current – this is due to the finite blanking period. Only the PWM_D pin will turn off the external power MOSFET.
Linear dimming is accomplished by applying a 0 to 250mV analog signal to the LD pin. This overrides the default 250mV threshold level of the CS pin and reduces the output current. If an input voltage greater than 250mV is applied to the LD then the output current will not change. When the linear dimming function is not used, it is recommended that the LD pin be connected to VDD pin.

PWM Dimming

PWM dimming is achieved by applying an external PWM signal to the PWM_D pin. The LEDs current is proportional to the PWM duty cycle and the light output can be adjusted between 0% and 100%. The PWM signal enables and disables the CS8902A modulating the LEDs current. The ultimate 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 LEDs light can be achieved by turning on and off the converter with low frequency 50Hz to 1kHz TTL logic level signal. See Figure 4 for linear and PWM dimming input waveforms.

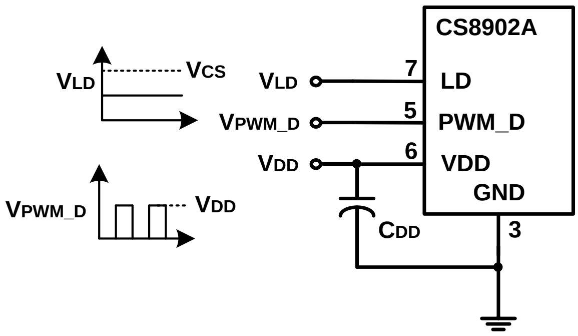


Figure 4. Linear and PWM Dimming Input Waveforms

With both modes of dimming it is not possible to achieve average brightness levels higher than the one set by the current sensing threshold level of the CS8902A. If a greater LEDs current is required then a smaller sensing resistor should be used.

Output Short Circuit Protection

The CS8902A can turn off external power MOSFET with minimum external sensing circuitry as soon as LED short circuit is detected. In order to achieve this, a sensing circuit, consisting of a resistor, R_{ST} and a photo-coupler, PC817, are added in parallel with output LEDs load as shown by Figure 5. In the normal operation when LEDs are present at output, a small current (I_F) flows through the resistor R_{ST} and this current transfers the output of the photo-coupler to turn on the photo-coupler, and then I_C flows through an internal 100kΩ pull-down resistance (R_{PWM_D}) via PWM_D pin. This on-state photo-coupler will set its emitter terminal at a voltage level close to V_{DD} which is above $V_{PWM\_D\_TH}$ (1.3V typical) and therefore PWM_D function is disabled. As soon as these two terminals, LED+ and LED- are shorted, there will be no voltage drop across the R_{ST} and PC817, so there is no current flowing through the photo-coupler, and PWM_D pin will be pulled down to below 1.3V due to internal pull-down resistance. The external power MOSFET is turned off as soon as V_{PWM_D} is below $V_{PWM\_D\_TH}$. For example, if PC817 forward current (I_F) is 1mA, then R_{ST} can be calculated as follows :

$$R_{ST} = \frac{VLED}{1mA}$$

Where R_{ST} unit is in kΩ.

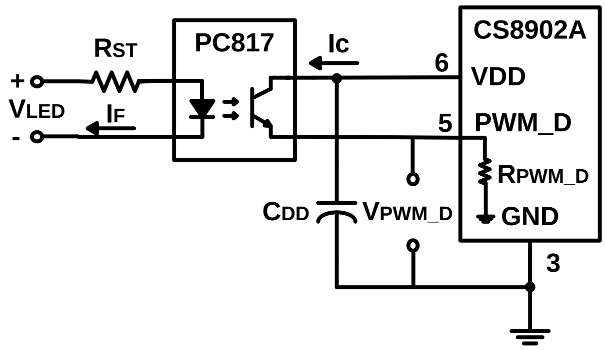


Figure 5. Output Short Circuit Protection Circuit

Output Open Circuit Protection

The non-isolated buck LEDs driver topology provides inherent protection against an open circuit condition in the LED string due to the LEDs being connected in series with the inductor. Should the LED string become open circuit then no switching occurs and the circuit can be permanently left in this state with damage to the rest of the circuit. To avoid this problem, the designer should add R_{OLP} resistor to LED- node.

