Universal High Brightness LED Driver

Product Description

The D80211 is pin-to-pin functionally backward compatible with D80210 for better system performance and cost. D80211 adds Soft Start to reduce input surge current during cold start. It typically waits for 400 µS before normal PWM function starts. D80211 also adds pseudo-random oscillator hopping function (Spread Spectrum) to reduce EMI emission so that input EMI filter cost can be reduced. Typical oscillator hopping range is approximately 8% around base frequency set by $R_{OSC.}$ D80211 also provides Short Circuit Protection (SCP) to turn off MOSFET with external LED short sensing circuit. D80211 allows efficient operation of High Brightness (HB) LEDs from voltage sources ranging from $85V_{AC}$ up to $265V_{AC}$. The D80211 controls an external MOSFET at fixed switching frequency up to 300kHz. The LED string is driven at constant current rather than constant voltage, thus providing constant light output and enhanced reliability. The output current can be programmed between a few milliamps and up to more than 1.0A.

D80211A allows wide range of external MOSFET which has lower R_{DSON} at higher V_{GS}.

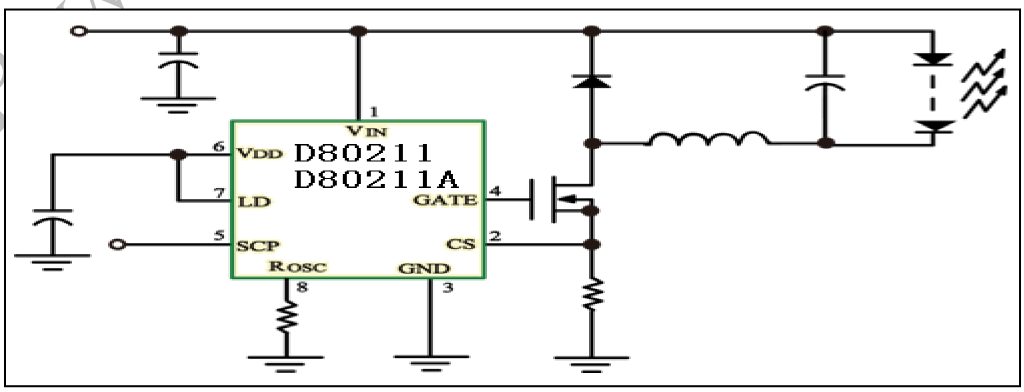
Features

- Backward compatible with D80210/D80210A
- >90% Efficiency
- Universal rectified 85 to $265V_{AC}$ input range
- Constant-current LED driver
- Applications from a few mA to more than 1A Output
- LED string from one to hundreds of diodes
- PWM Low-Frequency Dimming via Enable pin
- Input voltage surge ratings up to 500V
- Power-on sequence control and Soft Start
- Spread Spectrum to reduce EMI filter Cost
- Short Circuit Protection (SCP)
- Internal Thermal Protection (OTP)
- 7.5V MOSFET drive – D80211
- 12V MOSFET drive – D80211A

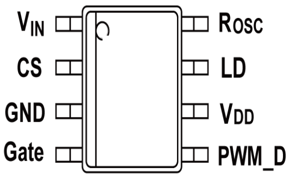
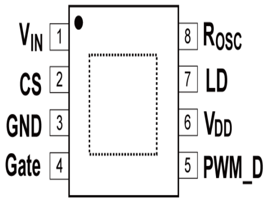
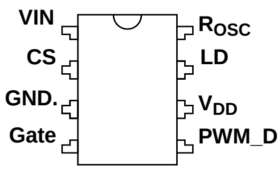
Typical Applications

- 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

Application Circuit



Packaging Information & Order Code

 8-Pin Plastic S.O.I.C. (Top View)	**D80211/D80211A MST**
 8-Pin Plastic S.O.I.C. EP (Top View)	**D80211/D80211A MPT**
 8-Pin Plastic DIP (Top View)	**D80211/D80211A M**

Absolute Maximum Ratings (Note)

