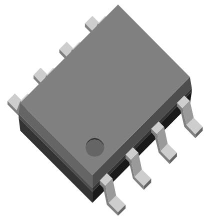
DESCRIPTION

The CK101 high voltage PWM LED driver- controller provides an efficient solution for offline high brightness LED lamps from rectified line voltages ranging from $85V_{AC}$ up to $277V_{AC}$. The CK101 drives external MOSFETs at switching frequencies up to 300kHz, with the switching frequency determined by a single resistor. The CK101 topology creates a constant current through the LEDs providing constant light output. The output current is programmed by one external resistor and is ultimately determined by the external MOSFET chosen and therefore allows many low current LEDs to be driven as well as a few high current LEDs.

The LED brightness can be varied by both Linear and PWM dimming using the CK101's LD and PWM_D pins respectively. The PWM_D input operates with duty ratio of 0-100% and frequency of up to several kHz.

The CK101 can withstand input voltages up to 500V which makes it very resilient to transients at standard mains voltages. The CK101 is available in the thermally enhanced SO-8EP package.



SO-8EP

ORDERING INFORMATION

Device	Package	Packing	Operating Temperature
CK101ASP-13	SO-8EP	T&R	-40ºC to 105ºC

APPLICATION

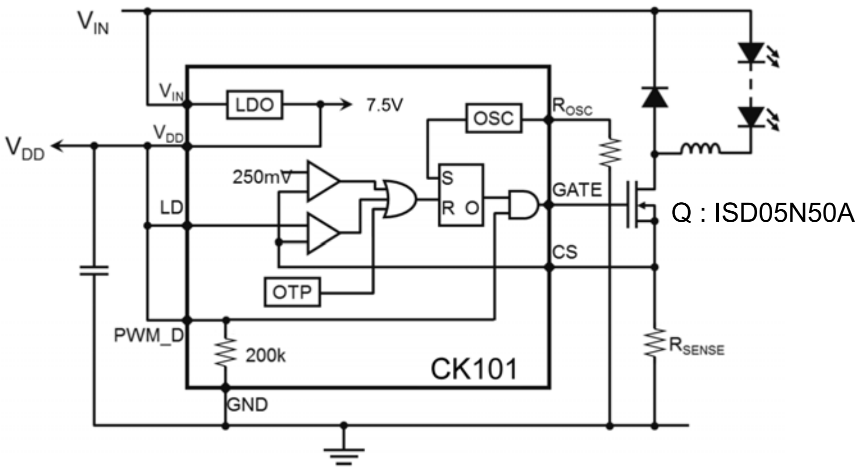
- LED offline lamps
- High voltage DC-DC LED Driver
- Signage and Decorative LED Lighting
- Back Lighting of Flat Panel Displays
- General purpose constant current source

FEATURES

- 90% Efficiency
- Universal rectified 85 to $277V_{AC}$ input range
- Input voltage up to 500V
- Internal voltage regulator removes start-up resistor
  · 7.5V MOSFET drive
- Tighter current sense tolerance: 5% CK101
- Drives LED Lamps with both high and low current LEDs
- LED brightness controlwith Linear and PWM dimming
- Internal Thermal Protection (OTP)
- SO-8EP: Available in “Green” Molding Compound (No Br, Sb) with lead Free Finish/ RoHS Compliant
  · Totally Lead-Free & Fully RoHS Compliant (Notes 1)
  · Halogen and Antimony Free. “Green” Device (Note 2)

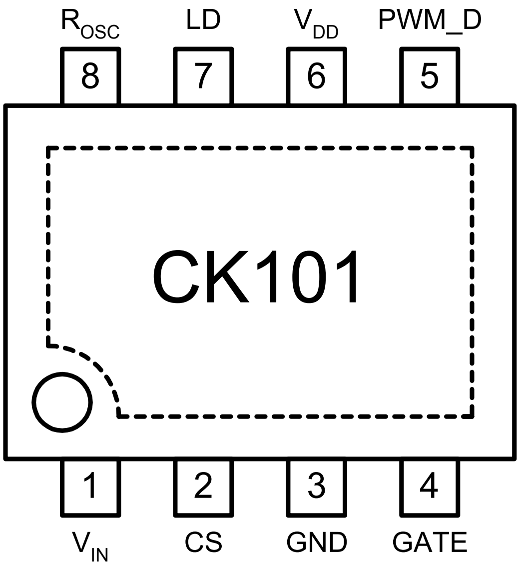
Notes: 1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS) & 2011/65/EU (RoHS 2) compliant.
2. Halogen and Antimony free "Green” products are defined as those which contain <900ppm bromine, <900ppm chlorine (<1500ppm total Br + Cl) and <1000ppm antimony compounds.