Over Temperature Protection

The CS8902A has a built-in OTP to detect the overheated condition on the die. When the junction temperature reaches over T_{SD} (150°C typical), the CS8902A stops switching and waits for the lower threshold temperature ($T_{SD} - \Delta T_{SD}$, 120°C typical) to start it again. The OTP can be observed in the real applications. When it reaches OTP upper threshold temperature, the LEDs blink off. It cools off below the lower threshold temperature, the LEDs blink on.

Drive Low-Cost N-channel MOSFET

While using low-cost N-channel MOSFET with small input capacitance (C_{ISS} = 180pF typical value, like Fairchild's FQP2N60C), the result is LEDs output current to decrease rapidly at higher AC line input voltage (e.g. 230V_{AC}). To improve linearity of LEDs output current, time of current sense blanking interval (t_{LEB}) must be increased. The CS8902A has a built-in this feature. Therefore, the CS8902A can drive an external low-cost N-channel MOSFET to get higher accuracy LEDs output current for higher universal AC line input voltage.

AC to DC Off-Line LEDs Driver

The CS8902A is a cost-effective off-line buck LEDs driven controller specifically designed for driving LED strings. It is suitable for being used with either rectified AC line voltage or any DC voltage between 9V to 500V. See Figure 1 for Typical Application Circuit without PFC (Power Factor Correction).

Buck design equations :

$$D = \frac{\mathrm{VLED}}{\mathrm{Vin}}$$

$$Ton = \frac{\mathrm{D}}{\mathrm{Fosc}}$$

$$Lmin = \frac{(\mathrm{Vin} - \mathrm{VLED})\mathrm{x\ Ton}}{0.3\ \mathrm{x\ ILED}}$$

$$Rcs = \frac{0.25}{1.15\ \mathrm{x\ ILED}}$$

Design Example

For an AC line voltage of 230V_{AC} the nominal rectified DC input voltage $\mathrm{Vin} = 230\mathrm{VAC}\ \mathrm{x}\ \sqrt{2} = 325\mathrm{V}$From this and the LEDs chain voltage the duty cycle can be determined :

$$D = \frac{\mathrm{VLED}}{\mathrm{Vin}}$$

$$= \frac{24}{325}$$

$$= 0.074$$

From the switching frequency, for example f_{OSC} = 47kHz, the required on-time of the external power MOSFET can be calculated :

$$Ton = \frac{\mathrm{D}}{\mathrm{Fosc}}$$

$$= \frac{0.074}{47K}$$

$$= 1.57\mathrm{us}$$

The minimum value of the inductor for LEDs current of 350mA is determined as follows :

$$Lmin = \frac{(\mathrm{Vin} - \mathrm{VLED})\mathrm{x\ Ton}}{0.3\ \mathrm{x\ ILED}}$$

$$= \frac{(325 - 24)\mathrm{x}\ 1.57\mathrm{us}}{0.3\ \mathrm{x}\ 350\mathrm{mA}}$$

$$= 4.5mH$$

Input Bulk Capacitor

For off-line lamps an input bulk capacitor is required to ensure that the rectified AC voltage is held above twice the LED string voltage throughout the AC line cycle. The value can be calculated from :

$$\mathrm{CIN} \geq \frac{PIN\ x\ (1 - DCH)}{\sqrt{2}\ x\ VAC\_\mathrm{min}\ x\ 2FL\ x\ \Delta VDC\_max}$$

Where

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

FL : input line frequency (47Hz ~ 63Hz) for full AC line voltage range (85V_{AC} ~ 305V_{AC}),

ΔVDC_max : should be set 10% ~ 15% of $(\sqrt{2}\ x\ VAC\_min)$

If the capacitor has a 15% voltage ripple then a simplified formula for the minimum value of the bulk input capacitor approximates to :

$$CIN\_min = \frac{\mathrm{ILED\ x\ VLED\ x\ 0.06}}{VIN^2}$$

$$= 4.77\ \mathrm{uF}$$

For this example, the voltage rating of the capacitor should be more than V_{IN} with some safety margin factored in. An electrolytic capacitor with a 400V, 6.8μF rating would be adequate.