V_{IN} to GND	-0.5V to +520V
CS	-0.3V to (Vdd + 0.3V)
OLP, SCP to GND	-0.3V to (Vdd - 0.3V)
GATE to GND	-0.3V to (Vdd + 0.3V)
$V_{DD(MAX)}$	13.5V
Continuous Power Dissipation (TA = 25°C)	
8 Pin DIP (derate 9mW/°C above +25°C)	900mW
8 Pin SO (derate 6.3mW/°C above +25°C)	630mW
8 Pin SO-EP (derate 16mW/°C above +25°C)	1600mW
Operating Temperature Range	-40°C to +85°C
Junction Temperature Range	+125°C
Storage Temperature Range	-65°C to 150°C

Note: 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

Electrical Characteristics

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

Parameter	Symbol	Min	Typ.	Max	Units	Conditions
Input DC supply voltage range	V_{INDC}	15.0		500	V	DC input voltage
Shut-down mode supply current	I_{Insd} [1]	-	0.5	1	mA	Pin PWM_D to GND, V_{IN} = 15V
	I_{Insd} [2]		**0.65**	1.2		
Internally regulated voltage	V_{DD} [1]	7.0	7.5	8.0	V	V_{IN} = 15 - 500V, $I_{DD(ext)}$ = 0, pin Gate open
	V_{DD} [2]	**11.5**	**12**	**12.5**		
Maximal pin V_{DD} voltage	V_{DDmax}			13.5	V	When an external voltage applied to pin Vdd
V_{DD} current available for external circuitry [3]	$I_{DD(ext)}$			1.0	mA	V_{IN} = 15-100V
VDD under voltage lockout threshold	UVLO1	6.4	6.7	7.0	V	Vin rising
	UVLO2	**7.6**	**8**	**8.4**		
VDD under voltage lockout hysteresis	ΔUVLO [1]		500		mV	Vin falling
	ΔUVLO [2]		**650**			
Pin SCP Enable threshold	V_{SCP}			1.2	V	V_{IN} = 15-500V
Pin SCP pull-down resistance	R_{SCP}	150	200	250	kΩ	**V_{EN} = 5V**
Current sense pull-in threshold voltage	V_{CS}	225	250	275	mV	@TA = -40°C to +85°C
GATE high output voltage	$V_{GATE(hi)}$	V_{DD} -0.3		V_{DD}	V	I_{OUT} = 10mA
GATE low output voltage	$V_{GATE(lo)}$	0		0.3	V	I_{OUT} = -10mA
Oscillator frequency	f_{OSC}	20	25	30	kHz	R_{OSC} = 1.00MΩ
		80	100	120		R_{OSC} = 226kΩ
Maximum Oscillator PWM Duty Cycle	D_{MAXhf}			100	%	F_{PWMhf} = 25kHz, at GATE, CS to GND.
Linear Dimming pin voltage range	V_{LD}	0	-	250	mV	@T_A = <85°C, V_{IN} = 20V
Current sense blanking interval	T_{BLANK}	160	250	440	ns	V_{CS} = 0.55V_{LD}, V_{LD} = V_{DD}
Delay from CS trip to GATE lo	t_{DELAY}			300	ns	V_{IN} = 20V, V_{LD} = 0.15, V_{CS} = 0 to 0.22V after T_{BLANK}
GATE output rise time	t_{RISE}		30	50	ns	C_{GATE} = 500pF
GATE output fall time	t_{FALL}		30	50	ns	C_{GATE} = 500pF

Soft-start time	t_{SS}	300	400	500	μS	From appearance of pulses at DRIVER pin to increase Duty Cycle more 50%
Thermal Shutdown	T_{SD}		150		°C	
Thermal Shutdown Hysteresis	T_{SDH}		50		°C	

