Universal High Brightness LED Driver

Description

The FP6700 is a PWM high-efficiency LED driver control IC. It allows efficient operation of High Brightness (HB) LEDs from voltage sources ranging from 8VDC up to 450VDC. The FP6700 controls an internal MOSFET at fixed switching frequency up to 300 kHz. The frequency can be programmed using a single resistor. 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.

FP6700 uses a rugged high voltage junction isolated process that can withstand an input voltage surge of up to 450V. Output current to an LED string can be programmed to any value between zero and its maximum value by applying an external control voltage at the linear dimming control input of the FP6700. The FP6700 provides a low-frequency PWM dimming input that can accept an external control signal with a duty ratio of 0-100% and a frequency of up to a few kilohertz.

Features

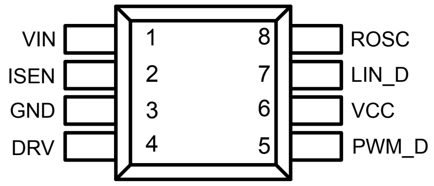
- >90% Efficiency
- 8V to 450V input range
- Constant-current LED driver
- Applications from a few mA to more than 1A Output
- LED string from one to hundreds of diodes
- PWM Low-Frequency Dimming via Enable pin
- Input Voltage Surge ratings up to 500V

Applications

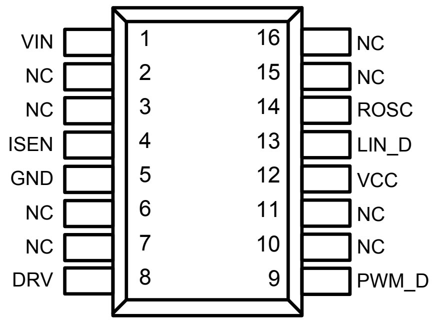
- DC/DC or AC/DC LED Driver applications
- RGB Backlighting LED Driver
- Back Lighting of Flat Panel Displays
- General purpose constant current source
- Signage and Decorative LED Lighting
- Automotive
- Chargers

Pin Assignments

SO Package (SOP-8,V_{IN} <250V)



SOX Package(SOP-16)



SPX Package(SOP-16 Expose pad)

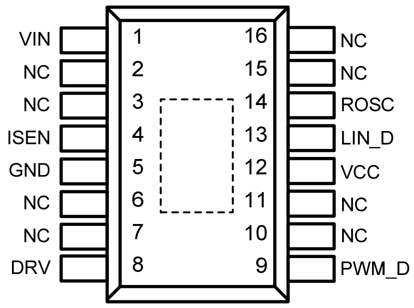
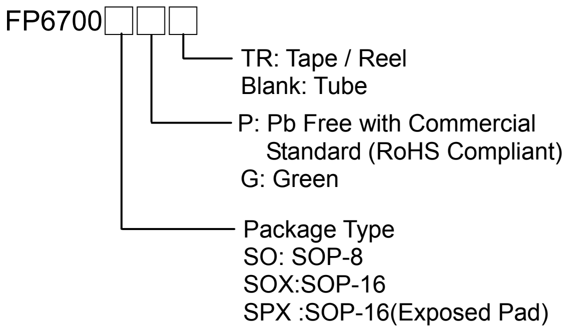