BLOCK DIAGRAM



*We reserve the right to alter product specifications at any time without notice.

PIN CONFIGURATION



PIN DESCRIPTION

NO	SYMBOL	DESCRIPTION
1	V_{IN}	Input voltage
2	CS	Senses LED string and external MOSFET switch current
3	GND	Device ground
4	GATE	Drives the gate of the external MOSFET switch.
5	PWM_D	Low Frequency PWM Dimming pin, also Enable input. Internal 200kΩ pull-down to GND
6	V_{DD}	Internally regulated supply voltage. • 7.5V nominal for CK101. Can supply up to 1mA for external circuitry. A sufficient storage capacitor is used to provide storage when the rectified AC input is near the zero crossing.
7	LD	Linear Dimming input. Changes the current limit threshold at current sense comparator and changes the average LED current.
8	R_{OSC}	Oscillator control. A resistor connected between this pin and ground sets the PWM frequency. The devices can be switched into constant off time (PFM) mode by connecting the external oscillator resistor between R_{OSC} pin and the gate of the external MOSFET.
N/A	EP PAD	Exposed Pad (bottom). Connect to GND directly underneath the package.

ABSOLUTE MAXIMUM RATINGS

CHARACTERISTICS	SYMBOL	VALUE	UNIT
Maximum input voltage, V_{IN}, to GND	$V_{IN\ (MAX)}$	-0.5 to +520	V
Maximum CS input pin voltage relative to GND	V_{CS}	-0.3 to +0.45	V
Maximum LD input pin voltage relative to GND	V_{LD}	-0.3 to (V_{DD}+0.3)	V
Maximum PWM_D input pin voltage relative to GND	V_{PWM_D}	-0.3 to (V_{DD}+0.3)	V
Maximum GATE pin voltage relative to GND	V_{GATE}	-0.3 to (V_{DD}+0.3)	V
Maximum V_{DD} pin voltage relative to GND	$V_{DD\ (MAX)}$	12	V
Continuous Power Dissipation (T_A = 25°C)			
SO-8EP (derate at 22mW/°C above 25°C)		2200	mW
Junction Temperature Range	T_J	+150	ºC
Storage Temperature Range	T_{ST}	-65 to +150	ºC
Human Body Model ESD Protection(Note 5)	ESD HBM	1500	V
Machine Model ESD Protection(Note 5)	ESD MM	300	V

Notes: 4. Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those listed in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

All voltages are with respect to Ground. Currents are positive into, negative out of the specified terminal.

5. Semiconductor devices are ESD sensitive and may be damaged by exposure to ESD events. Suitable ESD precautions should be taken when handling and transporting these devices

RECOMMENDED OPERATING CONDITIONS

CHARACTERISTICS	SYMBOL	MIN	MAX	UNIT
Input DC supply voltage range	V_{INDC}	15.0	500	V
Ambient temperature range (Note 6)	T_A	-40	+105	ºC
Maximum recommended voltage applied to V_{DD} pin (Note7)	V_{DD}		10	V
Pin PWM_D input low voltage	V_{EN} EN(HI) $_{(LO)}$	0	1	V
Pin PWM_D input high voltage	V	2.4	V_{DD}	

Notes: 6. Maximum ambient temperature range is limited by allowable power dissipation. The Exposed pad SO-8EP with its lower thermal impedance allows the variants using this package to extend the allowable maximum ambient temperature range.