[1] For D80211

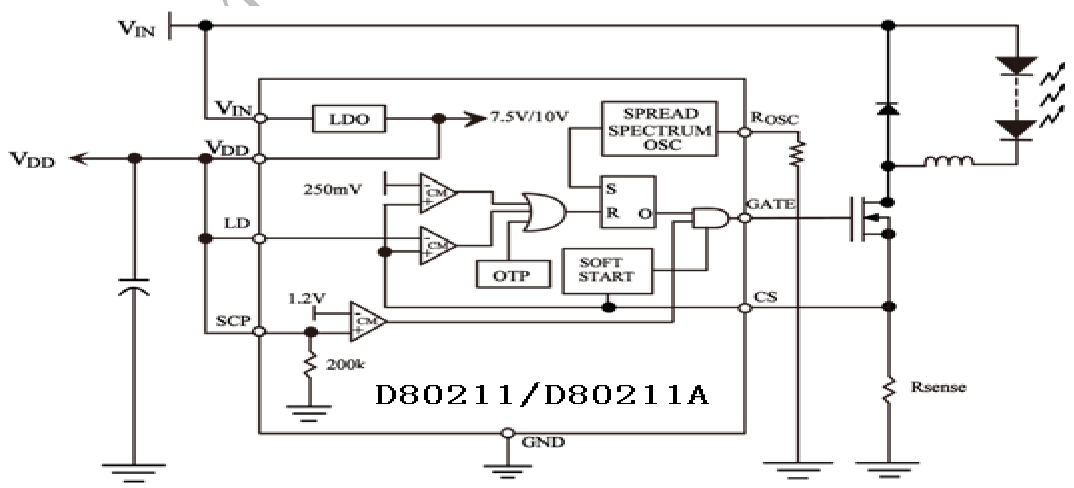
[2] For D80211A

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

Pin out

Pin No.	Pin Name	Function
1	V_{IN}	Input voltage
2	CS	Senses LED string current
3	GND	Device ground
4	GATE	Drives the gate of the external MOSFET
5	SCP	Short Circuit Protection pin triggered at voltage level below 1.2V. Internal 200kΩ pull-down to GND
6	V_{DD}	Internally regulated supply voltage. 7.5V nominal for D80211 and 12V nominal for D80211A. Can supply up to 1 mA for external circuitry. A sufficient storage capacitor is used to provide storage when the rectified AC input is near the zero crossings
7	LD	Linear Dimming by changing the current limit threshold at current sense comparator
8	R_{OSC}	Oscillator control. A resistor connected between this pin and ground sets the PWM frequency.

Block Diagram & Typical Applications



OTP: Over temperature protection at 125℃

Application Information

AC/DC Off-Line Applications

The D80211 is a low-cost off-line buck or boost converter control IC specifically designed for driving multi-LED stings or arrays. It can be operated from either universal AC line or any DC voltage between 14-450V. 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 D80211 can drive up to hundreds of High-Brightness (HB) LEDs or multiple strings of HB LEDs. The LED arrays can be configured as a series or series/parallel connection. The D80211 regulates constant current that ensures controlled brightness and spectrum of the LEDs, and extends their lifetime.

The D80211 can also control brightness of LEDs by programming continuous output current of the LED driver (so-called linear dimming) when a control voltage is applied to the LD pin.

The D80211 is offered in a standard 8-pin SOIC package.

The D80211 includes an internal high-voltage linear regulator that powers all internal circuits and can also serve as a bias supply for low voltage and low power external circuitry.

LED Driver Operation

The D80211 can control all basic types of converters, isolated or non-isolated, operating in continuous or discontinuous conduction mode. When the gate signal turns on 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 LEDs 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 LEDs (Flyback mode of operation).

When the voltage at the VDD pin exceeds the 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 D80211. 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 Fig. 4.

Supply Current

A current of 1mA is needed to start the D80211. As shown in the block diagram on page 4, this current is internally generated in the D80211 without using bulky startup resistors typically required in the offline applications. Moreover, in many applications the D80211 can be continuously powered using its internal linear regulator that provides a regulated voltage of 7.5V for all internal circuits. (12V for D80211A)

Setting Light Output

When the buck converter topology of Figure 3 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 should be 250mV/(500mA+ 0.5*150mA) = 0.43Ω

Linear Dimming (LD)

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 VDD 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.