Figure 1.Pin Assignment of FP6700

Ordering Information



Typical Application Circuit

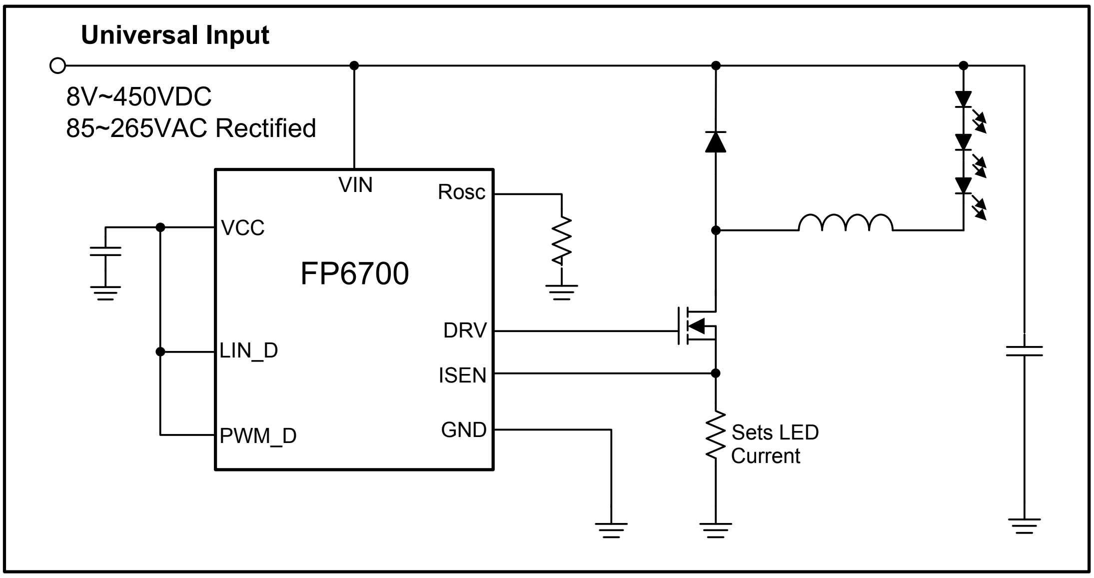


Figure 2. Typical Application Circuit of FP6700

Functional Pin Description

Pin Name	Pin Function
VIN	Input voltage 8V to 450V DC
ISEN	Senses LED string current
GND	Device ground
DRV	Drives the DRV of the internal MOSFET
PWM_D	Low Frequency PWM Dimming pin, also Enable input. Internal 100kΩ pull-down to GND
VCC	Internally regulated supply voltage. 7.5Vnominal. 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 crossings.
LIN_D	Linear Dimming by changing the current limit
ROSC	Threshold at current sense comparator Oscillator control. A resistor connected between this pin and ground sets the PWM frequency.