7. When using the CK101 in isolated LED lamps an auxiliary winding might be used.

ELECTRICAL CHARACTERISTICS

(Over recommended operating conditions unless otherwise specified - TA = 25°C)

CHARACTERISTICS	SYMBOL	TEST CONDITION	MIN	TYP	MAX	UNIT
Shut-down mode supply current	I_{INSD}	Pin PWM_D to GND, $V_{IN}=V_{IN(MIN)}$(Note8)		0.50	1.0	mA
Internally regulated voltage	V_{DD}	$V_{IN}=C_{IN(MIN)}$~500V, (Note8) $I_{DD(ext)}=0$, Gate pin open	7.0	7.5	8.0	V
V_{DD} current available for external circuitry	$I_{DD(ext)}$	$V_{IN}=V_{IN(MIN)}$ to 100V(Notes 8&9)			1.0	mA
V_{DD} under voltage lockout threshold	UVLO	V_{DD} rising	6.4	6.7	7	V
V_{DD} under voltage lockout hysteresis	ΔUVLO	V_{DD} falling		500		mV
PWM_D pull-down resistance	R_{PWM_D}	V_{PWM_D}=5V	150	200	250	kΩ
Current sense threshold voltage	$V_{CS(HI)}$	Full ambient temperature range	237.5	250	262.5	mV
GATE high output voltage	$V_{GATE(HI)}$	I_{OUT}=10mA	V_{DD}-.0.3		V_{DD}	mV
GATE low output voltage	$V_{GATE(LO)}$	I_{OUT}=10mA	0		0.3	V
Oscillator frequency	f_{OSC}	R_{OSC}=1MΩ	20	25	30	kHz
		R_{OSC}=226kΩ	80	100	120	
Maximum Oscillator PWM Duty Cycle	D_{MAXhf}	f_{PWMhf}=25kHz, at GATE, CS to GND.			100	%
Linear Dimming pin voltage range	V_{LD}	Full ambient temperature range (Note10), VIN=20V	0	-	250	mV
Current sense blanking interval	t_{BLANK}	V_{CS}=0.45V, $V_{LD}=V_{DD}$	160	250	440	ns
Delay from CS trip to GATE lo	t_{DELAY}	V_{IN}=20V, V_{LD}=0.15, V_{CS}=0 to 0.22V after T_{BLANK}			300	ns
GATE output rise time	t_{RISE}	CGATE=500pF		30	50	ns
GATE output fall time	t_{FALL}	CGATE=500pF		30	50	na
Thermal shut down	T_{SD}			150		ºC
Thermal shut down hysteresis	T_{SDH}			50		
Thermal Resistance Junction-to-Ambient	$θ_{JA}$	SO-8EP (Note10)		66		ºC/W
Thermal Resistance Junction-to-Case	$θ_{JC}$	SO-8EP (Note10)		9		ºC/W

Notes: 8. $V_{IN(MIN)}$for the CK101 is 15V.
9. Also limited by package power dissipation limit, whichever is lower.
10. Device mounted on FR-4 PCB (51mm x 51mm 2oz copper, minimum recommended and thermal vias to bottom layer ground plane. For better thermal performance, larger copper pad for heat-sink is needed.

APPLICATIONS INFORMATION

The CK101 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.