Programming Operating Frequency

The operating frequency of the oscillator is programmed between 25 and 300kHz using an external resistor connected to the ROSC pin:
Equation:

$$F_{osc} = \frac{25000}{R_{osc} + 22}$$

FOSC = 25000/(ROSC [kΩ] + 22) [kHz]

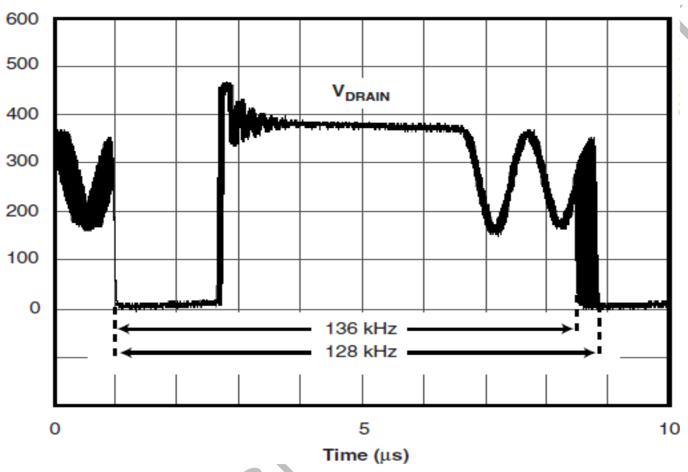
Be noted, ROSC shall be 820KΩ~1MΩ for the case of Vout＜7V because it has to satisfy the condition of Ton＞TBLANK. The efficiency can be improved as well.

Soft Start

At initial power start, because the output voltage or current is not established yet, the feedback voltage (VCS) generated from the output LED current 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 power supply circuit. D80211 has an internal Soft Start (SS) circuit which does not require any external capacitor. This Soft-Start circuit will compare the voltage level at VCS pin and limit the input current by generating small duty cycle pulses at the GATE pin at ¼ of the oscillation frequency to gradually increase the output current until it reaches final stable duty cycle and enter normal operation mode. This slowly increased input current will prevent surge current from happening to avoid damage to the circuit. The typical Soft Start period is set about 400µS.

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 D80211 typical application circuit in Fig. 4 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 Fig. 3 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 LEDs and each diode has a forward voltage drop of 3.0V at its nominal current; the total LED voltage V_{LEDS} is 30V

Equation：

$$D = \frac{V_{LEDs(VF)}}{V_{in}}$$

$$T_{on} = \frac{D}{F_{osc}}$$

$$L \geq \frac{(V_{in} - V_{LEDs(VF)}) \times T_{on}}{0.3 \times I_{LED}}$$

$$R_{sense} = \frac{0.25}{I_{LED} + (0.5 \times (I_{LED} \times 0.2))}$$

Assuming the nominal rectified input voltage V_{IN} = 120V*1.41 = 169V, the switching duty ratio can be determined, as:

D = V_{LEDs} /V_{IN} = 30/169 = 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} = D/f_{OSC} = 3.5 microsecond

The required value of the inductor is given by:

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

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:

Equation:

$$C_{in} \geq \frac{P_{in} \times (1 - D_{ch})}{\sqrt{2V_{Line\_min}} \times 2 f_L \times \Delta V_{DC\_max}}$$

Where

D_{ch} : C_{in} 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% $\sqrt{2V_{Line\_min}}$ of
And

$C_{MIN} = I_{LED} * V_{LEDs} * 0.06 / V_{IN}^2$

C_{MIN} = 22 µF, a value 22µF/250V can be used

A passive PFC circuit at the input requires using two series connected capacitors at the place of calculated C_{MIN}. Each of these identical capacitors should be rated for ½ of the input voltage and have twice as much capacitance.