Note that electrolytic bulk capacitors contain parasitic elements that cause their performance to be less than ideal. One important parasitic is the capacitor's Equivalent Series Resistance (ESR), which causes internal heating as the ripple current flows into and out of the capacitor. In order to select a proper capacitor, the designer should consider capacitors that are specifically designed to endure the ripple current at the maximum temperature, and that have an ESR that is guaranteed within a specific frequency range (usually provided by manufacturers in the 120Hz to 100kHz range). The Effective Series Inductance (ESL) is another parasitic that limits the effectiveness of the electrolytic capacitor at high frequencies.

The combination of the variation of ESR over temperature and a high ESL may require adding a parallel film or tantalum capacitor (C_C) to absorb the high-frequency ripple component. This keeps the combined ESR within the required limit over the full design temperature range.

Power Factor Collection

If power factor improvement is required then for the input power less than 25W, a simple passive power factor correction circuit can be added to the CS8902A typical application circuit. Figure 6 show that passive PFC circuitry (3 current steering diodes and 2 identical capacitors) does not significantly affect the rest of the circuit. Simple passive PFC circuit improves the line current harmonic distortion and achieves a power factor greater than 0.85.

Each of these identical capacitors should be rated for half of the maximum input DC voltage and have twice as much capacitance as the calculated C_{IN_MIN} of the buck converter circuit without passive PFC (see above section on input bulk capacitor calculation).

DC-DC Buck LEDs Driver

The design procedure for an AC input buck LEDs driver outlined in the previous chapters equally applies DC input LEDs drivers. When driving long LEDs chains care should be taken not to induce SBO – maximum LED chain voltage should be less half of V_{IN}. So either maximum duty cycle should be kept below 50% or use of constant off-time operation removes this issue.

DC-DC Boost LEDs Driver

Due to the topology of the CS8902A LEDs driven controller it is capable of being used in boost configurations – at reduced accuracy. The current accuracy can be improved by measuring the LEDs current with an Op Amp and use the Op Amp's output to drive the LD pin.

A boost LEDs driver is used when the forward voltage drop of the LED string is higher than the input supply voltage. For example, the boost topology (see Figure 8) can be appropriate when input voltage is supplied by a 48V power supply and the LED string consists of twenty high-brightness LEDs, as the case may be for a street light.

In a boost converter, when the external power MOSFET is on the energy is stored in the inductor which is then delivered to the output when the external power MOSFET switches off. If the energy stored in the inductor is not fully depleted by the next switching cycle (continuous conduction mode) the DC conversion between input and output voltage is given by :

$$\frac{VLED}{VIN} = \frac{1}{1-D}$$

$$\mathrm{D} = \frac{VLED - VIN}{VLED}$$

From the switching frequency, F_{OSC}, the on-time of the external power MOSFET can be calculated :

$$\mathrm{Ton} = \frac{D}{Fosc}$$

From this the required inductor value can be determined by :

$$\mathrm{L} \geq \frac{VIN\ x\ Ton}{0.3\ x\ ILED}$$

The boost topology LEDs driver requires an output capacitor to deliver current to the LED string during the time that the external power MOSFET is on. In boost LEDs driver topologies if the LEDs should become open circuit damage may occur to the power switch and so some form of detection should be present to provide over-voltage detection/protection.