Block Diagram

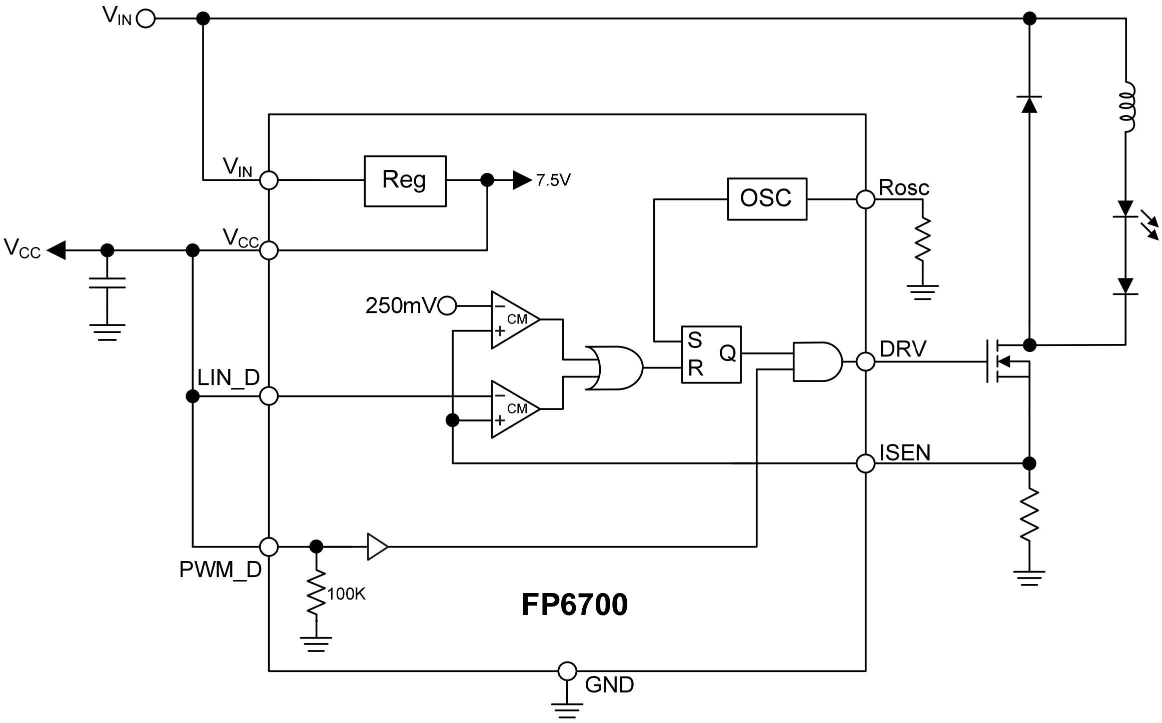


Figure 3. Block Diagram of FP6700

Absolute Maximum Ratings

- VIN -- - 0.5V to + 500V
- ISEN -- - 0.3V to (V_{CC} + 0.3V)
- LIN_D, PWM_D -- - 0.3V to (V_{CC} - 0.3V)
- DRV -- - 0.3V to (V_{CC} + 0.3V)
- VCC -- +13.5V
- Power Dissipation @T_A=70℃ :
  - SOP-8 (P_D) -- 0.34W
  - SOP-16 (P_D) -- 0.55W
  - SOP-16 (Exposed Pad) (P_D)-- 0.92W
- Package Thermal Resistance :
  - SOP-8 (θ_{JA}) -- 160°C/W
  - SOP-16 (θ_{JA}) -- 100°C/W
  - SOP-16 (Exposed Pad) (θ_{JA}) -- 60°C/W
- Operating Temperature Range -- - 40°C to + 85°C
- Junction Temperature -- + 125°C
- Storage Temperature Range -- - 65°C to + 150°C

Note1：Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Electrical Characteristics

(T_A = 25°C unless noted otherwise)

Description	Symbol	Conditions	Min	Typ	Max	Units
Input DC supply voltage range	V_{INDC}	DC input voltage	8.0		450	V
Shut-Down mode supply current	I_{INSD}	Pin PWM_D to GND, V_{IN} = 8V	0.5		1	mA
Internally regulated voltage	V_{CC}	V_{IN} = 8–450V, $I_{CC(ext)}$=0, pin DRV open	7.3	7.5	8.5	V
Maximal pin VCC voltage	V_{CCMAX}	When an external voltage applied to pin VCC			13.5	V
V_{CC} current available for external circuitry[2]	$I_{CC(EXT)}$	V_{IN} = 8–100V			1	mA
V_{CC} under voltage lockout threshold	UVLO	V_{IN} rising	6.2	6.7	7.2	V
V_{CC} under voltage lockout hysteresis	ΔUVLO	V_{IN} falling		500		mV
Pin PWM_D input low voltage	$V_{EN(lo)}$	V_{IN} = 8–450V			1.0	V
Pin PWM_D input high voltage	$V_{EN(hi)}$	V_{IN} = 8–450V	2.4			V
Pin PWM_D pull-down resistance	R_{EN}	V_{EN} = 5V	50	100	150	kΩ
Current sense pull in threshold voltage	$V_{ISEN(HI)}$		225	250	275	mV
DRV high output voltage	$V_{DRV(HI)}$	I_{OUT} = 10mA	V_{CC}-0.3		VCC	V
DRV low output voltage	$V_{DRV(lo)}$	I_{OUT} = -10mA	0	0.3		V
Oscillator frequency	f_{OSC}	R_{OSC} = 1MΩ	16	18	20	kHz
		R_{OSC} = 300kΩ	45	50	55	
Maximum Oscillator PWM Duty Cycle	D_{MAXHF}	F_{PWMHF} = 25kHz, at DRV, ISEN to GND. GBD			100	%
Linear Dimming pin voltage range	V_{LIN_D}	V_{IN} = 12V	0		250	mV
Current sense blanking interval	T_{BLANK}	V_{ISEN} = 0.55V_{LIN_D}, V_{LIN_D} = V_{CC}	150	215	280	ns
Delay from ISEN trip to DRV lo	t_{DELAY}	V_{IN} = 12V, V_{LIN_D} = 0.15, V_{ISEN} = 0 to 0.22V after T_{BLANK}			150	ns
DRV output rise time	t_{RISE}	C_{DRV} = 500pF		30	50	ns
DRV output fall time	t_{FALL}	C_{DRV} = 500pF		30	50	ns

Note2：Also limited by package power dissipation limit, whichever is lower.