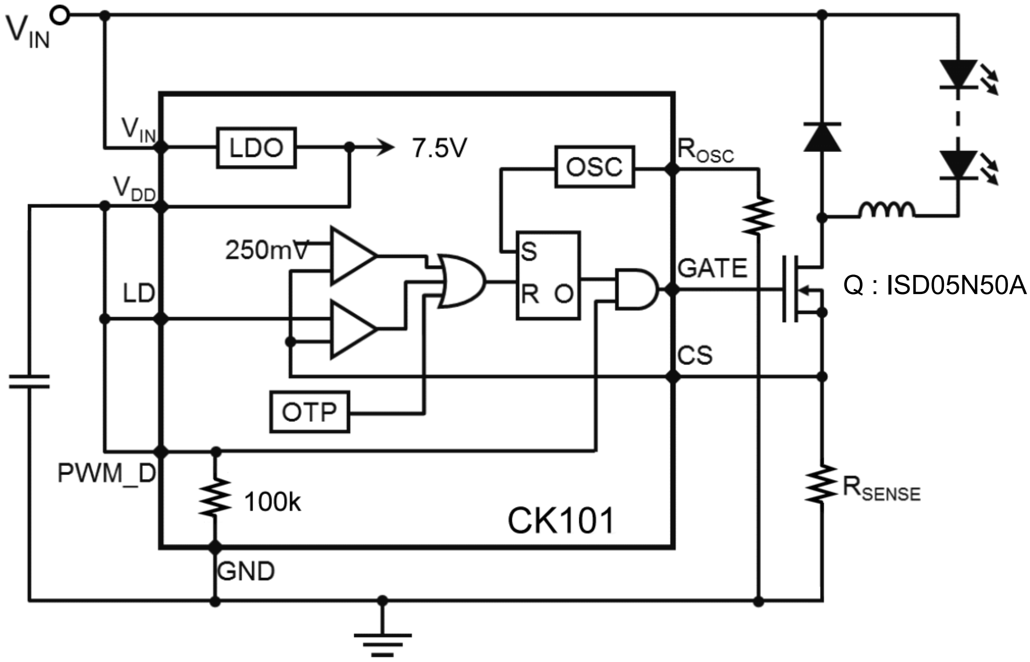


Fig. 1 Functional Block Diagram

The CK101 contains a high voltage LDO (see figure 1) the output of the LDO provides a power rail to the internal circuitry including the gate driver. A UVLO on the output of the LDO prevents incorrect operation at low input voltage to the V_{IN} pin. In a non-isolated Buck LED driver when the gate pin goes high the external power MOSFET Q1 is turned on causing current to flow through the LEDs, inductor (L1) and current sense resistor (R_{SENSE}). When the voltage across R_{SENSE} exceeds the current sense pin threshold the external MOSFET Q1 is turned off. The stored energy in the inductor causes the current to continue to flow through the LEDs via diode D1.

The CK101's LDO 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 0.5mA from the high voltage power rail. The LDO can also be used to supply up to 1mA to external circuits.

The CK101 operates and regulates by limiting the peak current of the external MOSFET; the peak current sense threshold 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 MOSFET.

Design Parameters

Setting the LED Current

In the non-isolated buck converter topology, figure 1, the average LED 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.

$$R_{SENSE} = \frac{250mV}{\left(I_{LED} + \left(0.5 * I_{RIPPLE}\right)\right)}$$

APPLICATIONS INFORMATION

Setting Operating Frequency

The CK101 is capable of operating over a 25 and 300kHz switching frequency range. The switching frequency is programmed by connecting an external resistor between R_{OSC} pin and ground. The corresponding oscillator period is:

$$t_{OSC} = \frac{R_{OSC} + 22}{25} \mu s \qquad \text{with } R_{OSC} \text{ in k}\Omega$$

The switching frequency is the reciprocal of the oscillator period. Typical values for R_{OSC} vary from 75kΩ to 1MΩ

When driving smaller numbers of LEDs, care should be taken to ensure that $t_{ON} > t_{BLANK}$. 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 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 CK101 operates at a duty cycle greater than 0.5. This instability reveals itself as an oscillation of the output current at a sub-harmonic (SBO) of the switching frequency.

The best solution is to adopt the so-called constant off-time operationas shown in Figure 2.The resistor (R_{OSC}) is, connected to ground by default, to set operating frequency. To force the CK101 to enter constant OFF time mode R_{OSC} is connected to the gate of the external MOSFET. This will decrease the duty cycle from 50% by increasing the total period, $t_{OFF} + t_{ON}$.

