Universal High Brightness LED Driver

Description

The D8030 is a pulse width modulated (PWM) high-efficiency LED driver converter IC. It allows efficient operation of LED strings from voltage sources ranging up to 500VDC. The D8030 includes an internal high voltage switching MOSFET controlled with fixed frequency (f_{OSC}) of approximately 100kHz. The LED string is driven at constant current, thus providing constant light output and enhanced reliability. The LED string current is set by an external resistor for up to 150mA. The peak current control scheme provides good regulation of the output current throughout the universal AC line voltage range of 85VAC to 265VAC or DC input voltage of 20V to 500V.

The D8030 uses internal soft-start to reduce input surge current during cold start. It also 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 fOSC. The D8030 also supports three-level toggle dimming with built-in input high voltage toggle switching detection. Once the toggle switching is detected, the dimming level can be determined by the built-in circuit which is set at 50% of output current.

The D8030 allows efficient operation of HV LEDs from voltage sources ranging from 85VAC up to 265VAC. These devices are available in SO8-EP package.

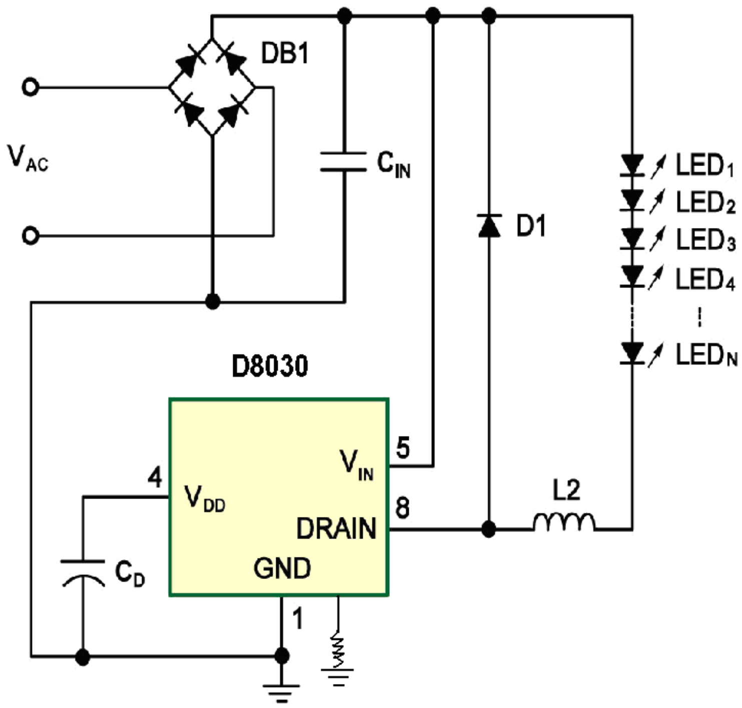
Features

- Universal rectified 85V_{AC} to 265V_{AC} input range
- Fixed frequency 100kHz buck converter
- Integrated 500V power MOSFET
- Power-on sequence control and soft-start (SS)
- Spread spectrum to reduce EMI filter cost
- Internal three-level input toggle dimming
- Internal over temperature protection (OTP)
- Programmable output current up to 150mA
- ±3% output LED current accuracy

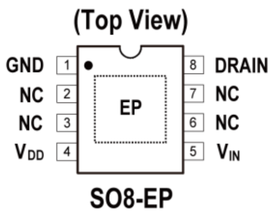
Typical Applications

- Decorative low power lighting
- High voltage (HV) LED lighting fixtures
- E26/E27 LED bulb
- E12/E14/E17 LED150 candle bulb

Typical Application Circuit



Pin Assignments and Ordering Information



Device	Packaging	Quantity of Tape & Reel
D8030	SO8-EP	3000

Pin Descriptions

Pin No.	Pin Name	Function
1	GND	Ground pin.
		Device ground. Common connection for all circuits.
2, 3, 6, 7	NC	No connection.
4	V_{DD}	Internal supply voltage pin.
		Internally regulated supply voltage 12V nominal. Power source pin for internal control circuits. Bypass this pin with a 22μF low ESR (Equivalent Series Resistance) capacitor.
5	V_{IN}	Input voltage pin.
		DC input supply voltage.