Application Information

AC/DC Off-Line Applications

The FP6700 is a low-cost off-line buck, boost or buck-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 8-450V.Optionally, 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 FP6700 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 FP6700 regulates constant current that ensures controlled brightness and spectrum of the LEDs, and extends their lifetime. The FP6700 features an enable pin (PWM_D) that allows PWM control of brightness.

The FP6700 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 LIN_D pin.

The FP6700 is offered in standard 8-pin SOIC and DIP packages. It is also available in a high voltage rated SOP-16 package for applications that require VIN greater than 250V.

The FP6700 includes an internal high-voltage linear regulator that powers all internal circuits and can also serve as a bias supply for low voltage external circuitry.

1. LED Driver Operation

The FP6700 can control all basic types of converters, isolated or non-isolated, operating in continuous or discontinuous conduction mode. When the gate signal enhances the internal 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 V_{CC} pin exceeds the UVLO threshold the gate drive is enabled. The output current is controlled by means of limiting peak current in the internal 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 ISEN pin of the FP6700. When the voltage at ISEN pinexceeds 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 LIN_D pin. When soft start is required, a capacitor can be connected to the LIN_D pin to allow this voltage to ramp at a desired rate, therefore, assuring that output current of the LED ramps gradually.

Optionally, a simple passive power factor correct- ion circuit, consisting of 3 diodes and 2 capacitors, can be added as shown in the application circuit diagram of Figure 1.

2. Supply Current

A current of 1mA is needed to start the FP6700. As shown in block diagram, this current is inter- nally generated in FP6700 without using bulky startup resistors typically required in the offline applications. Moreover, in many applications the FP6700 can be continuously powered using its internal linear regulator that provides a regulated voltage of 7.5V for all internal circuits.

3. Setting Light Output

When the buck converter topology of Figure 1 is selected, the peak ISEN 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 100mA, to get a 350mA LED current, the sense resistor should be 250mV/(350mA+ 0.5*100mA) =0.625 ohm

4. Dimming

Dimming can be accomplished in two ways, sepa- rately or combined, depending on the application. Light output of the LED can be controlled either by linear change of its current, or by switching the current on and off while maintaining it constant.

The second dimming method (so-called PWM dimming) controls the LED brightness by varying the duty ratio of the output current.

Application Information (Continued)

The linear dimming can be implemented by applying a control voltage from 0 to 250mV to the LIN_D pin. This control voltage overrides the internally set 250mV threshold level of the ISEN pin and programs the output current accordingly. For example, a potentiometer connected between V_{CC} and ground can program the control voltage at the ISEN 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.

The PWM dimming scheme can be implemented by applying an external PWM signal to the PWM_D pin. The PWM signal can be generated by a microcontroller or a pulse generator with a duty cycle proportional to the amount of desired light output. This signal enables and disables the converter modulating the LED current in the PWM fashion. In this mode, LED current can be in one of the two states: zero or the nominal current set by the current sense resistor. It is not possible to use this method to achieve average brightness levels higher than the one set by the current sense threshold level of the FP6700. By using the PWM control method of the FP6700, the light output can be adjusted between zero and 100%. The accuracy of the PWM dimming method is limited only by the minimum gate pulse width, which is a fraction of a percent of the low frequency duty cycle.

5. Programming Operating Frequency

The operating frequency of the oscillator is programmed between 18 and 300 kHz using an external resistor connected to the R_{OSC} pin:

F_{OSC} = 19687.5/(R_{OSC} [k&] + 93.75) [kHz]

6. 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 FP6700 application circuit of Figure 1 in order to pass the AC line harmonic limits of the EN61000-3-2 stand- ard 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.