Short Circuit Protection

The D80211 can turn off 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, $R_{PD,}$ and a photo-coupler, PC817, are added in parallel with output LED load as shown by Fig. 3 & 4. In the normal operation when LEDs are present at output, a smaller current flows through the resistor R_{PD} and turns ON the photo-coupler, PC817, and then flows through an internal 200KΩ pull-down resistor at SCP pin. This ON-state photo-coupler will set its emitter terminal at a voltage level close to VDD which is above 1.2V and therefore, SCP function is disabled. As soon as these two terminals, LED+ and LED-, are shorted, there will be no voltage drop across the R_{PD} and PC817, so there is no current flowing through the photo-coupler, and SCP pin will be pulled down to below 1.2V due to internal pull-down resistor. As soon as SCP is below 1.2V, MOSFET is turned off.

DC/DC Low Voltage Applications

Buck Converter Operation

D80211 is an offline AC-DC solution for LED lighting system. Due to its simplicity of buck topology when the LED string voltage is lower than the input supply voltage, this solution can be designed to meet various non-isolation applications including T-8, LED lamps

The design procedure for a buck LED driver outlined in the previous sections 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 LEDs. This limitation is related to the output current instability that may develop when the D80211 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 D80211 inherited high voltage feature, rectified DC high voltage ($V_{DC} = V_{AC}$ x 1.414) can be directly fed into power pin of it to achieve high duty cycle, which is only limited by V_{OUT} / V_{IN}, 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.

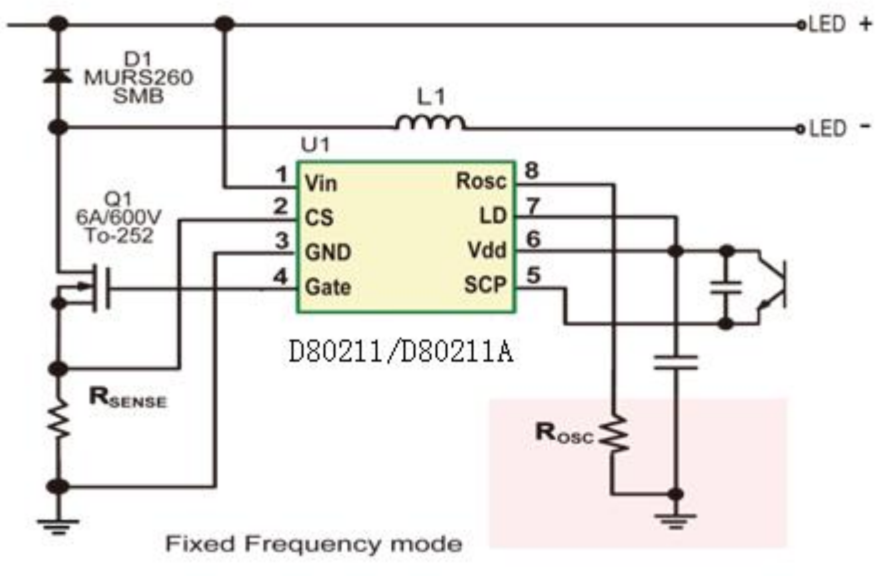
The best solution is to adopt the so-called constant off-time operation as shown below. The resistor (ROSC) is, connected to ground by default, to set operating frequency. This resistor can alternatively be connected to gate of MOSFET to force D80211 to enter constant OFF time mode which will decrease duty cycle from 50% by increase total period, Toff + Ton.

Normally fixed frequency design is chosen as shown in Fig. 1 because it has better efficiency.

For general LED lighting application, PFC becomes a necessary factor in order to meet the emergent international standard of solid state lighting. If passive Valley-Fill PFC is chosen, then, D80211 is biased right after passive PFC stage. The DC voltage rail, Vin, is halved and it will easily create a more than 50% duty cycle for the same LED loading due to V_{OUT}/V_{IN} ratio is doubled. An SBO noise can be generated. In this case, the constant OFF time mode as shown in Fig. 2 will be chosen.