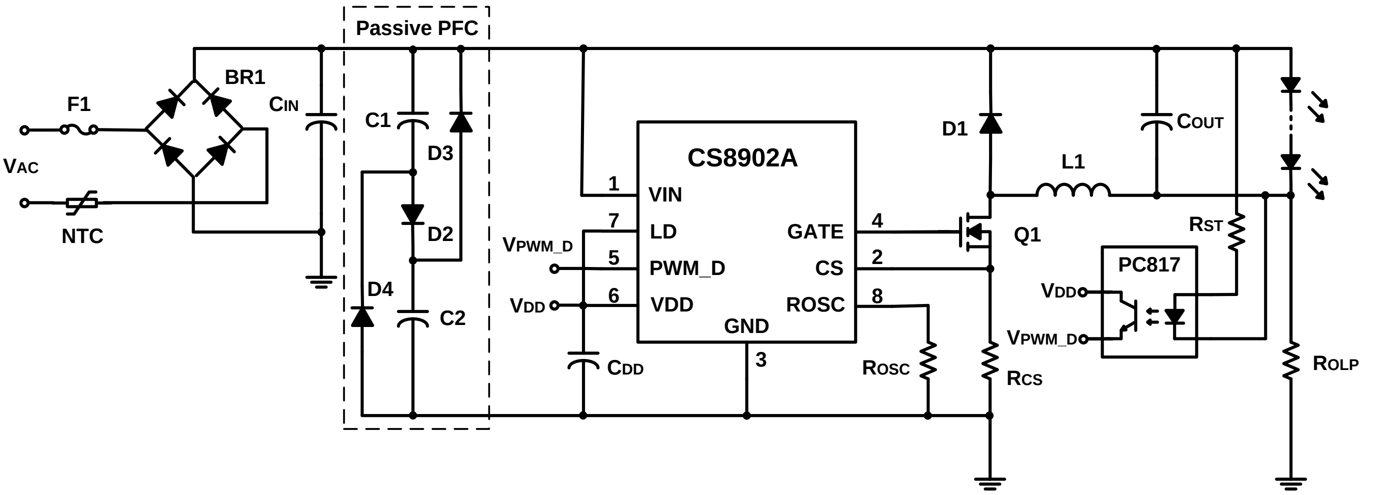


Figure 6. Typical Application Circuit with Passive PFC

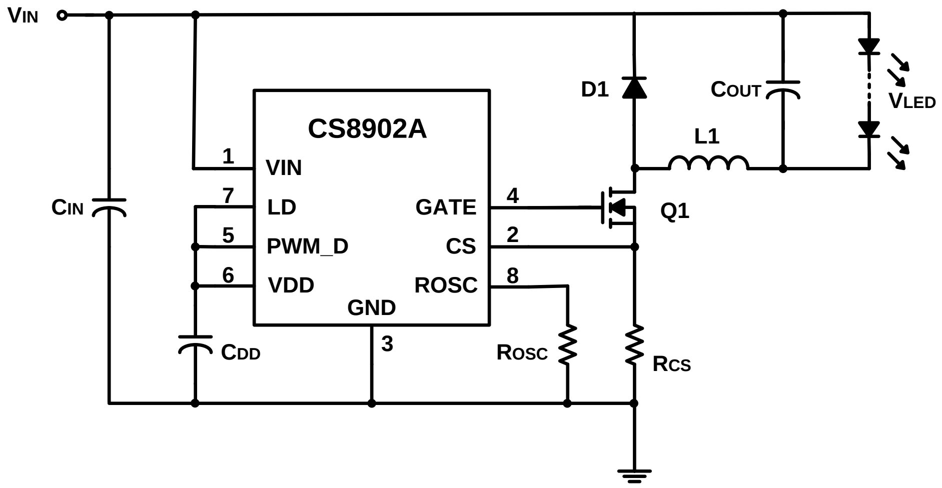