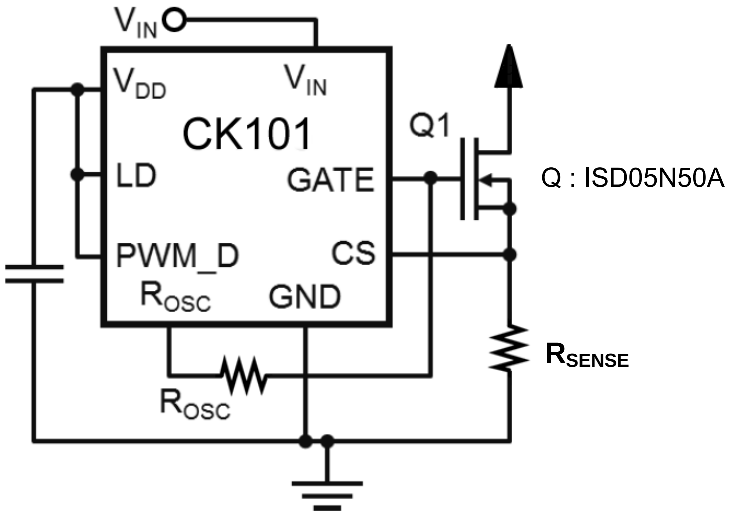


Fig.2 Constant Off-Time Configuration

The oscillator period equation above now defines the CK101 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:

$$t_{OFF} = \left(1 - \frac{V_{OUT(nom)}}{V_{IN(nom)}}\right) * \frac{1}{f_{OSC}}$$

From this the timing resistor, R_{OSC}, can be calculated: $R_{OSC}=(t_{OFF}(\mu s)*25)-22(k\Omega)$

APPLICATIONS INFORMATION

Inductor Selection

The non-isolated buck circuit, 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 inductor value is determined from the desired peak-to-peak LED ripple current in the inductor; typically around 30% of the nominal LED current.

$$L = \frac{(V_{IN} - V_{LEDs}) \times D}{(0.3 \times I_{LED}) \times f_{OSC}}$$

Where D is duty cycle

The next step is determining the total voltage drop across the LED string. For example, when the string consists of 10High-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.

Dimming

The LED 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 CK101. When disabled, the CK101's quiescent current is typically 0.5mA. Reducing the LD voltage will reduce the LED current but it will not entirely turn off the external power transistor and hence the LED current – this is due to the finite blanking period. Only the PWM_D pin will turn off the power transistor.

Linear dimming is accomplished by applying a 45 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.

The LD pin also provides a simple cost effective solution to soft start; by connecting a capacitor to the LD pin down to ground at initial power up the LD pin will be held low causing the sense threshold to be low. As the capacitor charges up the current sense threshold will increase there by causing the average LED current to increase.

PWM dimming is achieved by applying an external PWM signal to the PWM_D pin. The LED current is proportional to the PWM duty cycle and the light output can be adjusted between zero and 100%.. The PWM signal enables and disables the CK101 -modulating the LED 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 LED light can be achieved by turning on and off the converter with low frequency 50Hz to 1000Hz TTL logic level signal.

With both modes of dimming it is not possible to achieve average brightness levels higher than the one set by the current sense threshold level of the CK101. If a greater LED current is required then a smaller sense resistor should be used

Output Open Circuit Protection

The non-isolated buck LED 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.

APPLICATIONS INFORMATION

AC/DC Off-Line LED Driver

The CK101 is a cost-effective off-line buck LED driver-controller specifically designed for driving LED strings. It is suitable for being used with either rectified AC line or any DC voltage between 15-500V. See figure 3 for typical circuit.

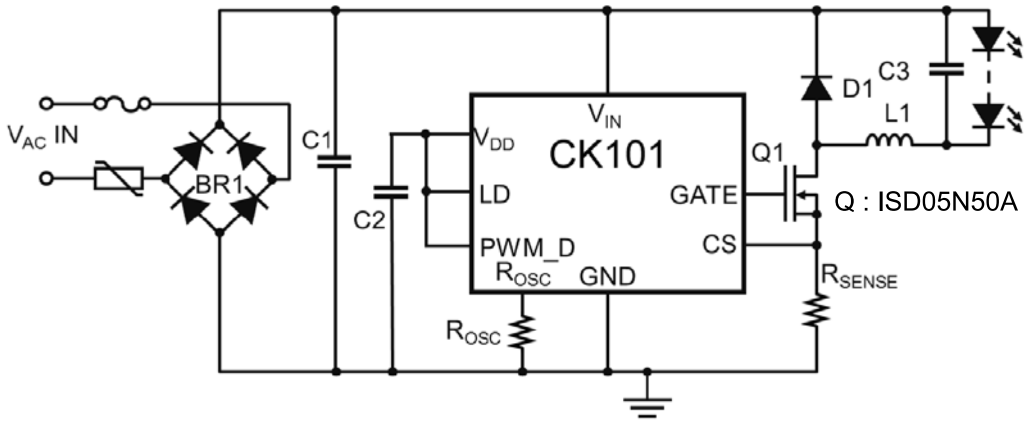


Fig. 3 Typical Application Circuit (without PFC)