The following example as shown in Fig. 2 can explain it in more details where Rsense is connected between Pin 8, Rosc, and Pin 4, GATE to set D80211 operate in fixed-off time mode

Fig. 1: Fixed Frequency Mode



Example :

V_{IN} - V_{AC} 110V with passive PFC

V_{OUT} - Consisting of 1W HB LED with nominal
V_f = 3.3V

Vin, after rectified and passing PFC stage, the actual DC rail will become

Vin =110V * 1.414 / 2 = 77.7V_{DC}

The duty cycle, D = V_{OUT} / V_{IN}, will reach above 50% when voltage drop of LED string, as the V_{OUT}, 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.

Fig. 2: Constant OFF Time Mode

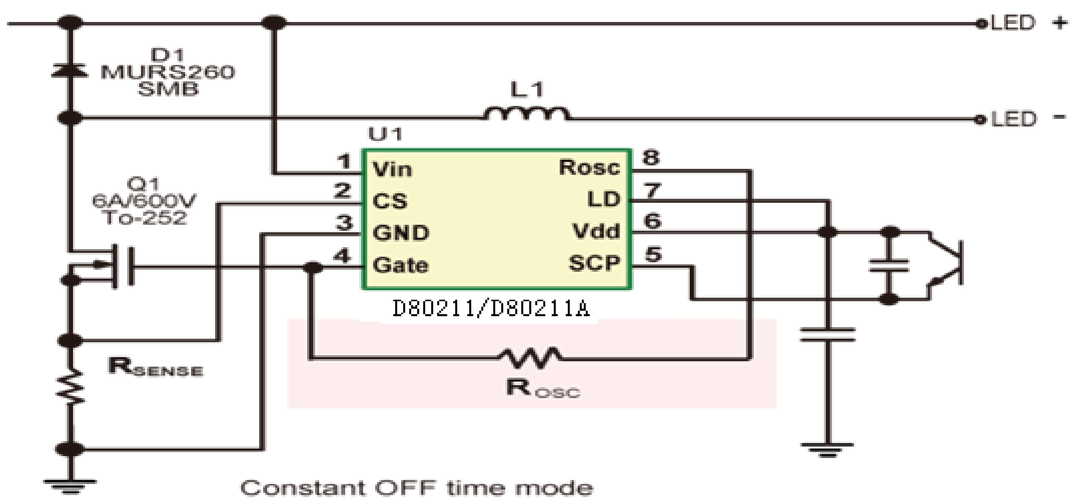


Fig. 3: Typical Application Circuit (without PFC)