8	DRAIN	DRAIN input pin.
		DRAIN terminal of the output switching MOSFET.

Absolute Maximum Ratings (Note 1)

Symbol	Parametar	Ratings	Unit
V_{INDC}	DC input supply voltage range, V_{IN} to GND	-0.5 ~ +520	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	-65 ~ +150	°C
θ_{JA}	Junction-to-ambient thermal resistance	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.

Recommended Operating Conditions

Symbol	Parametar	Min.	Max.	Unit
V_{INDC}	DC input supply voltage range, V_{IN} to GND	20	500	V
T_A	Ambient temperature range (Note 2)	-40	+105	°C

Note :

2. Maximum ambient temperature range is limited by allowable power dissipation. The exposed pad SO8-EP with its lower thermal impedance allows the variants using this package to extend the allowable maximum ambient temperature range.

Electrical Characteristics

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

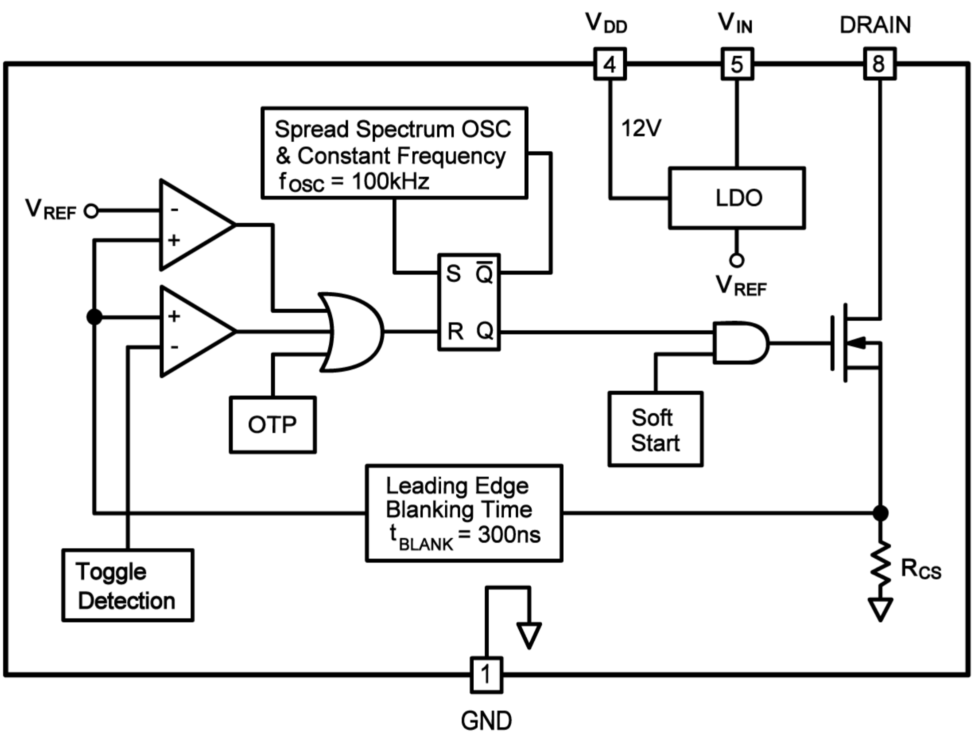
Parameter	Symbol	Min.	Typ.	Max.	Unit	Condition
Regulator (V_{DD})						
Input DC supply voltage range	V_{INDC}	20		500	V	
Shut down mode supply current	I_{INSD}		200	350	μA	V_{IN} = 40V
Internally regulated voltage	V_{DD}	11	12	13	V	
V_{DD} under voltage lockout threshold	V_{UVLO}		9.2		V	V_{DD} rising
V_{DD} under voltage lockout hysteresis	ΔV_{UVLO}		1.1		V	V_{DD} falling
Output (DRAIN)						
Breakdown voltage (Note 3)	V_{BR}	550			V	
On-resistance	R_{ON}			20	Ω	D8030, I_{DRAIN} = 100mA
				20		D8030, I_{DRAIN} = 150mA
Output capacitance (Note 3)	C_{DRAIN}		1.0		pF	D8030, V_{IN} = 40V