Figure 7. DC-DC Buck LEDs Driver

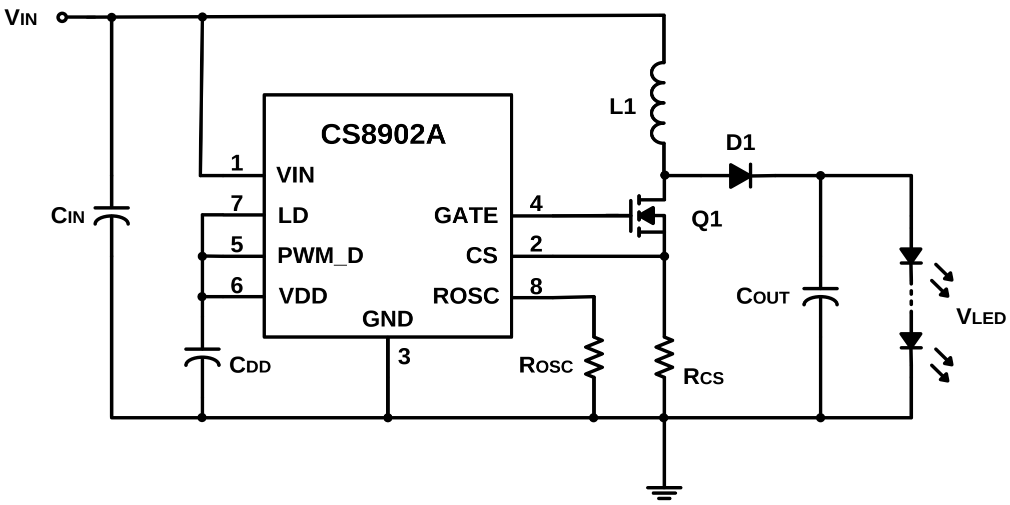
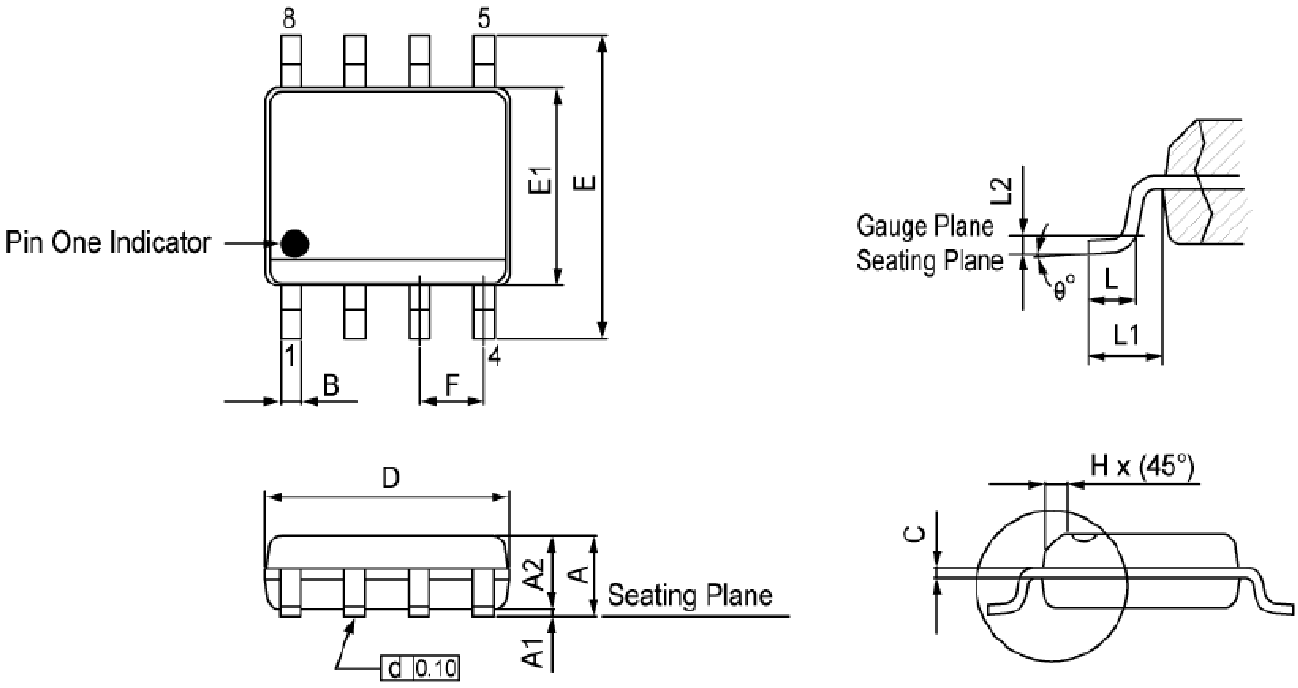