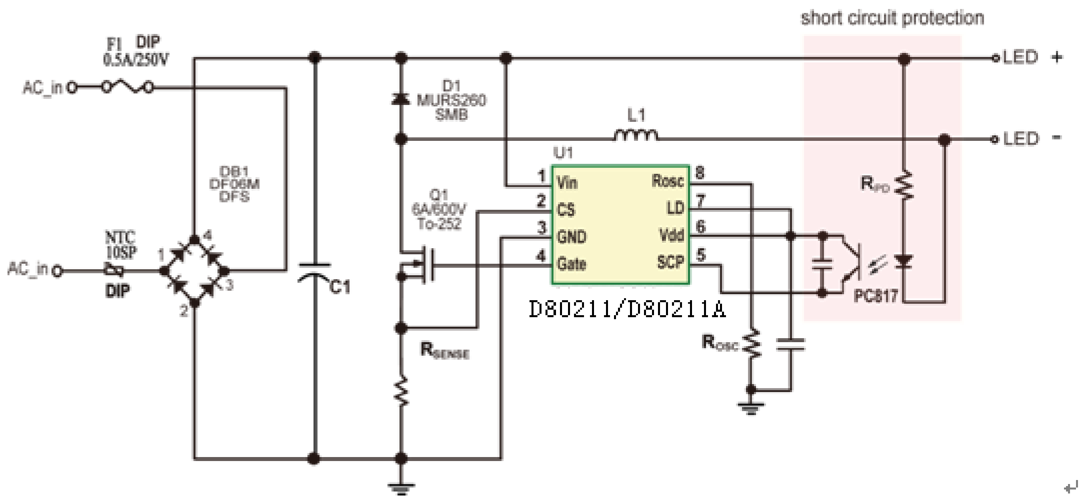
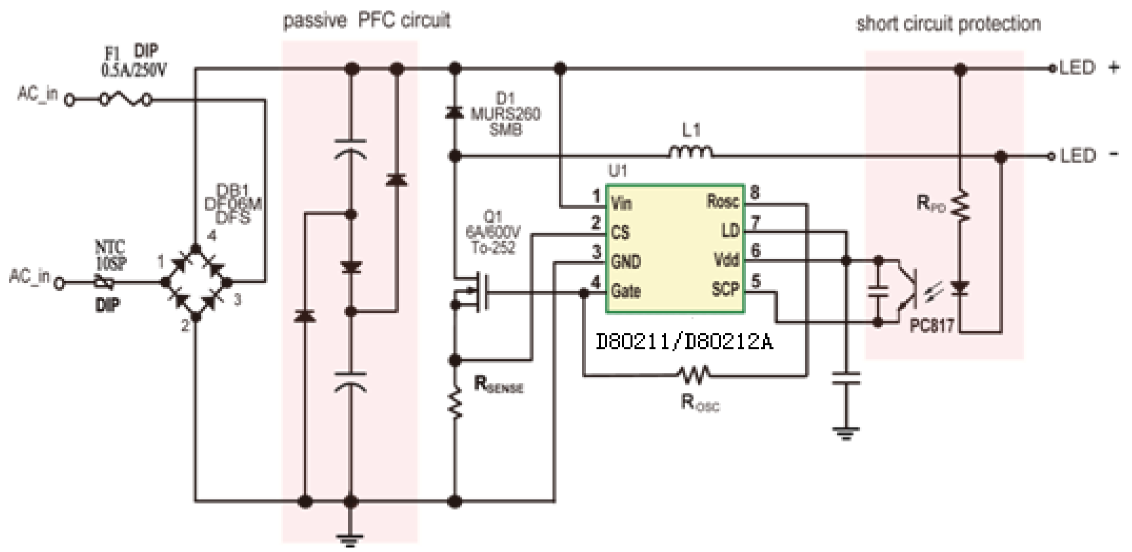
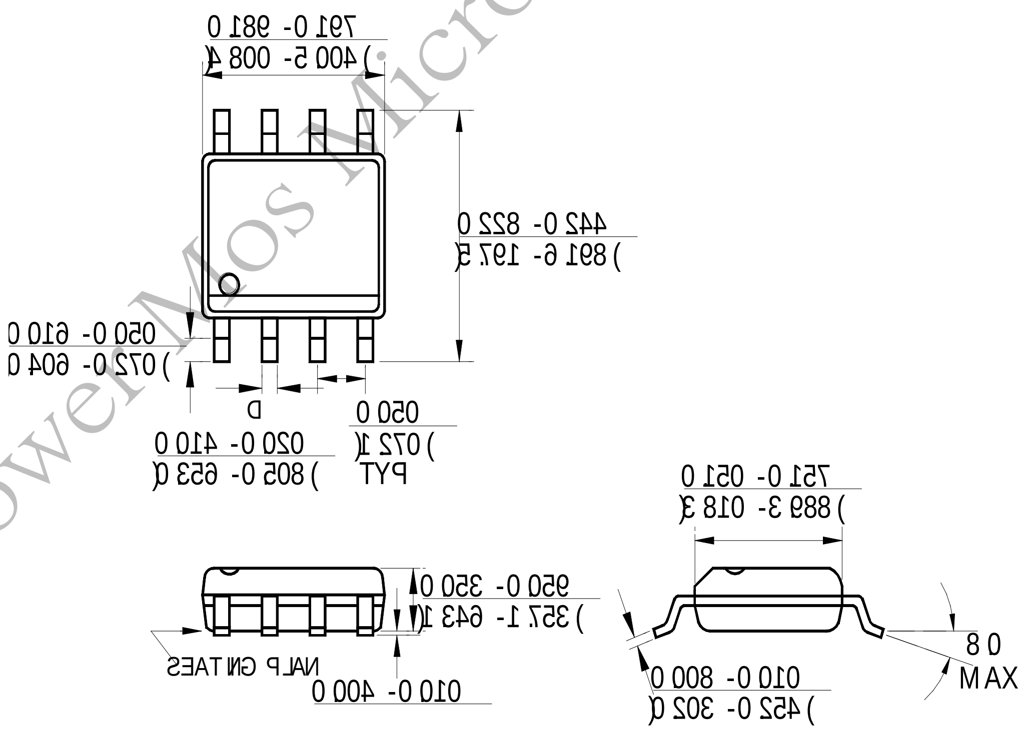