			1.0			D8030, V_{IN} =40V
MOSFET saturation current (Note 3)	I_{SAT}		250		mA	D8030
			300			D8030
Current sense comparator						
Threshold current (Note 3)	I_{TH}		120		mA	D8030
			180			D8030
Current sensing blanking interval (Note 3)	t_{BLANK}		400		ns	
Minimum on-time (Note 3)	$t_{ON(MIN)}$	650			ns	
Oscillator						
Oscillator frequency (Note 3)	f_{OSC}		100		kHz	
Frequency hopping range (Note 3)	$\Delta f_{OSC} / f_{OSC}$		8		%	
Protections						
Soft-start time (Note 3)	t_{SS}		400		μs	From applying voltage at DRAIN pin to DRAIN current reaches to I_{TH}
Thermal shut down	T_{SD}		150		°C	
Thermal shut down hysteresis	ΔT_{SD}		50		°C	

Note :

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

Functional Block Diagram



Function Descriptions

The D8030 is a PWM peak current converter for controlling a buck topology in continuous conduction mode (CCM). The output current is internally preset at 100mA/150mA for D8030 respectively. When the input voltage of 20V to 500V appears at the DRAIN pin, the internal high-voltage linear regulator seeks to maintain a voltage of 12V at the V_{DD} pin. This 12V drives all internal circuits and MOSFET to assure lower $R_{DS(ON)}$ (drain-source on resistance). Until this voltage exceeds the internally programmed under-voltage threshold (V_{UVLO}), 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 under-voltage comparator to prevent oscillation.

At initial power start, because the output voltage or current is not established yet, the low feedback voltage generated from the initial internal current sensing resistor is less than reference level; the internal error amplifier will be activated and pushes PWM duty cycle to maximum. This sudden maximum duty cycle will generate a high input surge current which might damage the internal power MOSFET. The D8030 has an internal soft-start circuit which does not require any external capacitor. At cold start, this soft-start circuit allows only 50% of normal operation mode current (50mA/75mA) as current limit for about 400μs, then switches to normal operation mode to generate 100mA/150mA constant current at DRAIN pin.

The D8030 operates at fixed frequency internally set at 100kHz. When the input current exceeds the internal preset level, a current sensing comparator resets an RS flip-flop, and the MOSFET turns off until next cycle starts. A leading edge blanking delay of 300ns 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 100kHz, 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.

Dimming can be accomplished through toggling the input AC source off and on. In order to activate the dimming function correctly, the off and on interval should be less than 500ms. If the interval is longer than 500ms, it is considered as intention to turn off the light. The dimming current is internally set at 40% of I_{TH}.

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 efficient. There is a 50°C hysteresis to re-start the internal MOSFET.

The D8030 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 $500V_{DC}$. All LEDs can be run in series and the D8030 regulates at constant current, yielding uniform illumination. The output current is internally fixed at 100mA/150mA respectively. This part is available in space saving SOT-223 package. For all component calculation in the following, please refer to Figure 1.

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_O) which is normally set at 30% of output current (I_O) and the equation can be expressed as below :

$$L2 \geqslant \frac{(V_{IN} - V_O) \times t_{ON}}{\Delta I_O} \qquad (1)$$

where V_O is the total forward voltage of the LED string. t_{ON} is the on-time, depending on duty ratio (D), as well as operation frequency (f) by $t_{ON} = D/f$. The output current in the LED string is calculated as

$$I_O = I_{TH} - \frac{\Delta I_O}{2} \qquad (2)$$

where I_{TH} is the current sensing comparator threshold. The ripple current introduces a peak-to-average error in the output current setting that needs to be accounted for.

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 D8030 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 converter 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. Minimizing these parasitic elements is essential for efficient and reliable operation of the D8030.

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. Therefore, 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 reduce 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 :

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

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 150mA typically. However, it may become lower at increased junction temperature. The duration of the leading edge current spike can be estimated as :

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

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

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

where $t_{BLANK(MIN)}$ is the minimum blanking time of 200ns, and $V_{IN(MAX)}$ is the maximum instantaneous input voltage.