7. Inductor Design

Referring to the Typical Application Circuit below 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.

Knowing 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 fosc=50 KHz, 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:

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

8. 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:

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

C_{MIN} = 22uF, a value 22uF/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.

9. Enable

The FP6700 can be turned off by pulling the PWM_D pin to ground. When disabled, the FP6700 draws quiescent current of les than 1mA.

Application Information (Continued)

10. Output Open Circuit Protection

When the buck topology is used, and the LED is connected in series with the inductor, there is no need for any protection against an open circuit condition in the LED string. Open LED connection means no switching and can be continuous. However, in the case of the buck-boost or the Flyback topology the FP6700 may cause excessive voltage stress of the switching transistor and the rectifier diode and potential failure. In this case, the FP6700 can be disabled by pulling the PMW_D pin to ground when the over voltage condition is detected.

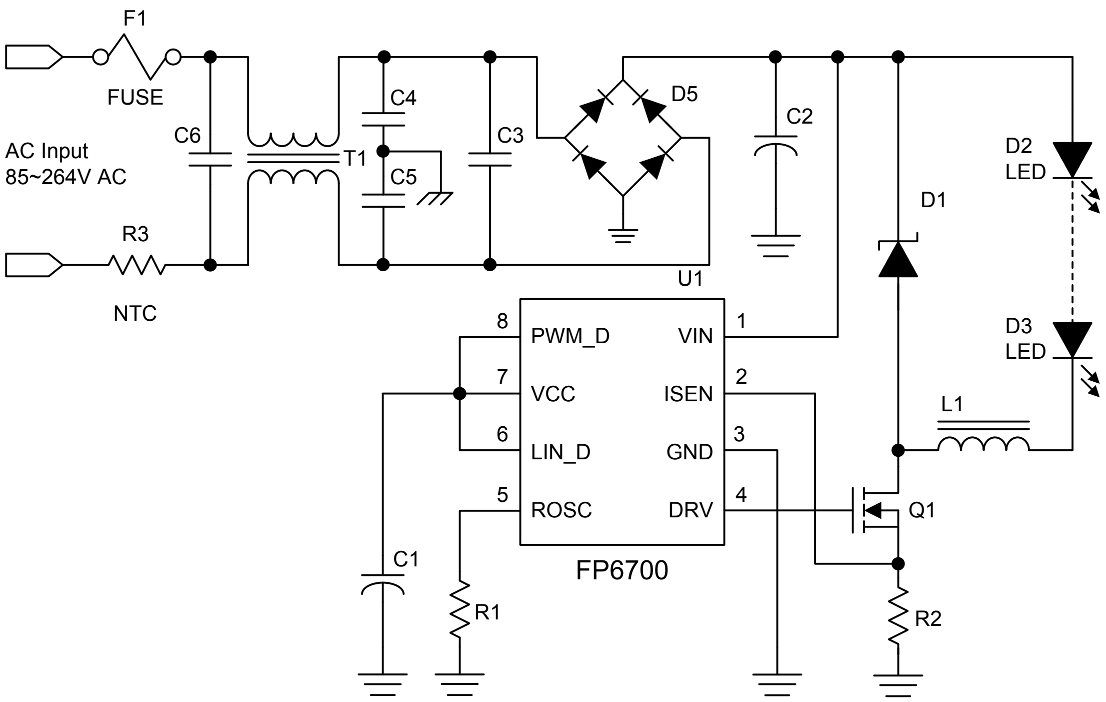


Figure 4：Typical Application Circuit

Application Information (Continued)

DC/DC Low Voltage Applications

1. Buck Converter Operation

The buck power conversion topology can be used when the LED string voltage is needed to be lower than the input supply voltage. The design procedure for a buck LED driver outlined in the previous chapters 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 FP6700 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.