Fig. 4: Typical Application Circuit (with PFC)

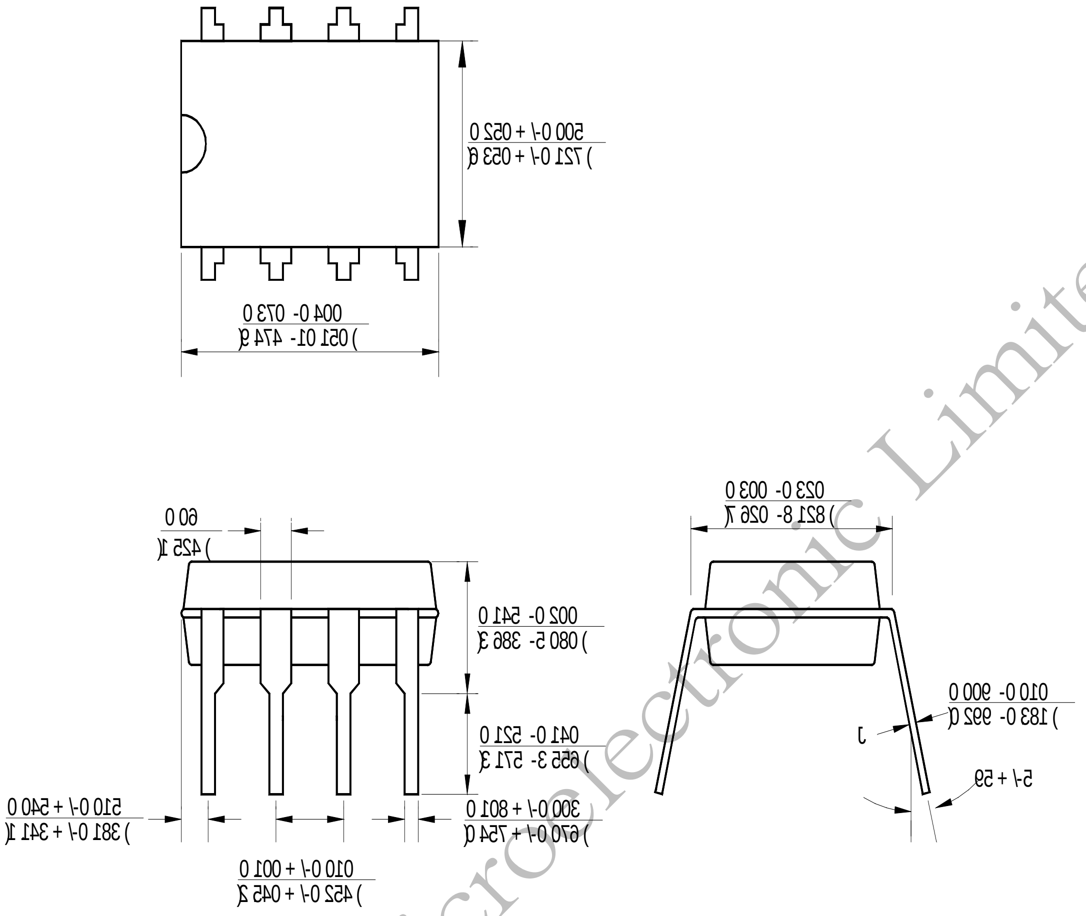


PACKAGING INFORMATION

SO8 / SO8-EP



DIP8



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