Estimating Power Loss

The power loss in this chip can be attributed to switching power loss and conduction power loss. Discharging the parasitic capacitance C_P into the DRAIN pin of the D8030 is responsible for the bulk of the switching power loss. When this chip is powered by DC input, the switching power loss can be estimated using the following equation :

$$P_{SWITCH(DC)} = \left(\frac{V_{IN}^2 \times C_P}{2} + V_{IN} \times I_{SAT} \times t_{RR}\right) \times f_S \quad (7)$$

where f_S is the switching frequency (100kHz), I_{SAT} is the saturated DRAIN current of the D8030. The switching loss is the greatest at the maximum input voltage.

When this chip is powered from the full-wave rectified AC input, the switching power loss can be estimated as :

$$P_{SWITCH(AC)} \approx \frac{f_S}{2(1-D)}(V_{AC} \times C_P + 2I_{SAT} \times t_{RR}) \times (V_{AC} - \frac{V_O}{\eta}) \quad (8)$$

Where V_{AC} is the input AC line voltage and η is the efficiency of the power converter.

The switching power loss associated with turn-off transitions of the DRAIN pin can be disregarded. Due to the large amount of parasitic capacitance connected to this switching node, the turn-off transition occurs essentially at zero-voltage.

DC Conduction power loss in this chip can be calculated as :

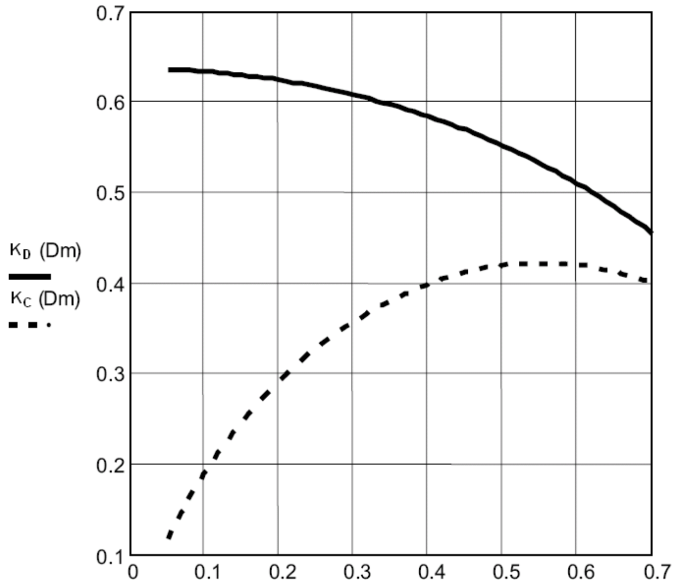
$$P_{COND(DC)} = (D \times I_O^2 \times R_{ON}) + [I_{DD} \times V_{IN} \times (1 - D)] \quad (9)$$

where $D = V_O/(\eta \times V_{IN})$ is the duty ratio, R_{ON} is the on-resistance, I_{DD} is the internal linear regulator current.

When the LED driver is powered from the full-wave rectified AC line input, the exact equation for calculating the conduction loss is more cumbersome. However, it can be estimated using the following equation :

$$P_{COND(AC)} = (K_C \times I_O^2 \times R_{ON}) + (K_D \times I_{DD} \times V_{AC}) \quad (10)$$

where V_{AC} is the input AC line voltage. The coefficients K_C and K_D can be determined from the minimum duty ratio of the chip as shown below :



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/W of LED output power. Since frequency jittering is adopted in this chip, a lower cost EMI filter can be used. A recommended input filter is shown in Figure 1 for the following design example.

Design Example

Let us design a LED lamp driver with the D8030 to meet the following specifications :

Input : Universal AC, $85V_{AC}$ ~ $265V_{AC}$

Output : 100mA

Loading : String of 12 LED (V_F = 3.4V max. each)

Step 1.

Calculating the output inductance L2

The output voltage $V_O = 12 \times V_F = 40.8V$ (max.)

Assuming a 30% peak-to-peak ripple.

$$L2_{MIN} = \frac{(V_{IN} - V_O) \times t_{ON}}{\Delta I_O}$$

$$= \frac{(265 \times \sqrt{2} - 40.8) \times 1.09\mu}{0.3 \times 100m}$$

$$= 12.13mH$$

where D = 40.8/(265 × 1.414) = 0.109,

and $t_{ON} = D/f_S$ = 0.109/100k = 1.09µs

Select L2 = 15mH, I_{TH} = 120mA. Typical SRF = 170kHz. From equation (3), the coil capacitance can be calculated by

$$C_{L2} = \frac{1}{L2 \times (2\pi \times SRF)^2}$$

$$= \frac{1}{15m \times (2\pi \times 170k)^2}$$

$$= 58.43pF$$

So, select C_{L2} = 60pF

Step 2.