2. Flyback (Buck-Boost) Operation

This power conversion topology can be used when the forward voltage drop of the LED string is higher, equal or lower than the input supply voltage. For example, the buck-boost topology can be appropriate when input voltage is supplied by an automotive battery (12V) and output string consists of three to six HB LEDs, as the case may be for tail and break signal lights.

In the buck-boost converter, the energy from the input source is first stored in the inductor or a Flyback transformer when the switching transistor is ON. The energy is then delivered to the output during the OFF time of the transistor. When the energy stored in the Flyback inductor is not fully depleted by the next switching cycle (continuous conduction mode) the DC conversion between input and output voltage is given by:

$V_{OUT} = - V_{IN}*D/(1-D)$

The output voltage can be either higher or lower than the input voltage, depending on duty ratio.

Let us discuss the above example of an auto- motive LED driver that needs to drive three HB LEDs at 350mA. Knowing the nominal input voltage VIN=12V, the nominal duty ratio can be determined, as

$D = V_{LEDs}/ (V_{IN}+V_{LEDs})=9/ (12+9)= 0.43$

Then, given the switching frequency, in this example f_{OSC}=50KHz, the required on-time of the MOSFET transistor can be calculated:

$T_{ON}=D/f_{OSC}$=8.6 microsecond

The required value of the inductor is given by:

$L = V_{IN}* T_{ON}/(0.3 * I_{LED}) = 0.98mH$, use 1mH

3. Output Capacitor

Unlike the buck topology, the buck-boost converter requires an output filter capacitor to deliver power to the LED string during the ON time of switching the transistor, when the Flyback inductor current is diverted from the output of the converter.

In order to average the current in the LED, this capacitor must present impedance to the switching output AC ripple current that is much lower than the dynamic impedance R_{OUT} of the LED string. If we assume R_{OUT}=3 Ohm in our example, in order to attenuate the switching ripple by a factor of 10, a capacitor with equivalent series resistance (ESR) of 0.3 Ohm is needed. A chip SMT tantalum capacitor can be selected for this purpose.

Application Information (Continued)

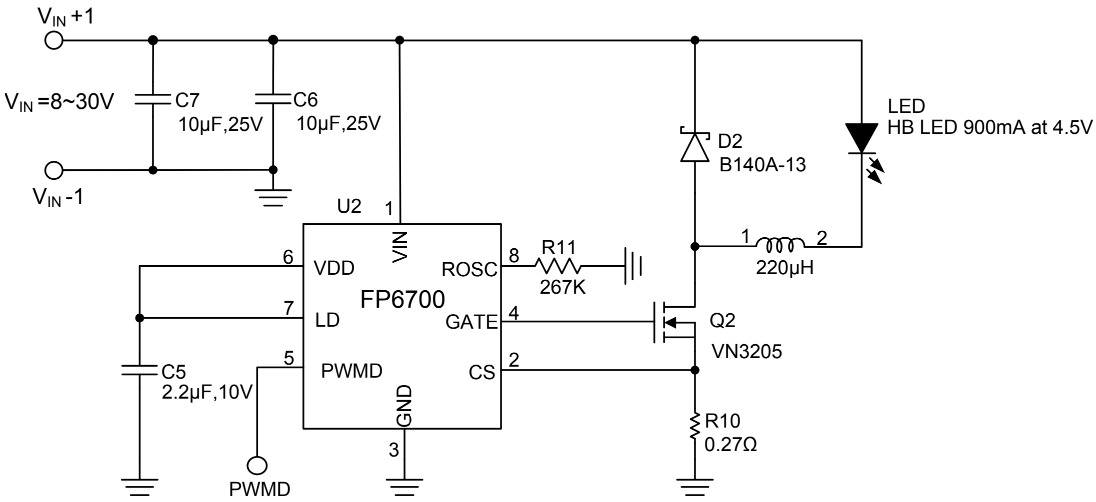


Figure 5：FP6700 Buck Driver for a single 900mA HB LED (VIN= 8 ~30V)