Buck Design Equations:

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

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

$$L \geq \frac{(V_{IN} - V_{LEDs}) \times t_{ON}}{0.3 \times I_{LED}}$$

$$R_{SENSE} = \frac{0.25}{I_{LED} + (0.5 \times (I_{LED} \times 0.3))}$$ where $I_{LED} \times 0.3 = I_{RIPPLE}$

Design Example

For an AC line voltage of 120V the nominal rectified input voltage V_{IN} = 120V*1.41 = 169V. From this and the LED chain voltage the duty cycle can be determined:

$D = V_{LEDs} / V_{IN} = 30/169 = 0.177$

From the switching frequency, for example f_{OSC} = 50kHz, the required on-time of the external MOSFET can be calculated:

$t_{ON} = D/f_{OSC} = 3.5\mu s$

The value of the inductor for an LED current of 350mA is determined as follows:

$L = (V_{IN} - V_{LEDs}) * t_{ON} / (0.3 * I_{LED}) = 4.6mH$

APPLICATIONS INFORMATION

Input Bulk Capacitor

For Offline 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:

$$C_{IN} \geq \frac{P_{IN} \times (1 - D_{CH})}{\sqrt{2} \times V_{LINE\_MIN} \times 2f_L \times \Delta V_{DC\_MAX}}$$

Where

D_{ch}: Capacity charge work period, generally about 0.2~0.25
f_L: Input frequency for full range (85~265V_{RMS})
ΔV_{DC_MAX} Should be set 10~15% of $\sqrt{2} V_{LINE\_MIN}$

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

$$C_{MIN} = \frac{I_{LED} \times V_{LEDs} \times 0.06}{V_{IN}^{2}}$$

Power Factor Correction

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 CK101 typical application circuit. Figure 4 shows that passive PFC circuitry (3 current steering diodes and 2 identical capacitors) does not significantly affect the rest of the circuit. Simple passive PFC improves the line current harmonic distortion and achieves a power factor greater than 0.85.