Selecting D1

Usually, the reverse recovery characteristics of ultra-fast rectifiers at I_F = 20mA ~ 50mA are 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 V_R = 600V, $t_{RR} \approx$ 50ns (I_F = 0.5A, I_{RR} = 1A) and $C_J \approx$ 45pF (V_F > 50V) as D1.

Step 3.

Calculating total parasitic capacitance using equation (4)

$$C_P = C_{DRAIN} + C_{PCB} + C_{L2} + C_J$$
$$= 5pF + 5pF + 60pF + 45pF$$
$$= 115pF$$

Step 4.

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

$$t_{SPIKE} = \frac{V_{IN} \times C_P}{I_{SAT}} + t_{RR}$$
$$= \frac{265 \times \sqrt{2} \times 115p}{250m} + 50n$$
$$\approx 222ns \quad < \quad t_{BLANK}$$

Step 5.

Estimating power dissipation in D8030 at 265V_{AC} using (8) and (10)

Let us assume that the overall efficiency $\eta = 0.8$

Switching Power Loss :

$$P_{SWITCH(AC)} \approx \frac{f_S}{2(1-D)} (V_{AC} \times C_P + 2I_{SAT} \times t_{RR}) \times (V_{AC} - \frac{V_O}{\eta})$$
$$= \frac{100k}{2(1-0.109)} (265 \times 115p + 500m \times 50n) \times (265 - \frac{40.8}{0.8})$$
$$= 666.19mW$$

Minimum Duty Ratio :

$$D_{MIN} = \frac{40.8}{0.8 \times 265 \times \sqrt{2}}$$
$$= 0.136$$

assuming the overall efficiency $\eta = 0.8$

Conduction Power Loss :

$$P_{COND(AC)} = (K_C \times I_O^2 \times R_{ON}) + (K_D \times I_{DD} \times V_{AC})$$
$$= 0.22 \times (100m)^2 \times 20 + 0.63 \times 200\mu \times 265$$
$$= 77.39mW$$

Total Power Dissipation in D8030 :

$P_{TOTAL} =$ 666.19mW + 77.39mW

= 743.58mW

Step 6.

Selecting input capacitor C_{IN1}

Output power = 40.8V × 100mA

= 4.08W

So, a 10μF capacitor, such as EEUEB2G100 by Panasonic (10μF, 400V, Aluminum Electrolytic Capacitors), would be meet this requirement.