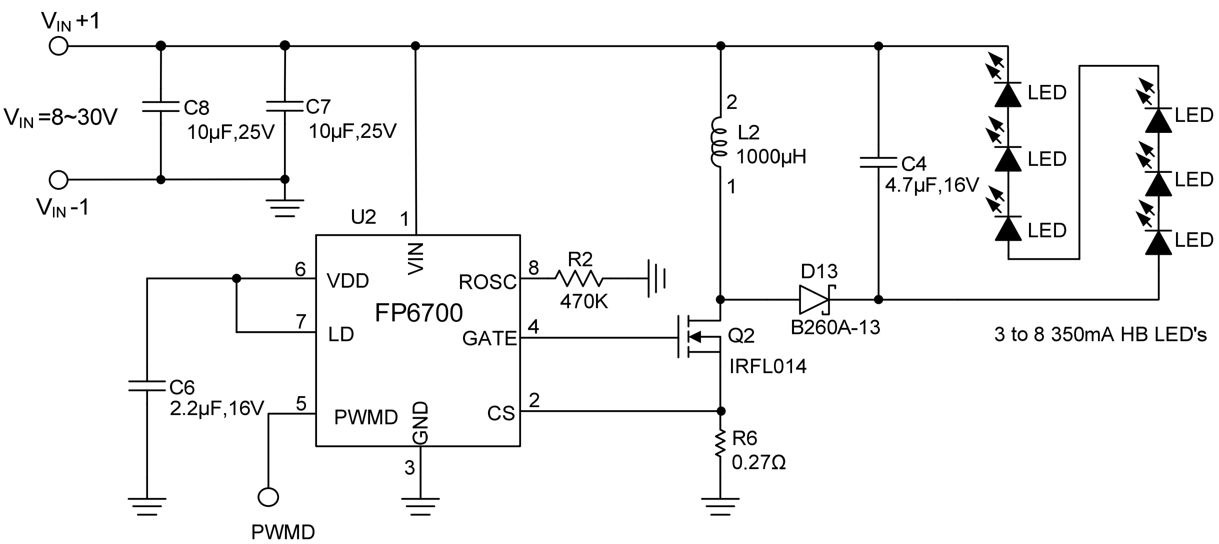
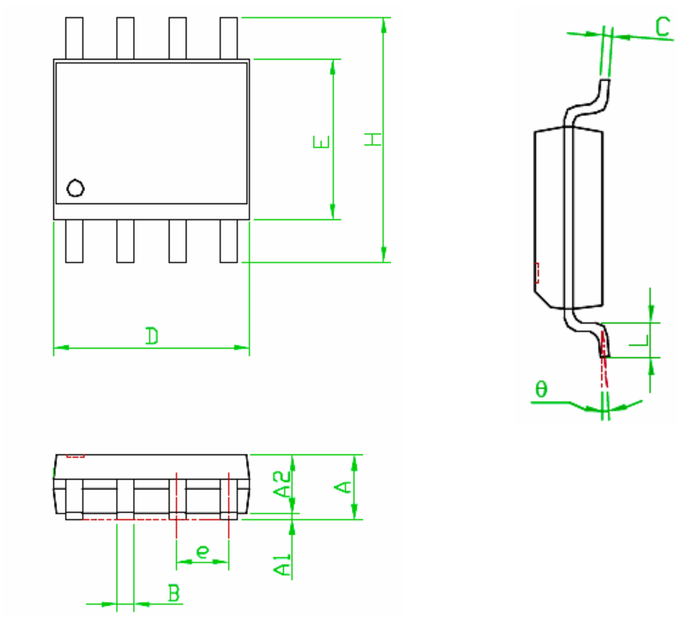


Figure 6：FP6700 Buck-Boost driver powering 3 to 8, 350mA HB LED's (VIN = 8 ~30VIN)