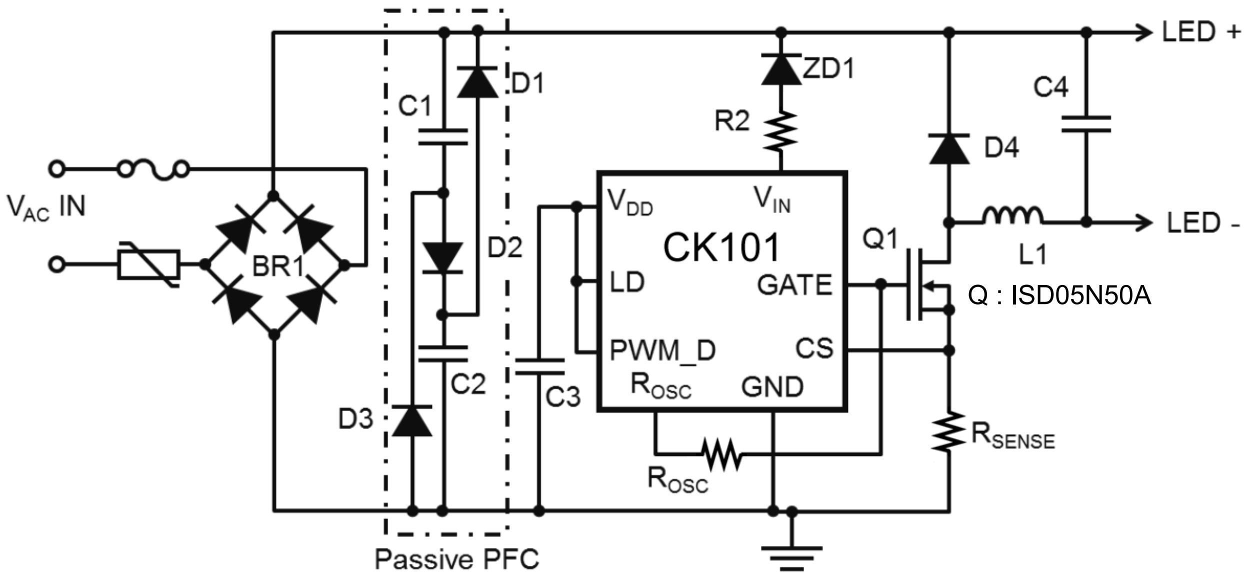
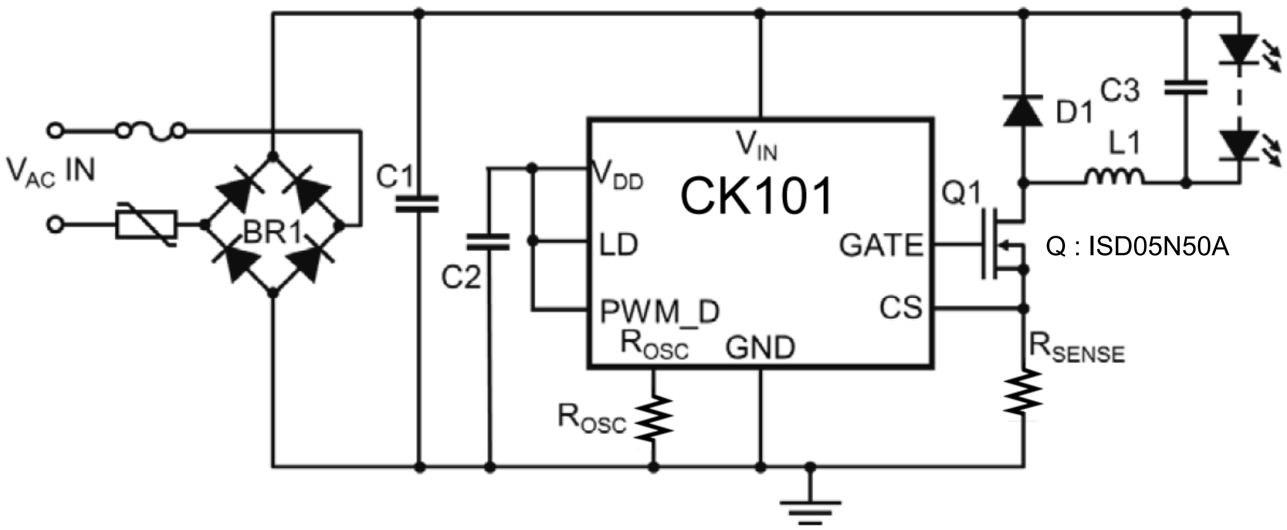


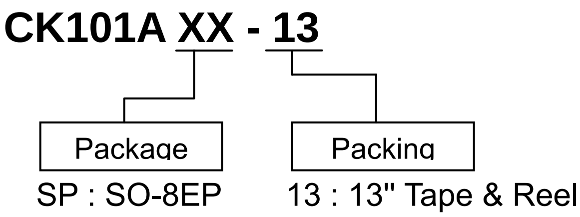
Fig. 4 Typical Application Circuit with Passive PFC

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

TYPICAL APPLICATION



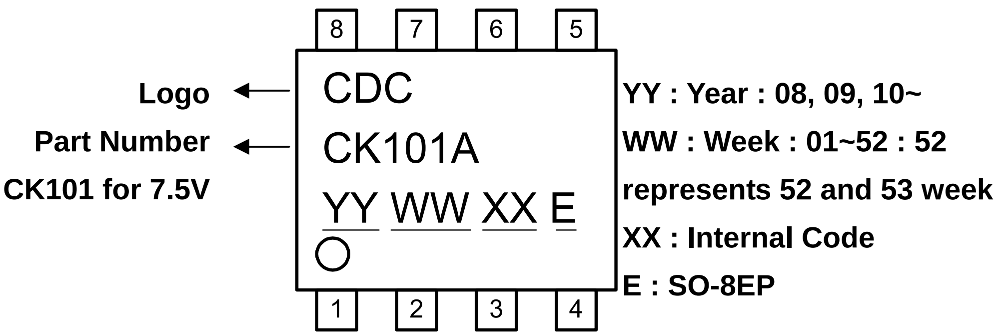
LINEUP



Device	Package Code	Packaging	13" Tape and Reel	
			Quantity	Part Number Suffix
CK101ASP-13	SP	SO-8EP	2500/Tape &Reel	-13