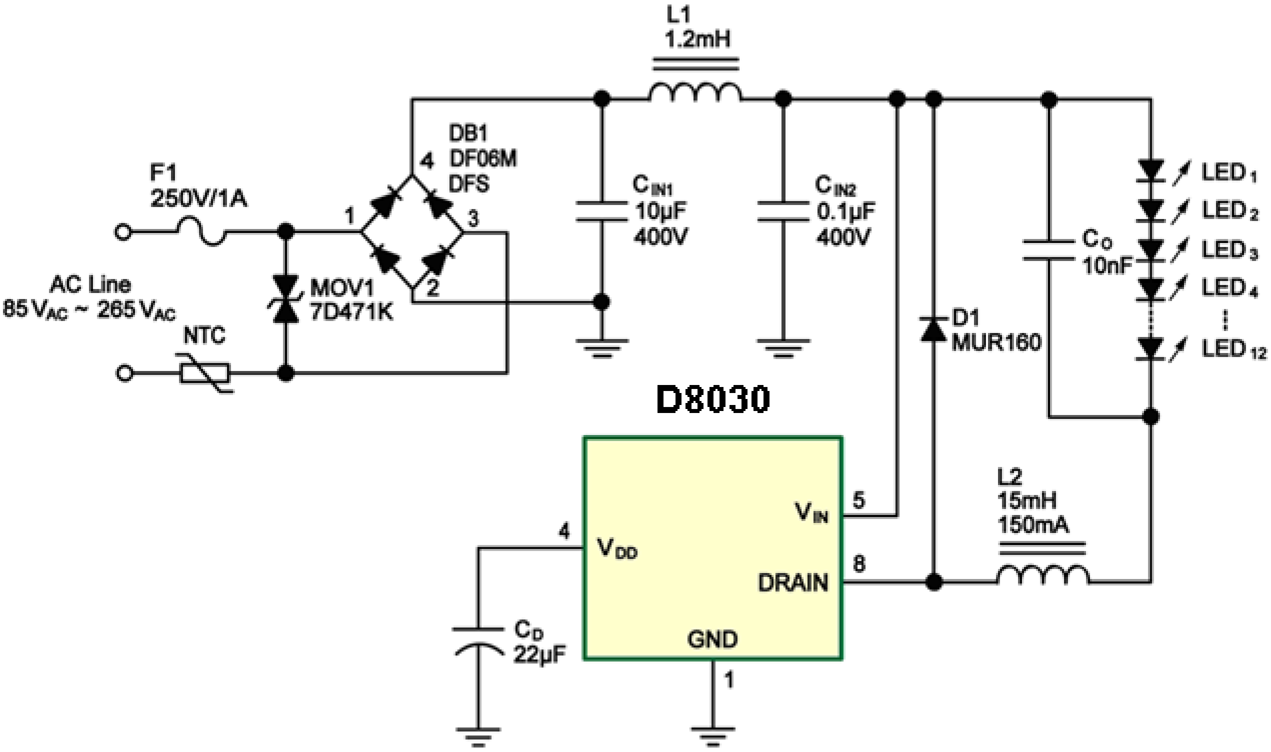
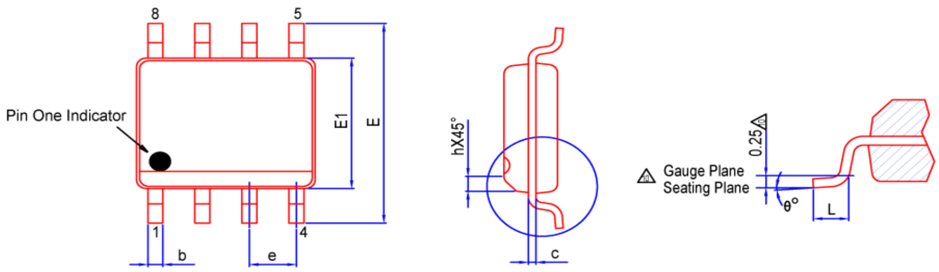
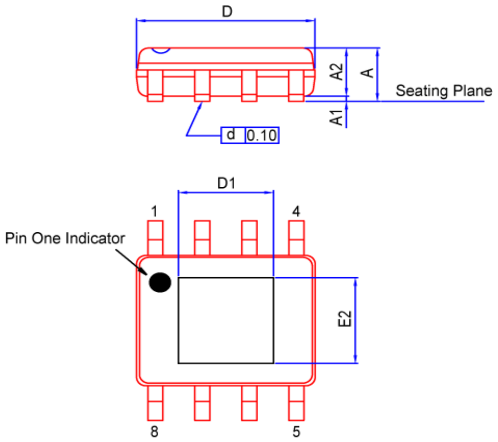


Figure 1. Universal 85VAC ~ 265VAC LED Lamp Driver Using D8030

Package Outline Dimensions

Package Type : SO8-EP





(Thermal Variations Only)

	Standard		Thermal	
Symbols	Min.	Max.	Min.	Max.
A	–	1.75	–	1.70
A1	0.10	0.25	0.00	0.15
A2	1.25	–	1.25	–
b	0.31	0.51	0.31	0.51
c	0.10	0.25	0.10	0.25
D	4.90 BSC		4.90 BSC	
E	6.00 BSC		6.00 BSC	
E1	3.90 BSC		3.90 BSC	
e	1.27 BSC		1.27 BSC	
L	0.40	1.27	0.40	1.27
h	0.25	0.50	0.25	0.50
θ°	0	8	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

日期 Date	版本 Version	说明 Description	制作人 producer	工程师 Engineer	状态 Status
2012-10-15	A0		W		
2014-4-12	A1		E		