Outline Information

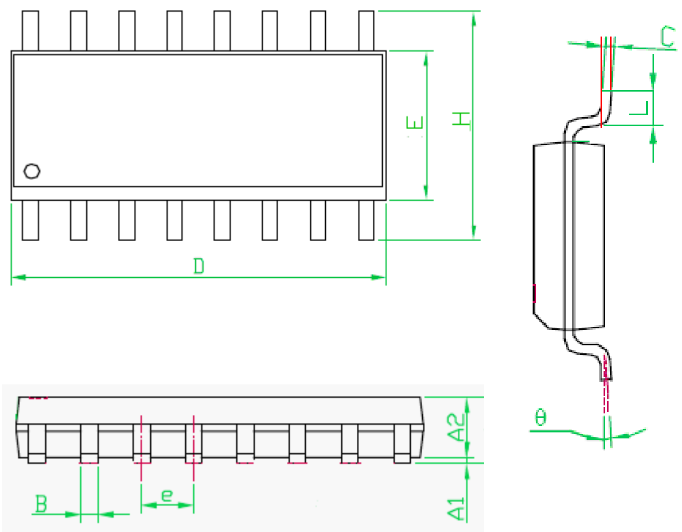
SOP-8 Package (Unit: mm)



SYMBOLS UNIT	DIMENSION IN MILLIMETER		
	MIN	NOM	MAX
A	---	---	1.75
A1	0.10	---	0.25
A2	1.25	---	---
B	0.31	---	0.51
C	0.17	---	0.25
D	---	4.9	---
E	---	3.9	---
e	---	1.27	---
H	---	6.0	---
L	0.40	---	1.27
θ	0º	4°	8º

Note 1：Followed From JEDEC MO-012-E.

SOP-16 Package (Unit: mm)

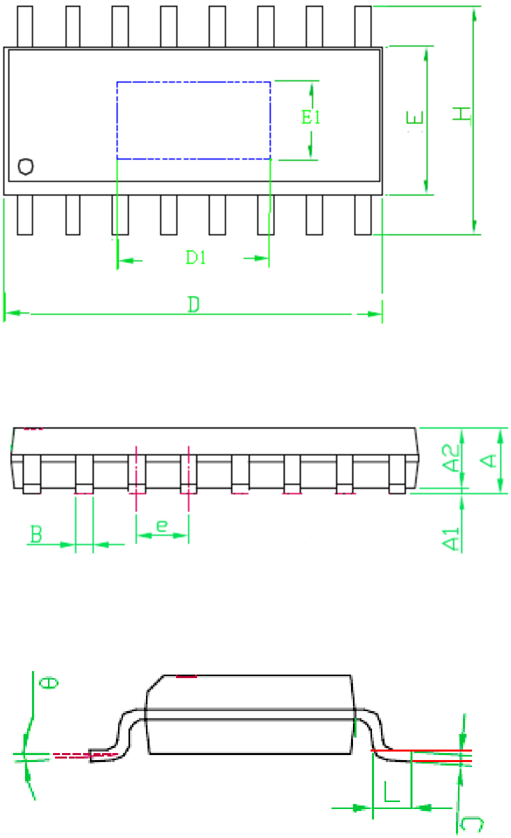


SYMBOLS UNIT	DIMENSION IN MILLIMETER		
	MIN	NOM	MAX
A	---	---	1.75
A1	0.10	---	0.25
A2	1.25	---	---
B	0.31	---	0.51
C	0.17	---	0.25
D	---	9.9	---
E	---	3.9	---
e	---	1.27	---
H	---	6.0	---
L	0.40	---	1.27
θ	0º	4°	8º

Note 1：Followed From JEDEC MO-012-E.

Outline Information (Continued)

SOP-16EP Package (Unit: mm)



SYMBOLS UNIT	DIMENSION IN MILLIMETER		
	MIN	NOM	MAX
A	---	---	1.70
A1	0.00	---	0.15
A2	1.25	---	---
B	0.31	---	0.51
C	0.17	---	0.25
D	---	9.9	---
E	---	3.9	---
e	---	1.27	---
H	---	6.0	---
L	0.40	---	1.27
θ	0°	4°	8°

PAD SIZE	DIMENSION IN MILLIMETER			
	E2		D1	
	MIN	MAX	MIN	MAX
95*18E	1.92	3.84	2.40	4.80

Note 1：Followed From JEDEC MO-012-E.

Life Support Policy
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