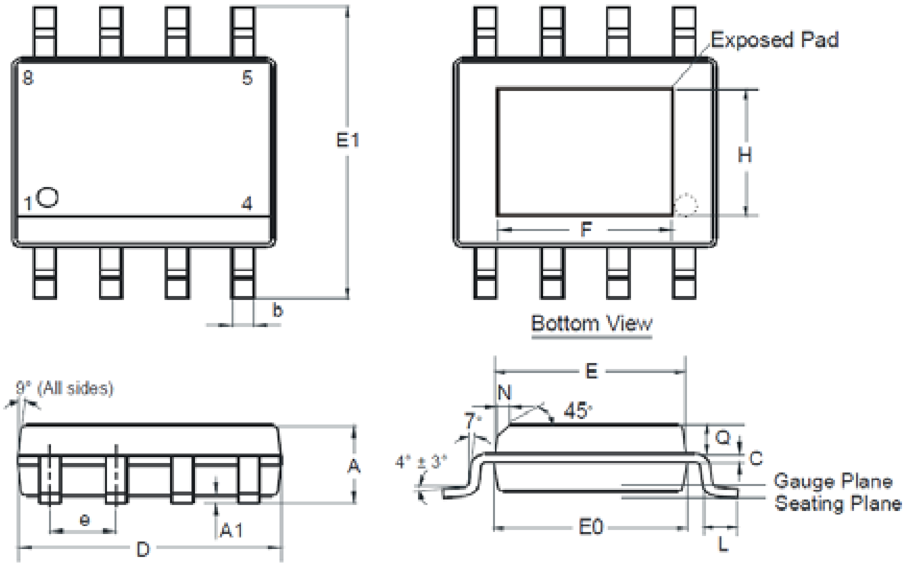
MARKING INFORMATION

(1) SO-8EP



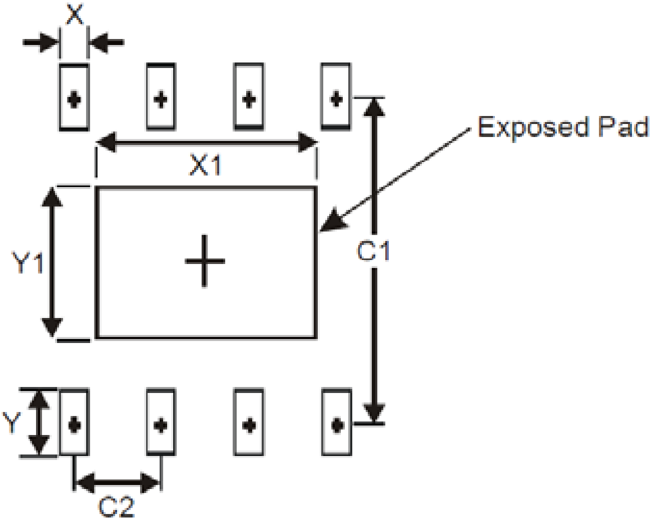
PACKAGE DIMENSIONS

SO-8EP



SO-8EP(SOP-8L-EP)			
Dim	Min	Max	Typ
A	1.40	1.50	1.45
A1	0.00	0.13	-
b	0.30	0.50	0.40
C	0.15	0.25	0.20
D	4.85	4.95	4.90
E	3.80	3.90	3.85
E0	3.85	3.95	3.90
E1	5.90	6.10	6.00
e	-	-	1.27
F	2.75	3.35	3.05
H	2.11	2.71	2.41
L	0.62	0.82	0.72
N	-	-	0.35
Q	0.60	0.70	0.65
All Dimensions in mm			

FOOT PATTERN



Dimensions	Value (in mm)
X	0.60
Y	1.55
X1	3.30
Y1	2.66
C1	5.4
C2	1.27

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