Figure 8. DC-DC Boost LEDs Driver

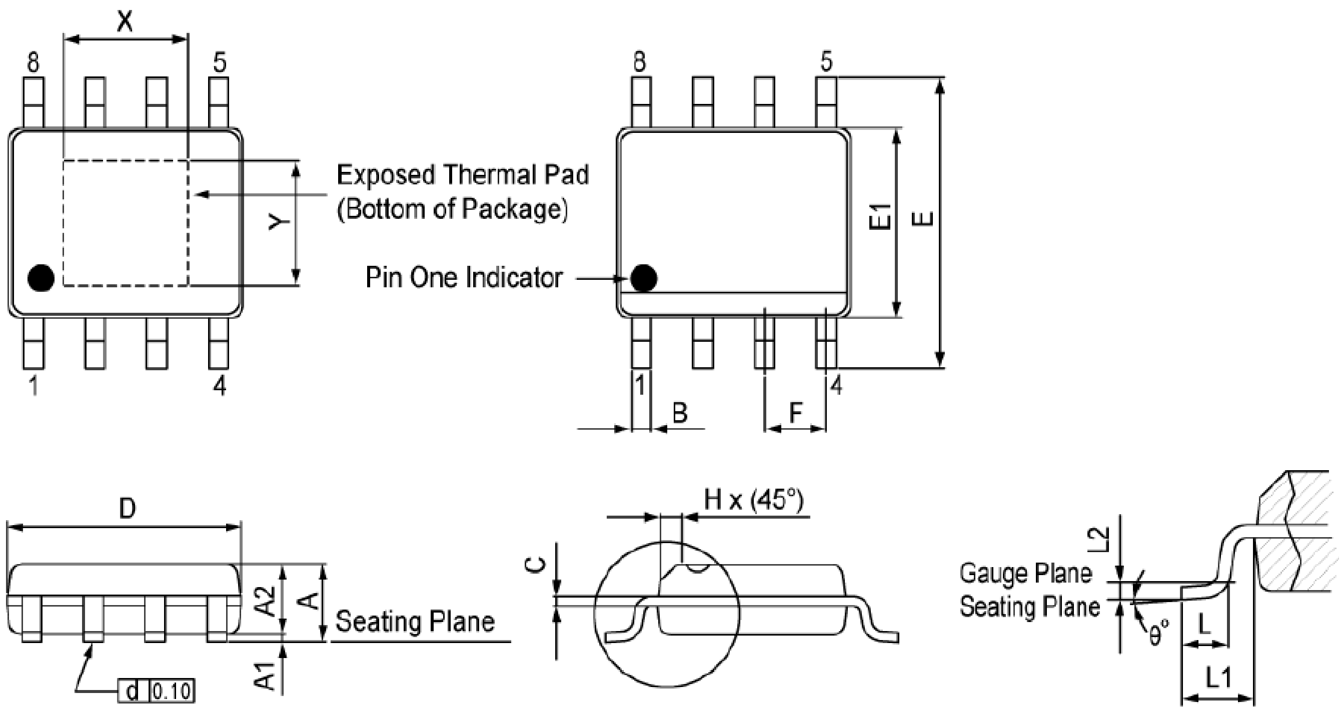
Package Outline Dimension

(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). PSOP-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